Rice in Laos

Edited by J.M. Schiller, M.B. Chanphengxay,
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Contents

Foreword

Rice has been identified with the area now known as the Lao People's Democratic Republic (Laos) for much longer than the country has existed. Archaeological evidence has shown that rice has been grown in the region for at least 6,000 years. Laos is known to be within the region generally accepted as the area of origin and domestication of Asiatic rice (*Oryza sativa*). It is also believed to be near the center of the area of origin of "glutinous" or "waxy" rice.

Rice has long been the most important food crop cultivated in Laos, and at the beginning of the third millennium still accounted for more than 80% of the area under cultivation within the country. With an average annual consumption of more than 170 kg of milled rice, Laos is among the group of countries with the highest per capita consumption of rice in the world. In most rural areas of Laos, rice accounts for almost 80% of calorie intake. The strong cultural identity of the people of Laos with the consumption of "sticky" or glutinous rice is widely acknowledged. Laos has the highest per capita production and consumption of glutinous or waxy rice in the world. The Lao language expression "to eat" not only means "to eat rice" as in the language of neighboring Thailand, but "to eat glutinous rice."

This book, *Rice in Laos*, helps document the long association of Laos and its people with rice in historical, cultural, and agricultural contexts. It provides a record of the diversity of, and biodiversity within, the rice ecosystems within the country. It is not meant to provide a detailed record of all recent advances in rice research, reports on which are available from other sources. However, it does provide a summary of some of the more salient recent advances in rice-related research undertaken since about 1990. It is anticipated that the book will be an important reference both nationally and internationally. The planned Lao language version of the book will also provide an important reference book for the agricultural education sector within Laos.

The compilation of the book has been a genuine collaborative effort among international scientists and scholars, and researchers within Laos. The support of the Australian Center for International Agricultural Research (ACIAR), in collaboration with the International Rice Research Institute (IRRI), in the publication of English and Lao language versions of the book is gratefully acknowledged.

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CHAPTER 1

Population diversity and rice in Laos

Martin Stuart-Fox

Modern humans evolved in Africa beginning around 200,000 years ago, from where they spread first to the Middle East and thence to Asia and Australia. They were hunter-gatherers who developed a profound knowledge of the natural environment and evolved a sophisticated material culture in the course of their search for food and shelter. A large number of their temporary and semipermanent settlement sites have been discovered and excavated in different parts of mainland Southeast Asia reaching back some 40,000 years.

Southeast Asian stone-age sites fall roughly into two groups: (1) coastal, especially estuarine, sites whose inhabitants exploited the bountiful resources of the sea as well as the coastal lowlands; and (2) inland sites situated in caves and rock shelters above river valleys. Many early coastal sites must have been progressively submerged as sea levels rose after the last ice age, around 20,000 years ago, forcing people to move to higher ground. Inland sites reveal that, though population was more thinly spread than along the coast, most of the interior of mainland Southeast Asia, including the area covered by present-day Laos, was already widely inhabited by these early hunter-gatherers. Who they were we do not know, though they may have been akin to the Orang Asli of peninsular Malaya or the negritos of the Andaman Islands.

By 15,000 years ago, a material culture known as the Hoabinhian, named after sites excavated in the 1920s in the Vietnamese province of Hoa Binh, began to spread throughout much of mainland Southeast Asia. Hoabinhian sites in Laos have yielded core choppers, usually worked on one face only, stone axes and flake knives and scrapers, and points and spatulae made of bone. These were used to make traps, snares, and containers of wood, bamboo, and rattan that were easier and lighter to carry than the stone tools left at sites to which bands would repeatedly return. These material remains were associated with a modern fauna, including frogs, turtles, monkeys, squirrels, civets, and small deer. Some larger species—pigs, cattle, and large deer—also appear. By 10,000 years ago, hand-made pottery was being produced.

The hunter-gatherer lifestyle represented by the Hoabinhian “techno-complex” (Gorman 1971) has persisted as a successful way of life for forest hunter-gatherers such as the Mlabri (Yumbri) right up to the present. It was not, however, a static culture, but one that creatively evolved with changing environmental conditions to form regional variants. A number of cave sites in northern Thailand illustrate such developments. As sites became more permanent, the collection and grinding of wild seeds and grains appear to have provided an increasing proportion of the diet. Few excavations have been carried out in Laos, but there is little doubt that similar developments took place within the Mekong basin as were happening within that of the Chao Phraya. One significant development over this period was that we occasionally find deliberate inhumation of the dead, mostly in a flexed position. Another, judging by the human remains available, was that the population was becoming more characteristically Mongoloid in anatomy.

The transition to settled agriculture

It used to be thought that the domestication of rice might have taken place in mainland Southeast Asia. More accurate dating procedures now make this unlikely. Charles Higham argues that rice was probably first domesticated from wild strains in the Yangzi valley, which was, therefore, "one of the very few areas in Eurasia that witnessed a Neolithic Revolution, the transition from hunting and gathering to agriculture" (Higham 2002, p 84). This probably occurred between 8,000 and 6,000 BCE, after which the innovation diffused slowly into southern China and west into Yunnan. From there, settled agriculture based on rice production filtered southeast down the Red River valley and south down the Mekong valley by at least 4,000 BCE. Rice became widespread throughout mainland Southeast Asia by 2,000 BCE.

The key role of the upper and middle Mekong in the expansion of settled agriculture from Yunnan to the plains of northern and northeastern Thailand has been indicated by a site survey of the upper reaches of the river and its northern tributaries. This revealed numerous small settlement mounds, along with samples of the black incised pottery common to Yunnan and Vietnam (Higham 2002). None of these sites in Laos have yet been scientifically excavated, but what the pattern of settlement suggests is the intrusion of a new population, in all likelihood speakers of Austroasiatic (Mon-Khmer) languages, which by the last centuries BCE had spread south across the plains of the central Chao Phraya and down the Mekong into Cambodia. They were accompanied by the domestic dog, the first remains of which date from early agricultural sites. At the same time, Austronesian speakers (of the Chamic subgroup) had settled along the coast of Vietnam, perhaps around the lower Mekong Delta area later identified with the kingdom of Funan.

Four archaeological sites in northeast Thailand, of which the two best known are Ban Chian and Non Nok Tha, provide important evidence of new Neolithic settlements in the Mekong valley in the early second millennium BCE. The picture we have is of quite large agricultural communities practicing horticulture and rainfed wet-rice production, probably in natural wetlands and seasonal shallow ponds. Most remarkable is the extensive use of pottery and burial of the dead in defined cemeteries, in the graves of which much of the pottery was found. From the excavations it is evident that hunting and fishing still supplied a good percentage of the diet, including large animals such as wild buffalo, pigs, and large deer. Turtles, fish, and shellfish provided important additions to the diet. Shell ornaments and copper and bronze items have also been excavated, though claims of very early dates for metallurgy are now discounted.

By the mid-second millennium BCE, the large Neolithic settlements were in trading contact with each other. Marine shells, ornaments, and stone tools were extensively traded, and along these routes passed knowledge of techniques such as copper smelting, bronze alloying, and pottery production. Bronze metallurgy is known from western China in the third millennium BCE. From there, knowledge of early techniques probably diffused east to give rise to the wonderful Chinese Shang bronzes, and could well have also percolated south to the northern part of the Khorat Plateau. There, several important excavations have revealed a flourishing bronze-age civilization dating from between 1,500 and 500 BCE, when bronze began to give way to iron.

This bronze-age culture undoubtedly extended across the Mekong to Laos, where the tin essential to form bronze (which is stronger than copper) alloys was being mined in the Nam Pa Taen valley. In the foothills east of the Mekong, it seems that a parallel culture was developing, based on horticulture and cultivation of taro and other root crops and dry-field rice. By the mid-first millennium BCE, farmers on the Khorat Plateau in northeast Thailand were using iron-tipped ploughs pulled by domesticated water buffaloes.

The early iron age lasted roughly a millennium until the rise of the first large-scale kingdoms (*mandalas*) in mainland Southeast Asia. This coincided with a remarkable culture located in the region of Xieng Khouang in Laos. This was the megalithic culture associated in its early (Hua Phan) phase with standing menhirs (preiron age) and in its later (Xieng Khouang) phase with the remarkable stone jars that give the Plain of Jars its name. These jars measure on average around 1.5 m in height and diameter, with some much larger, weighing as much as 15 tons. That these were part of a funerary cult is indicated by what appears to be a central crematorium at Ban Ang. Higham (1989) dates the jars to between the third century BCE and the third century CE.

Archaeological investigations have thrown no light on the ethnic or linguistic affinities of the "people of the jars," but it seems more likely that they spoke an Austroasiatic rather than an Austronesian language. This would accord with a strong oral tradition among the Khmu, the largest Austroasiatic-speaking minority in northern Laos, that the jars were sculpted by their ancestors. Lao tradition concurs in ascribing the jars to the Khom, early Mon-Khmer speakers (Stuart-Fox 1998).

Ethnic diversity in mainland Southeast Asia

By the mid-first millennium CE, small, local principalities ruled by powerful families were beginning to coalesce into larger kingdoms. This process is often referred to as "state formation," but these expanding "circles of power" are better described by the Indian term *mandala* (Wolters 1982). At the time of Funan, in the first known mandala in mainland Southeast Asia, located in southeastern Cambodia and southern Vietnam, Austroasiatic-speaking peoples were spread thinly across all of what is now southern Vietnam, Cambodia, Laos, Thailand, and southern Myanmar. An Austronesian-speaking people, the Cham, were creating their own polity along the coast of central Vietnam, while, in the Red River Delta, Vietnamese and Muong speakers had been incorporated into the southernmost province of China.

Around the fifth century CE, a center of Khmer power developed in the region of Champassak, in what is now southern Laos. This kingdom extended its power south of the Falls of Khon marking the present-day boundary between Laos and Cambodia. It subsequently divided into two mandalas—"land Zhenla" on the middle Mekong and "water Zhenla" in Cambodia. Land Zhenla succeeded in defeating Funan to establish the basis for the growth of Cambodian power in the ninth century that came with the establishment of the mandala of Angkor. Meanwhile, a center of Mon power developed in southern Thailand, with smaller mandalas on the Khorat Plateau.

The economic basis for this process of mandala formation lay in the tribute extracted from villages (in the form of rice, other staples, resources, and products) by a powerful central ruler. Faced with demands for tribute, established villages could do little but pay. The only alternative was to move. Land was plentiful and people could reconstruct their villages relatively easily. This was more difficult if they grew wet rice, but was easy for villages growing dry-field rice, supplemented by vegetables and root crops. The dispersion of Austroasiatic (Mon-Khmer)-speaking peoples into the uplands of Laos, Cambodia, and Thailand and of Austronesian-speaking minorities into the highlands of southern Vietnam was probably partly a response to mandala formation by peoples determined to avoid being drawn into these early circles of power. This was a process that occurred frequently in the history of the region, right through to French colonial times.

By the beginning of the second millennium CE, centers of power, principally Khmer or Mon, were scattered across mainland Southeast Asia from southern Cambodia to northern Thailand, including in Laos—Champassak, the Thakhek region, the Vientiane plain, and probably also Luang Prabang (all four straddling the Mekong). Mon mandalas existed in northern as well as southern Thailand, and Mon influence probably extended throughout much of the middle Mekong. As the power of Angkor grew in the eleventh century, Khmer power extended up the Mekong and across the Khorat Plateau to reach its greatest extent in the twelfth century. Thereafter, it waned, leaving something of a vacuum that was quickly filled by new peoples who had been filtering for at least two or three centuries into northern and central Thailand and Laos.

These peoples spoke Tai (Daic) languages. They included peoples who came to be known as the Tai-Lao of the Mekong valley, the Tai-Phuan of Xieng Khouang, the Tai-Shan of the northeast Burma highlands, the Tai-Nyuan of northern Thailand, and the Tai-Sayam of central Thailand. All share certain cultural characteristics, including wet-field rice cultivation (of one variety or another), worship of nature spirits (*phi*), and political organization in the form of *meuang*. This was not a territorial unit, but a socio-political structure in which a hereditary aristocratic elite claimed the loyalty of a free peasantry based on reciprocal obligations. The peasantry helped cultivate the lands of the ruling family and could be conscripted to fight under its command. In return, the ruling elite was responsible for the protection and well-being of the *meuang* through propitiation of the *phi meuang* and organization of military defense.

Little is kown about the slow migration, probably from before the eighth century, of Tai peoples from southern China into northern Vietnam, Laos, and Burma (now Myanmar). It may have been, however, partly in response to Chinese attempts to tighten their administrative control over minority peoples in southern China (Wyatt 1984). Their movement would have been slow, from one river valley to the next as population expanded and land could be wrested from whoever was already there. Partly the process would have been peaceful: Tai farmers taking up vacant land along valley floors, laboriously constructing their rice fields and irrigation channels, intermingling with people already there, speaking Austroasiatic languages, and farming rain-dependent rice supplemented by hunting and gathering of forest products. At first, the Tai speakers were probably partly dependent on these neighbors (Khmu, Lamet) for food and assistance. But, as their numbers grew, conflict must have at times occurred. Eventually, their superior political organization would have enabled the Tai to take control of the valley and force the earlier inhabitants to move to higher ground.

For the Tai-Lao, this slow migration eventually brought them down the southwest-flowing tributaries of the Mekong from the Tai highlands of Vietnam (and the region of Dien Bien Phu, known to the Tai as Meuang Thaeng). One of these tributaries was the Nam U and another was the Nam Khan, which brought them to Luang Prabang, then known as Meuang Sua, a river junction probably ruled over by a local Khmu prince. This became the first center of Lao power in northern Laos, and the first capital of the Lao kingdom of Lan Xang (founded in the mid-fourteenth century).

Migration of Tai peoples continued elsewhere—into the headwaters and central basin of the Chao Phraya River, onto the plateau of Xieng Khouang and the plateaus of central Laos, and south to the riverine plains along the Mekong. There they encountered what remained of earlier organized principalities of Austroasiatic-speaking peoples—Khmer, Mon, and others—with higher levels of material culture (based on Buddhism and Indian-derived writing systems and artistic canons). In the long process of mutual assimilation that followed, Tai princes adopted much of the superior Mon-Khmer culture of the Chao Phraya and Mekong basins, but imposed both their political control and their language on the existing population. Lao *meuang* thus came to incorporate a mixed population, in which intermarriage would have been increasingly common. As these expanded in power, they probably drew within their orbit upland villages of people determined to preserve their own ways of life. Other peoples moved deeper into the mountains to escape any form of political control.

Much later, in the late eighteenth and early nineteenth centuries, yet other ethnic groups began migrating into Laos mainly from southern China, once again to escape tightening administrative controls that threatened their cultural independence and freedom. These were the Hmong-Mien- and Tibeto-Burman-speaking peoples. Of these two broad groups, the Hmong spread most deeply into Laos, settling at high altitudes in the mountains of northern Laos, the mountainous areas surrounding the Plain of Jars in Xieng Kouang Province, to the provinces of Borikhamxay, and across to Sayabouly Province. The Mien and Tibeto-Burman tribes such as the Akha, Phunoi, and Lolo confined themselves to the far north. Thus was finally created the patchwork pattern of ethnic and linguistic diversity characteristic of Laos today.

Ethno-linguistic diversity in Laos

In its 1995 census, the government of the Lao People's Democratic Republic recognized 47 official ethno-linguistic groups (National Statistical Centre 1997). Other counts have identified as many as 130 different groups, based on self-definition (Chazée 1999). These can be divided into four major groups on the basis of language: Lao-Tai (66.2%), Austroasiatic (Mon-Khmer) (22.7%), Hmong-Yao (or Miao-Yao) (7.4%), and Tibeto-Burman (2.9%). To these may be added a fifth group comprising small numbers of Chinese from Yunnan, known as the Ho, who have been resident in northern Phongsaly Province for some two centuries. Some scholars include the Ho in the Tibeto-Burman family and distinguish them from immigrant Chinese from other parts of China, who together with resident Cambodians, Burmese (mainly Shan), Thai, and Vietnamese constitute the fifth population group. None in this fifth group are rice-growers, however.

Ethnic Lao (including the Phuan of Xieng Khouang) constitute 52.5% of the total Lao population and are concentrated in the Mekong lowlands, along river valleys and on plateaus. In the northern provinces of Phongsaly, Luang Namtha, and Bokeo, their place is taken by the Tai-Leu, accounting for 2.6%. A further 10.3% are upland Tai (Phutai), including Black, Red, and White Tai, named for the colors of their traditional dress, and the Phou Tai of Khammouane and Savannakhet in central Laos (Goudineau 2003, p 14). Several other small Tai groups speak different dialects and define themselves as different from the Lao. Chazée (1999, p 2) lists 27 different ethno-linguistic groups within the Lao-Tai family, though officially only six are recognized (Lao, Leu, Nyuan, Sek, Yang, and Phutai).

All groups in the Lao-Tai family cultivate wet-field rice, most commonly glutinous varieties. They live in sedentary villages, often quite large, of houses built off the ground on stilts or poles. Social distinctions persist, separating aristocrats from commoners. Most are Buddhists, and all propitiate local spirits (*phi*). The Lao-Tai family forms the general category of Lao Loum, or lowland Lao (UNDP 2002).

The 30 officially recognized ethno-linguistic groups of the Austroasiatic family can be divided into five subcategories, of which two—Palaungic and Khmuic—are located only in northern Laos, one (Vietic) is confined to a strip along the Lao-Vietnamese frontier, and the remaining two—Katuic and Bahnaric—are found only in the plateaus and mountains of southern Laos. Chazée (1999, p 51) reports having identified 59 distinct ethnic and "subethnic" minorities in this family. Many of the largest group are the Khamu, accounting for 11% of the Lao population. The two largest groups in the south are the Katang (2.1%) and the Makong (2%). No other group numbers more than 1%.

The minorities composing the Austroasiatic family all live at higher altitudes than the Lao, in smaller villages containing houses on shorter stilts or poles. Some produce rice in rainfed paddies; others grow dry-field rice using slash-and-burn methods. Communities are not hierarchically stratified, but kin groups may be identified with totemic animals. Most are animist, worshipping a variety of spirits identified with the locality, house, or family. Some have converted to Buddhism or Christianity through contact with Lao neighbors or foreign missionaries. Together these minorities in the Austroasiatic family constitute the general category of Lao Theung, Lao of the (mid-altitude) slopes.

The Hmong-Yao group contains the Hmong (6.9%) (divided by Chazée into two subgroups) and two smaller Yao minorities together amounting to 0.5%. Eight Tibeto-Burman minorities are officially recognized, of which only the Akha (1.9%) account for more than 1% of the total population. In contrast, Chazée recognizes 33 ethnic and subethnic groups. Both Hmong and Yao are further divided into exogamous patrilineal clans, 15 for the Hmong and 12 for the Yao, who are further divided into subclans. Most reside at higher altitudes than the Austroasiatic minorities, and differ from them by building their houses on the ground. They grow nonglutinous rice using slash-and-burn methods. Both have been influenced by centuries of contact with the Chinese before migrating to Laos, the Yao more than the Hmong. For example, the Yao use Chinese characters to write their religious and customary texts, and for both the worship of ancestral spirits is important.

The Tibeto-Burman minorities are mostly confined to the far north of Laos in the province of Phongsaly. They generally live at slightly lower altitudes than the Hmong and Yao, but like them build their houses on the ground. They are also swidden farmers who prefer nonglutinous rice to the glutinous varieties. Each group worships its own pantheon of animist spirits, except the Phounoi, who have converted to Buddhism. Minorities of the Hmong-Yao and Tibeto-Burman families are together referred to as Lao Soung, Lao of the mountain tops.

The persistence of the extraordinary ethno-linguistic diversity in Laos reflects, in part, past difficulties in communication throughout the country. The diversity and history of the individual ethnic groups are also reflected in the diversity of, and within, the rice-growing environments within the country that have also persisted until relatively recently, and which are reported elsewhere in this book. Changes, both government-initiated and as a direct result of improvements in communication, are resulting in increased interaction among the ethnic groups, with minority groups having increased contact with the ethnic Lao majority, particularly as a result of education initiatives and increased commercialization of agriculture. Traditional upland cultivation practices based on slash-and-burn systems will be replaced by more sustainable forms of agriculture. In the lowland environment, modern improved rice varieties have already largely replaced traditional varieties. Fortunately, extensive germplasm collections undertaken during 1995 to 2000 will enable the conservation and preservation of much of the traditional rice germplasm of Laos (see Chapter 9). However, much of the indigenous knowledge associated with past traditional agricultural practices has a high probability of being lost.

Government policies are not the only basis of the changes that are taking place in Laos. As in other parts of Southeast Asia, people of Laos are moving from villages into towns to seek employment and a better life. Although this is a movement that is now primarily affecting ethnic Lao, it is also likely to affect ethnic minority families in the future as differences in standards of living increase between the provincial cities along the Mekong and rural areas. Considerable internal migration is already taking place within provinces as families move to district and provincial capitals (Bounthavy and Taillard 2000, p 50-57).

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Notes

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CHAPTER 2

A history of rice in Laos

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Most historians trace the origins of the Lao nation-state back to 1353, the date of the coronation of Fa Ngum as the first ruler of the kingdom (mandala) of Lan Xang. The history of rice in what is now known as Laos predates the founding of Lan Xang, however, by thousands of years.

Although the history of the ethnic diversity of what is now known as Laos is generally well documented (Dommen 1995, Simms and Simms 1999, Stuart-Fox 1998), the history of some aspects of rice cultivation within the area is still open to conjecture. What is accepted, however, is that rice has been cultivated in the region for a long time. This is reflected in linguistic evidence where, in the Lao language, as in several other languages in the Asian region, the words for rice and food are synonymous. Anthropological studies in northeast Thailand have provided evidence of rice cultivation from pottery imprints of grain and husks of *Oryza sativa* dated to at least 2,000 BC and probably older (Khush 1997, White 1997). Palaeoenvironmental evidence suggests the presence of even older plant cultivation in the middle Mekong basin (White et al 2004), although the precise crops grown have yet to be determined. In a review of "the peopling and prehistory of Laos," Stuart-Fox (1998) suggests that rice was cultivated, using broadcasting techniques, along the margins of ponds and streams by small settlements in the area, from the late fourth and early third millennia BC. It is conjectured that, before the deliberate cultivation of rice in the region, harvesting of the grain of its wild rice progenitors probably took place (Harlan 1995, Oka 1988, Vaughan 1994, White 1995).

"Wet"-rice cultivation in the lowlands of Laos and neighboring countries has long been associated with ethnic groups connected with the main linguistic group of the region, the Tai. The Tai, in their area of origin in southern China, probably already had a staple diet of wet rice. They built their villages in river valleys where there was plenty of water and level ground that could be flooded in the growing season (Simms and Simms 1999). Golomb (1976) also supports the belief that the Tai were traditionally wet-rice cultivators in their ancestral homeland.

Stuart-Fox (1998) and Higham (2002) indicate that, as early as 500 BC, the local population in what is now known as the Khorat Plateau of northeast Thailand was using domesticated buffalo and iron-tipped ploughs for wet-rice cultivation. He suggests that, despite a lack of systematic evidence to date, similar agricultural developments likely occurred on the plains of the Lao provinces of Vientiane, Khammouane, and Savannakhet. When the Tai people moved into what now constitutes Laos, Thailand, and upper Myanmar, they brought with them their own wet-rice cultivation practices.

The Tai-Lao currently form the dominant linguistic group in several provinces of Laos, including Vientiane, Luang Prabang, Khammouane, Savannakhet, and Champassak (Batson 1991). Other Tai groups that live in Laos are the Tai-Leu of Luang Prabang and areas to the north, the Tai-Neua of Houaphanh, and the Tai-Dam (Black Tai) and Tai-Deng (Red Tai) of Phongsaly and Houaphanh. Of the Austroasiatic groups who live in the adjoining uplands, the Kasseng, Loven, Souay, and Bru are the larger groups inhabiting southern Laos, while the Lamet and Khmou are the major groups in the north. The largest single grouping of the Mon-Khmer comprises the Khmou, now concentrated in parts of Luang Prabang, Houaphanh, and Oudomxay provinces. The existence of canals and reservoirs in the southern Lao province of Champassak suggests that lowland irrigated rice cultivation was the principal sustenance crop in southern Laos during the period of Khmer dominance from the 5th to 11th centuries CE.

It is therefore reasonable to assume that, for the last two millennia, the main form of rice cultivation in what is now Laos was wet-rice cultivation in the lowlands. Just when dryland rice cultivation, which is found in the upland environment of Laos and neighboring countries, developed is a matter of conjecture. Khush (1997) suggests that early rice crops in the Asian arc were "probably grown by direct seeding and without standing water." Harlan (1995) also infers that, at least in the areas of original domestication of rice in Asia, wet-rice cultivation is a relatively more recent production method than dryland cultivation techniques. However, White (1995) argues on ecological grounds that dryland rice cultivation must have emerged from initial domestication in a wetland environment. The process of soil puddling and transplanting of seedlings seems to have originated in China and been brought to Southeast Asia (including Laos) through migration. It should be noted, however, that the last ethnic groups to arrive in Laos, the Hmong and Mien (Yao), who settled in the highlands of Laos in the 19th and early 20th centuries, brought with them dryland rice cultivation practices (Dommen 1995).

Laos and the origins of cultivated Asiatic rice

Though rice cultivation in Laos may date back only to the second millennium BCE, it should be acknowledged that Laos lies within the broader region of likely domestication of Asiatic rice (*Oryza sativa*) (Chang 1976, Oka 1988). Laos is also believed to be near the center of origin of glutinous rice (Golomb 1976, Watabe 1967). Laos is still rich in genetic diversity of wild and weedy rice, with 6 of the known 21 species of wild rice still to be found in the country: *O. rufipogon*, *O. nivara*, *O. minuta*, *O. officinalis*, *O. ridleyi*, and *O. granulata* (Kuroda et al, see Chapter 15). Two of these, *O. nivara* and *O. rufipogon*, are the generally accepted progenitors of Asian rice, *O.*

sativa (Chang 1976, Oka 1988, Yamanaka et al 2003). Weedy rice, believed to be the interspecific hybrids between the cultivated rice species (*O. sativa*) and wild rice species, has also been commonly observed in Laos.

Historical evidence for the quality of Lao rice

Reference to the quality of rice produced in Laos comes from historical records from the early 1660s, when the description of Laos by an Italian Jesuit priest who worked in the country between 1642 and 1648 was published. The account by Father Givvani Maria Leria was first published in Italian in 1663 (de Marini 1998). The description of rice (and other matters of interest) on both banks of the Mekong River runs as follows:

"However, one must understand that this part of the kingdom, west of the river, is not as prosperous or as fertile as that in the east which greatly surpasses in all respects. The elephants are bigger and stronger there, better trained and more suitable for warfare. The unicorns (rhinoceroses) are also better there than elsewhere. The staple rice is incomparable there and it has a characteristic odour and wildness that is specific to all that grows in this eastern part of the kingdom. There, forests and trees are high, straight and almost all durable, a quality which those growing on the eastern side of this river do not possess: there the virtue of the unicorns is not at all comparable to that of the eastern side. The rice is so hard that one could never boil it and the wood, badly shaped and twisted—it is more suitable for making smoke than fire. There is a kind of a small strait—it is like the center and middle of the kingdom—which produced such excellent rice that I do not believe that it has its equal anywhere else in the Orient" (de Marini 1998, p 4-5).

Ngaosyvanthn and Ngaosyvanthn (1998) also cite other sources from the 18th century saying that "this country produces abundantly the best kind of rice." Reference is also made to the royal paddy fields established by the last king of Vientiane, Chao Anouvong (1804-28), within an 18-km wall encircling the city. The occupying Thai armies of 1827 were reportedly surprised at how well endowed Vientiane was with rice. The royal rice fields were apparently still discernible more than 60 years later.

Rice-based power

Following the settlement of the Tai-Lao in the lowland areas in what now comprises Laos, and northeast Thailand, there evolved a number of small political centers known as *muang*, which were concentrations of social, economic, and military power. Stuart-Fox (1998) reports that the earliest of these Tai muang "of more than local extent" on the upper Mekong "probably dates from no earlier than the 11th century." These muang were generally centered in valley areas from where they controlled surrounding territory. Control over areas of reliable food production provided the basis of muang power for hundreds of years. The four oldest and strongest muang in what constitutes modern-day Laos were centered on what are currently the provinces of Luang Prabang, Xieng Khouang, Vientiane, and Champassak. All exercised domination over rice-growing areas that produced signficant surpluses (Whitmore 1970).

The decision, in 1560, of King Xetthathirât of Lan Xang to move the royal court from Luang Prabang (or Xieng Thong as it was called at that time) to Vientiane was partly based on the growing food needs (mainly rice) of the administrative center. As well as being at the crossroads for much overland commerce, compared with Luang Prabang, Vientiane lay in a much larger rich and fertile plain well suited to wet-rice cultivation (Simms and Simms 1999).

The significance of rice politically was demonstrated during the rule of Chao Anou, King of Vientiane (1805-28), who led the Lao war of independence against Siam (Thailand) in 1827-28. After Chao Anou's initial defeat, he returned to Vientiane, where he found a Siamese garrison in control of the only available rice supplies. Conflict again broke out between the Siamese and the Lao, leading to Chao Anou's capture and death, and the final destruction of Vientiane (Stuart-Fox 1998).

Rice and French colonialism

During the period of French colonialism in Laos (1893-1945), although coffee and potato growing were introduced to the Boloven Plateau in the south of the country, little effort was made to improve production of the staple crops of rice and maize (McCoy 1970). Almost 100% of the rice produced was grown under rainfed conditions and thereby subject to the vagaries of the weather, with periodic droughts affecting both upland and lowland crops, and periodic flooding occasionally devastating wet-season lowland rice and other crops grown in areas adjacent to the Mekong River and its tributaries. Production for most of this period did not exceed 350,000 t annually (equal to about 1 kg of rice per day per person for the population of that time) (Gunn 1990). An exception was in 1923 when production was reported to have reached a high of 500,000 t. Gunn (1990) reports that, for most of the period of French colonialism, Laos was a net rice-importing country, with only the Champassak area consistently producing a rice surplus. One of the few interventions by the French to address the chronic rice deficit during the time of their administration of Laos was to actually ban the export of rice in 1936 (Gunn 1990, Stuart-Fox 1997). This was in response to a drop in the estimated harvest from about 258,000 t in 1935 to about 204,000 t in 1936 (the cause of this reduction is not indicated but, as it was mainly from the traditional rice-exporting provinces adjacent to the Mekong River, it is likely to have been severe flooding). The rice deficit was of such a magnitude in Thakek Province (Khammouane) that there was a fear of starvation. At the time, emergency supplies of rice were requested by the *Résident Supérieur* from Tonkin and Annam (Gunn 1990).

USAID

The period 1955 to 1963 was a time when the per capita U.S. assistance to Laos exceeded, several fold, that given to other countries in the region. However, very little was spent on agriculture, although more than 90% of the population at that time was farmers (Stuart-Fox 1997). During the 1960s and early 1970s, agricultural development and efforts to achieve rice self-sufficiency were of minor importance in comparison to the escalating military conflict. In 1969 and 1970, USAID did undertake the evaluation of a number of introduced lines and varieties from IRRI, together with some well-known traditional varieties. The lines and varieties from IRRI would have been some of the earliest available, as the institution was established only in 1960. Early multilocation yield trials were undertaken in the provinces of Sayabouly, Khammouane, Luang Prabang, Vientiane, and Sedone (Sedone Province was later incorporated into the province of Champassak). Seed multiplication of several of these IRRI lines and varieties was undertaken for distribution at the Salakham Rice Research Station near the capital, Vientiane, in the 1973 wet season. In addition to the IRRI material (which included both glutinous and nonglutinous lines, the latter including IR22 and IR24), the Lao traditional glutinous variety *Do nang nouan* and the Thai glutinous variety *Sanpatong* were also multiplied and distributed to farmers (see Chapter 21). Some of these varieties were still being grown on a limited scale in the mid-1990s, being known as American rice, reflecting their origins as part of the USAID seed distribution program (Appa Rao et al 2000). Apart from the limited work on the introduction and distribution of rice varieties, little other agricultural development took place during this period because of the displacement of large parts of the population in many areas by the war, and the associated disruption of normal cropping cycles.

Socialist assistance 1977-90

Vietnam

In support of the agricultural cooperatives that were established in 1978 to 1984 in an attempt to improve agricultural productivity, Vietnamese agricultural advisers introduced and evaluated many improved lowland rice varieties from Vietnam. Most of these introductions were nonglutinous and many had IRRI parentage. However, few of the Vietnamese introductions were actually adopted by Lao farmers because of their poorer eating qualities relative to the traditional Lao varieties. One of the Vietnamese introductions, CR203, did become popular for the production of rice noodles and brewing of Lao beer. In 2002, it was still being grown on a limited scale.

USSR

Although large numbers of advisers from the socialist block countries (particularly Russia) were present in Laos during the late 1970s and 1980s, these advisers and related assistance programs had little influence on agricultural production. The advisers did undertake serious soil surveys and soil-mapping exercises during this time, the results of which were later used for the production of more standardized USDA-type soil maps that, in turn, were used for land-use planning purposes in the late 1990s. In 1982-84, in collaboration with USSR experts, a number of field trials were undertaken on rice, focusing on yield responses to fertilizer inputs. These studies were part of the soils classification mapping exercises.

The rise and fall of agricultural cooperatives: 1978-88

The most significant change relating to rice production in the period immediately after the Lao People's Revolutionary Party (LPRP) came to power in December 1975 was the adoption of a policy for the "collectivization of agricultural production" through the formation of "agricultural cooperatives." This was seen as the most appropriate strategy for "revolutionizing the country, both socially and technologically." The history of the "rise and fall" of these cooperatives has been reviewed in detail by Stuart-Fox (1980) and Evans (1988, 1995). As reported by Evans, the "experiment with collectivization was associated with attempts by the new government to revive the Lao economy following its collapse due to the flight of both capital and business entrepreneurs." It was hoped to use agricultural cooperatives as the basis for quickly increasing rice production to alleviate a serious and chronic rice deficit in the country. At the time, Laos was importing approximately 15% of its rice requirements. It was believed that cooperatives were the only way peasant agriculture could overcome natural calamities and achieve national food self-sufficiency (Evans 1995). To support these objectives, controls were placed on the price of a range of agricultural commodities, including rice.

Although the policy to create production-based collectives was announced soon after the change of government in 1975, it was not implemented until 1978, following a severe drought in 1977 that further aggravated the already serious rice deficit in the country. The focus of the move to cooperative-based production was in areas of lowland rice cultivation (mainly rainfed, as there was only a very small area of irrigated rice at the time the cooperatives were formed) in provinces with large lowland rice-growing areas in the Mekong River Valley, and in some northern provinces where the LPRP had a strong political base (particularly the provinces of Xieng Khouang, Houaphanh, and Phongsaly). A characteristic of the cooperatives was that they were generally small "village-level" initiatives involving an average of 30 to 40 families, rather than large area collectives. Although a few numbered over 200 families, generally such large cooperatives were not encouraged. The initial basis for the formation and operation of the early cooperatives was at a low level, involving the establishment of labor exchange units that could be used in a coordinated calendar of rice production. Members of the cooperative were expected to contribute their cultivated land for the cooperative's use (while property of other types remained under the control of individual households) (Evans 1988). From the outset, it was official government policy that the decision to join or leave a cooperative was to be left to the individual households. In practice, however, coercion was often used to encourage people to join a cooperative, and even more so to discourage a household from withdrawing. In late 1978, Stuart-Fox (1980) reported that 1,600 cooperatives had been set up throughout the country, involving 16% of all farming families. The majority were in the provinces of Khammouane and Champassak, in the central and southern parts of the Mekong River Valley. By early 1979, more than 2,500 cooperatives were reported to have been established. However, by mid-1979, it was recognized that the move to collectivization was seriously disrupting production rather than improving it. The disruptive effects

Table 1. Expansion of agricultural cooperatives in Laos, 1979-86.

Province	Year							
	1979	1980	1981	1982	1983	1984	1985	1986
Phongsaly	73	152	152	156	167	167	167	167
Luang Namtha	59	74	74	74	74	74	74	69
Oudomxay	72	93	93	98	98	111	115	182
Sayabouly	120	44	44	89	129	160	160	154
Luang Prabang	41	44	44	76	82	98	101	152
Xieng Khouang	200	212	212	252	251	251	247	247
Houaphanh	155	263	263	274	311	311	318	374
Vientiane[a] Municipality	–	–	–	63	104	119	167	192
Vientiane	486	101	101	47	71	93	176	242
Khammouane	433	12	12	24	67	99	104	372
Savannakhet	250	12	12	18	53	164	547	579
Saravane	235	18	18	168	107	216	254	314
Champassak	304	306	306	587	587	597	651	659
Attapeu	24	12	12	12	13	19	19	14
Bokeo[a]	–	–	–	–	–	40	40	67
Borikhamxay[a]	–	–	–	–	–	17	34	76
Sekong[a]	–	–	–	–	–	10	10	120
Total	2,452	1,343	1,352	1,943	2,114	2,546	3,184	3,976

[a]–indicates that the administrative area did not exist at the time statistics were recorded.
Source: Evans (1988, 1995).

on rice production of a severe drought in 1977, followed by a severe flood in 1978, which devastated rice crops in the main rice-growing areas of central and southern Laos, also affected the move to cooperative production. A lack of management skills on the part of officials responsible for the cooperatives was a further major obstacle to both their establishment and operation. In July 1979, a stop was put to the further expansion of the cooperative program, as there was little support for cooperative-based rice production in most rural areas (Stuart-Fox 1980).

Even so, the government restated its commitment to collectivization of production, by emphasizing strengthening existing cooperatives rather than creating new ones. Because of a general lack of enthusiasm and support in many rural areas, from 1979 to 1980 the number of cooperatives dropped by 45% (from about 2,450 to about 1,340) (Table 1). However, official policy still favored the cooperative approach to production and in 1982 some attempt was made to extend cooperative-based rice production to areas of “swidden farming.” Tax incentives and preferential terms for access to credit were offered as inducements to encourage rural households to join the cooperative movement. It was reported that, by mid-1984, 37.6% of the farm families and 35.3% of the farming land were involved in 2,402 cooperatives nationwide. The cooperative movement was recorded as having reached its peak in 1986, with almost 4,000 cooperatives being reported as having been established (Table 1). However, several authors (Zasloff 1991, Evans 1995, Stuart-Fox 1997) have indicated that most of these cooperatives existed "in name only," and that in reality there were very few genuine working cooperatives. In fact, the cooperative movement was steadily weakened as members became disillusioned and used their "right to withdraw." The provinces where the cooperative movement was most successful were Champassak, Savannakhet, Xieng Khouang, Saravane, and Sayabouly (Evans 1988). By mid-1988, the government officially recognized the lack of success of the "cooperative concept" under Lao conditions and a decision was made to formally abandon the movement as the basis for improving production. It was acknowledged that the family or individual household unit was a more appropriate basis for achieving both political stability and improved agricultural production, particularly of rice. At about the same time, a number of state farms, which were also established as part of the cooperative movement but that occupied no more than 0.2% of cultivated land, were also privatized, as they were absorbing a disproportionate component of public and other resources (World Bank 1995).

Independent of the cooperative movement (but also influencing it), a significant change in government policy that influenced rice production in the early 1980s was the increased flexibility of pricing and market exchange in the agricultural sector (Evans 1991). In 1980, the prices of most crops and export products were raised by 300% to 500%; retail prices of commodities marketed by the state went up by 200% to 300% and approached parallel market prices. One immediate consequence of these increased incentives was a 16.5% increase in rice production. However, it has also been surmised that some of the production increase reported about this time resulted from changes in tax policy. In 1979, the government replaced the rice output tax with a land tax. One result of this was to remove the incentive to underreport yields and production (though this was replaced by an incentive to underreport the area under cultivation, the basis of the land tax). Although in the early years of the cooperative movement the land of those wishing to withdraw was expropriated, this policy was halted in 1979 and land was returned to those households that had opted to leave the cooperatives. As no general program of land reform had been associated with the cooperative movement, the reversion back to the family unit as the basis of production was not difficult.

Development of irrigated rice production

Farmers throughout Laos have been building traditional weirs and canals for centuries to provide supplementary irrigation to their wet-season rice crops. A typical traditional scheme would include a weir made of logs, stones, and sometimes bamboo and earth, with small hand-dug canals. The command area of these traditional irrigation schemes has varied from a few hectares to about 100 ha, governed mostly by the limited areas of flat land within the mountainous watersheds. These small diversion schemes irrigate terraced or valley-floor paddy fields. As of 2002, thousands of these small weir and canal systems were still in operation in Laos.

Although traditional schemes mainly focus on wet-season rice production, some also produce limited dry-season crops in areas where the streams have a significant dry-season flow, and where farmers have seen the potential for producing additional crops. However, on account of low efficiency levels and high labor demand for frequent repairs of the traditional weirs, over the past 20 years, hundreds of traditional systems have been replaced by more permanent structures.

Irrigation schemes

As recently as 1976, shortly after the LPRP came to power within the country, less than 1% (2,700 ha) of the planted rice area, and less than 1% of rice production (about 3,000 t), was associated with dry-season irrigated cultivation (Table 2). The relatively small irrigated area that existed prior to 1975 was mainly in the form of small weir schemes developed by USAID in the north of the country, particularly in the 1960s. The first relatively large scheme, about 900 ha in area, also initiated by USAID, was the Faay Namtane scheme in Phiang District of Xayabouly Province.

In 1977-78, the expansion of irrigated rice cultivation became one of the agricultural development objectives of the socialist government in its bid to achieve food self-sufficiency (basically rice self-sufficiency), and to reduce the year-to-year vagaries in food production caused by the effects of the weather. This development initiative was closely linked to the policy to develop a national network of agricultural cooperatives as the basis for achieving improvements in agricultural production (Evans 1991).

The first large irrigation schemes to be developed in Laos began in the late 1970s and were located on the floodplains of the Mekong River, not far from the capital, Vientiane. The first of these schemes, the Nam Houm scheme, was implemented through the Ministry of Agriculture and Forestry in Nasaythong District of Vientiane Municipality. This reservoir-based scheme, whose development commenced in 1977, had a projected capacity of about 3,000 ha of dry-season irrigated crop production. In its development phase, the Mekong Committee provided some financial assistance for the purchase and installation of pumping equipment for the scheme. The second scheme, also initiated in Nasaythong District of Vientiane Municipality, was the Nam Soang scheme. With a projected dry-season irrigation capacity of 4,000 ha, the development of this scheme began in 1978 through the Ministry of Defense. Despite the construction of reservoirs, a lack of funds to complete the network of delivery canals resulted in failure to meet the planned irrigation potential of both these schemes, and they did little to improve productivity at the time of their development (World Bank 1995). A lack of appropriate management and technical skills also contributed to the inability to properly develop and use these two schemes.

In the early 1990s, a decision was made to expand the area of rice under irrigated production in order to accelerate improvements in rice production to achieve the joint goals of national rice self-sufficiency and greater production stability. The expanded irrigated production was to focus on developing irrigation schemes that could be used for dry-season cropping activities rather than for wet-season production. However, it was also recognized that the proposed schemes had the potential for wet-season supplementary irrigation use as well. From 1990 to 2001, the dry-season irrigated

Table 2. Development of irrigated rice cultivation, 1976-2002.

Year	Area (000 ha)(% total)				Production (000 t)(% total)			
	Rainfed lowland	Rainfed upland	Irrigated lowland[a]	Total	Rainfed lowland	Rainfed upland	Irrigated lowland[a]	Total
1976	317.7	204.1	2.7	524.5	455	202	3	660
(%)	(60.6)	(38.9)	(0.5)	(100.0)	(68.9)	(30.6)	(0.5)	(100.0)
1978	398.6	216.6	7.5	622.7	508	217	9	734
(%)	(64.0)	(34.8)	(1.2)	(100.0)	(69.2)	(29.6)	(1.2)	(100.0)
1980	426.9	297.4	7.7	732.0	705	337	11	1,053
(%)	(58.3)	(40.6)	(1.1)	(100.0)	(67.0)	(32.0)	(1.1)	(100.0)
1982	435.2	296.2	5.7	737.1	731	349	12	1,092
(%)	(59.0)	(40.2)	(0.8)	(100.0)	(66.9)	(32.0)	(1.1)	(100.0)
1984	360.3	256.2	8.6	625.1	919	380	21	1,320
(%)	(57.6)	(41.0)	(1.4)	(100.0)	(69.6)	(28.8)	(1.6)	(100.0)
1986	385.0	256.6	10.1	651.7	1,082	341	27	1,450
(%)	(59.1)	(39.4)	(1.6)	(100.0)	(74.7)	(23.5)	(1.9)	(100.0)
1988	331.3	213.5	11.4	556.2	686	283	35	1,004
(%)	(59.6)	(38.4)	(2.1)	(100.0)	(68.3)	(28.2)	(3.5)	(100.0)
1990	392.4	245.9	12.0	650.3	1,081	369	41	1,491
(%)	(60.3)	(37.8)	(1.9)	(100.0)	(72.5)	(24.8)	(2.8)	(100.0)
1991	322.8	234.1	13.3	570.2	842	337	44	1,223
(%)	(56.6)	(41.1)	(2.3)	(100.0)	(68.9)	(27.6)	(3.6)	(100.0)
1992	392.5	200.1	15.5	608.1	1,153	292	55	1,500
(%)	(64.6)	(32.9)	(2.5)	(100.0)	(76.9)	(19.5)	(3.7)	(100.0)
1993	350.4	188.3	13.0	551.7	921	284	46	1,251
(%)	(63.5)	(34.1)	(2.7)	(100.0)	(73.6)	(22.7)	(3.7)	(100.0)
1994	380.9	219.1	11.0	611.0	1,198	342	38	1,578
(%)	(62.3)	(35.9)	(1.8)	(100.0)	(75.9)	(21.7)	(2.4)	(100.0)
1995	367.3	179.0	13.6	559.9	1,071	296	50	1,417
(%)	(65.6)	(32.0)	(2.4)	(100.0)	(75.6)	(20.9)	(3.5)	(100.0)
1996	363.1	172.6	18.0	553.7	1,076	266	72	1,414
(%)	(65.6)	(31.2)	(3.3)	(100.0)	(76.1)	(18.8)	(5.1)	(100.0)
1997	421.1	153.6	26.6	601.3	1,300	247	114	1,661
(%)	(70.0)	(25.5)	(4.4)	(100.0)	(78.3)	(14.9)	(6.9)	(100.0)
1998	430.2	134.2	53.1	617.5	1,249	214	212	1,675
(%)	(69.7)	(21.7)	(8.6)	(100.0)	(74.6)	(12.8)	(12.7)	(100.0)
1999	477.2	153.4	87.0	717.6	1,502	247	354	2,103
(%)	(66.5)	(21.4)	(12.1)	(100.0)	(71.4)	(11.8)	(16.8)	(100.0)
2000	475.5	152.1	91.8	719.4	1,553	259	390	2,202
(%)	(66.1)	(21.1)	(12.8)	(100.0)	(70.5)	(11.8)	(17.7)	(100.0)
2001	486.8	158.1	102.0	746.9	1,620	279	436	2,335
(%)	(65.2)	(21.2)	(13.7)	(100.0)	(69.4)	(12.0)	(18.7)	(100.0)
2002	519.5	134.6	84.0	738.1	1,801	240	375	2,416
(%)	(70.4)	(18.2)	(11.4)	(100.0)	(74.6)	(10.0)	(15.5)	(100.0)

[a]Statistics represent dry-season (Nov.-April) irrigated area only and do not take into account areas receiving supplementary irrigation during the wet season (May-October).
Sources: World Bank (1995), Ministry of Agriculture and Forestry, Vientiane, Lao PDR.

capacity increased by 750% (from 12,000 to 102,000 ha). Production from the dry-season irrigated environment during this time also increased more than tenfold, from 41,000 to 436,000 t (Table 2).

Most (94.5%) of the expansion in irrigated area took place in the central (70,816 ha) and southern (25,578 ha) agricultural regions. In 2001, still only about 5,600 ha were developed for irrigation in the northern agricultural region. Most of this expansion in irrigated capacity during the 1990s depended on pumping water directly from the Mekong River and, to a lesser extent, from tributaries of the Mekong. There was less investment in the development of appropriate water reticulation systems. However, by 2001, the capacity of these recently developed schemes was being underused because of a combination of factors. Farmer groups were increasingly unable and unwilling to meet the increasing fuel costs of diesel pumps (both diesel and electric pump programs had been installed). This was aggravated by the fact that crop yields were well below the expected potential because of low levels of inputs, particularly fertilizer. In some areas, farmers also encountered difficulties in marketing the second rice crop (the dry-season irrigated crop). Water-use efficiency in many scheme areas was also well below the potential because of a lack of concurrent investment in networks of water distribution canals. Further, farmer organizations, to which responsibility for the pumping schemes was being transferred, did not possess the required skills and resources to maintain the systems. By 2002, it also started to be recognized that the dry-season irrigation potential might be better used for crops with higher returns than rice. The 2002-03 dry season therefore saw a significant reduction in the use of the potential of many of the schemes developed during the 1990s.

In 2000, it was estimated that Laos had 22,240 irrigation systems, with a capacity to serve about 280,000 ha in the wet season, or about 36% of the country's 800,000 ha of annually cultivated land. Irrigated land accounted for about 65% of total agricultural production. The majority of the schemes were traditional weirs, some 18,150 in total, located mostly in mountainous areas, and accounting for about 35% of the total irrigated area.

Since 1975, various agencies have been involved in programs of assistance to improve irrigation capacity within Laos. These agencies are the European Community, United Nations Development Programme (UNDP), United Nations Capital Development Project (UNCDP), Mekong River Commission, Organization of Petroleum Exporting Countries (OPEC), the World Bank, the national assistance agencies of Australia and Sweden, and many NGOs.

The impact of natural disasters on rice production

Lao agriculture generally and rice production in particular have always been at the mercy of the weather, bad years being fatalistically accepted along with the good ones. With rice production accounting for more than 80% of the cultivated land area and rice consumption accounting for more than 80% of the calorie intake in many rural areas, the impact of adverse climatic conditions on the livelihood of the Lao people has always been potentially threatening. The occurrence and level of poverty in many areas are recognized as being largely determined by the level and frequency of natural disasters, particularly droughts and floods (ADB 2001).

Droughts and floods

Although detailed historical records on the frequency and severity of droughts and floods do not exist, some severe droughts and their effects were recorded in court chronicles (Stuart-Fox 1998). Recent records clearly indicate the high level of both incidence and significance of floods and droughts. In the 37-year period from 1966 to 2002, for every year, at least part of the country was affected by either drought or flood, or a combination of both (Table 3). The potential impact on rice production was dramatically demonstrated shortly after the LPRP came to power in 1975. As previously noted, in 1977, severe drought conditions throughout the country reduced the national rice harvest by 40% relative to that of 1976 (which was already a year of deficit), with some southern provinces experiencing a decline of up to 95% (Evans 1988). It was estimated that more than 350,000 t of rice aid were required to prevent famine conditions in 1977. In 1978, a disaster of the reverse order—serious flooding—occurred. In some areas of central and southern Laos, crop losses on the order of 90% were reported. At the time, it was estimated that half the population was potentially affected by famine conditions. In both years, without reserve stocks of rice, the government depended on rice donations from the international community to avert potentially serious catastrophes. It was partly in response to the impact of the 1977 and 1978 disasters that the socialist government initiated the agricultural cooperatives movement in an effort to improve rice production and achieve a higher level of rice self-sufficiency. In 1988 and 1989, severe droughts cut annual yield by about one-third, again forcing the government to rely on food aid for its domestic requirements. In 1988 and 1989, approximately 140,000 t of rice were donated or sold to Laos (Hopkins 1995).

More recently, in 8 of the 12 years from 1991 to 2002, significant areas of lowland rice in the Mekong River Valley were destroyed by floods (Table 4). In 1991, more than 21% (about 70,000 ha) of the rice area was destroyed; in 1995, almost 30% of the planted area in the central agricultural region was destroyed; whereas, in 1996, 17.5% and 18.7% of the rice area in the central and southern agricultural regions, respectively, were destroyed. As periods of submersion associated with the flooding of the Mekong River can often extend beyond 2 weeks, total crop loss usually results in areas affected by flooding. Some areas particularly prone to flooding have recently been withdrawn from wet-season cropping activities following the development and expansion of the potential for dry-season irrigated cropping. Flooding in the northern mountainous agricultural region is usually of short duration and crops can sometimes recover from the impact of such floods; however, the nature of floods is such that they are potentially capable of causing significant levels of soil erosion, particularly in areas with a history of intensive slash-and-burn agriculture.

Drought, although less spectacular than devastating floods, is a regular occurrence throughout the rice-growing areas of Laos (Table 3). Farmers in the rainfed lowland environment of the Mekong River Valley consider drought as their most

Table 3. Occurrence of damage to rice crops by floods and drought, 1966-2002.

Year	Type of damage	Region affected
1966	Severe flood	Central
1967	Drought	Central, southern
1968	Flood	Central
1969	Flood	Central
1970	Flood	Central
1971	Severe flood	Central
1972	Flood and drought	Central
1973	Flood	Central
1974	Flood	Southern
1975	Drought	All regions
1976	Flash flood	Central
1977	Severe drought	All regions
1978	Severe flood	Central, southern
1979	Drought and flood	Northern (drought), southern (flood)
1980	Flood	Central
1981	Flood	Central
1982	Drought	All regions
1983	Drought	All regions
1984	Flood	Central, southern
1985	Flash flood	Northern
1986	Flood and drought	Central, southern
1987	Drought	Central, northern
1988	Drought	Southern
1989	Drought	Southern
1990	Flood	Central
1991	Flood and drought	Central
1992	Flood and drought	Central (flood and drought), northern (drought), southern (flood)
1993	Flood and drought	Central, southern
1994	Flood and drought	Central (flood and drought), southern (drought)
1995	Flood	Central, southern
1996	Flash flood, drought	Central
1997	Flood	Central, southern
1998	Drought	All regions
1999	Flood	Central, southern
2000	Flood	Central, southern
2001	Flood	Central, southern
2002	Flood	Central, southern

Source: Unpublished reports of Department of Meteorology, Ministry of Agriculture and Forestry.

Table 4. Wet-season lowland crop losses (ha destroyed) due to flood damage, 1991-2002.

Region	Year							
	1991[a]	1994	1995	1996	1997	2000	2001	2002
Central								
(ha)		28,783	55,061	41,863	26,300	28,350	30,193	24,151
(%)		(13.7)	(29.0)	(17.5)	(10.2)	(10.6)	(11.4)	(8.5)
Southern								
(ha		3,135	5,759	23,720	6,750	14,530	11,790	8,103
(%)		(2.6)	(4.9)	(18.7)	(5.2)	(11.0)	(8.2)	(5.3)
Northern								
(ha)		4,464	1,500	354	225	20	240	1,810
(%)		(8.3)	(2.5)	(0.5)	(0.3)	(<0.1))	(0.3)	(2.2)
Total								
(ha)	70,000	36,382	62,820	65,937	33,275	42,900	42,223	34,064
(%)	(21.3)	(9.5)	(16.9)	(15.3)	(7.9)	(9.0)	(8.7)	(6.6)

[a]Regional flood damage data are unavailable.
Source: Ministry of Agriculture and Forestry and the Ministry of Labor and Social Welfare.

consistent production constraint (Khotsimuang et al 1995). The soils in this region are predominantly loams, sandy loams, and sands, and are particularly drought-prone (Lathvilayvong et al 1996). Although the effects of drought can often be less severe than those of floods, drought usually affects a much larger area than floods. Both early and late wet-season droughts occur and affect rice production (Fukai et al 1998). Early-season drought usually occurs from mid-June to mid-July as the monsoons change from southeast to southwest. The effects of this type of drought can be reduced by appropriate crop management practices, particularly by matching crop phenology with water availability (Fukai et al 1998). Late-season drought occurs if the regular monsoon rains end early. Fukai et al (1995) have demonstrated that late-season drought alone can reduce grain yields by an average of 30%. The use of earlier-maturing improved varieties to replace later-maturing, and often lower-yielding, traditional varieties can significantly reduce the potential impact of late-season drought. Fukai et al (1998) also demonstrated that the effect of drought on grain yield also depends on soil fertility, and that improved soil fertility increases grain yield, even in drought-affected seasons.

The occurrence of drought in uplands is equally as frequent and can be equally as severe as in lowlands. Lebar and Suddard (1960) reported on the occurrence of a serious drought throughout much of northern Laos in 1955, the severity of which was so great that rice was flown in on U.S. planes and dropped by parachute to villagers in order to avert potential starvation. Although ranked third among production constraints by upland farmers (Roder et al 1997), the impact of drought in the upland environment is of increasing significance and concern. Dry conditions in this environment have the greatest impact when occurring at or about the time of dry-seeding, affecting both germination and establishment. Late-season drought (i.e., when the wet-season rains end early) is not normally a concern, as most upland crops are harvested 30 to 50 days earlier than lowland crops in the same region.

Even with the recent increase in the area of cultivation under irrigated conditions (Table 2), the majority of both the planted area and production in Laos will remain at the mercy of the vagaries of the weather for the foreseeable future. However, it is possible to achieve greater yield stability under such conditions through varietal improvement.

Biotic disasters

Pests and diseases are also chronic production constraints for both upland and lowland environments (Schiller et al 2001). Normally, their impact is relatively localized and often the implementation of appropriate management practices can minimize their potential damage to rice crops. However, one category of pest in upland environments that has traditionally had an impact on production often of the same magnitude as natural disasters is rodents (Roder et al 1997, Singleton et al 1999). Although actual grain losses due to rodents have yet to be quantified, it is estimated that they probably account for at least 15% of the annual rice harvest (Singleton and Petch 1994). At irregular intervals, conditions favor massive rodent population explosions, resulting in local losses of more than 50% of the rice crop. Occasionally, entire rice crops are lost, as happened in parts of Luang Prabang Province in 1991 (details of the ecology of rodent and related problems in relation to rice production in Laos are reviewed by Aplin et al in Chapter 19).

National rice sufficiency

Rice production in Laos has generally been on the basis of meeting immediate household needs. In the absence of an established market for rice, until recently, there has been little incentive to produce a rice surplus, particularly under upland conditions. As a result, small fluctuations in yield caused by climate, pest problems, or labor shortages have usually been immediately reflected in rice shortages (Roder et al 1996). These authors also report that occasional shortages of rice are not a recent phenomenon. Observations in the uplands as long ago as the early 1940s report rice stores often being empty in July, forcing farming families to rely on hunting and gathering for provisions for periods of 3–4 months before the harvest of the next rice crop.

Independent of the impact of the vagaries of the weather and pest problems, changes in the level of rice self-sufficiency have, until relatively recently, often reflected the level of political stability throughout the country. During the period of French administration from 1893 to 1945, there was considerable resistance of many ethnic groups to a number of government policies. In particular, resistance was strong to some of the taxation measures, as well as the system of annual unpaid labor that was imposed (Batson 1991, Simms and Simms 1999). The often physical resistance of some ethnic groups to the implementation of these laws and measures was associated with a lack of stability in many upland areas, which interrupted normal upland rice-cropping cycles. As a result, during the period of French administration, significant areas of Laos often had periodic and chronic rice shortages because of factors other than the impact of natural disasters and pest damage. Total annual rice production during this period fluctuated from a maximum of just over 500,000 t in 1923 to an average of less than 300,000 t during the 1930s. In upland areas, shortages were made up by maize (from upland swiddens) and various tuber crops. However, in lowland areas, the deficits were not so readily replaced by alternative foods. A 20% decline in the national rice harvest in 1936 was associated with subsequent near-starvation conditions in parts of Khammouane Province.

After Lao independence in 1953, under the Royal Lao government there was a 20-year period during which the disruptive effects of the ongoing civil conflict in much of the country also disrupted the normal rice-cropping cycles, in both upland and lowland environments. For much of this time, there was a chronic national rice deficit, with shortages at both regional and local levels often being critical. In the upland environment, the frequent displacement of villages in some areas generally meant that the rice shortages were more acute than in lowland areas. At the height of the conflict in the 1960s and early 1970s, tens of thousands of members of mainly upland ethnic groups fled their villages to avoid the fighting in the north of the country, while the Plain of Jars in the northeastern region was almost depopulated (Stuart-Fox 1997). Stuart-Fox (1997) reports that during this time "as many as three-quarters of a million people, a quarter of the entire population, had been driven from their homes to become refugees in their own country." In some remote areas, displaced villages became totally dependent on food supplies dropped by American planes. At the peak of the shortages in the early 1970s, more than 170,000 refugees were understood to be dependent on receiving rice in this way in the north of the country alone. The rice used for these "sky drops" was all imported. It was even reported that some young children of this era came to believe that "rice came from the sky." Appa Rao et al (Chapter 10) report that some of this "rice from the sky" was used as seed for planting, and was still being planted at the time varieties were collected for conservation and preservation in the latter part of the 1990s, having been given the varietal name "American rice." Batson (1991) reports that it was not until 1984 that some degree of national rice self-sufficiency was first achieved. However, even for that year, the same author noted that "a combination of uneven production, poor land, poor transportation, and climatic vagaries left people in the rugged, highland areas without enough rice or with very marginal surpluses."

In the main areas of lowland rice cultivation, rice self-sufficiency from year to year has primarily reflected the occurrence of natural disasters—droughts and floods, and occasionally pest and disease problems. At a national level, the decision in the early 1990s to expand the area of irrigated rice production has, in association with the adoption of improved production practices in lowland environments, brought about a rapid change in the reported level of national rice self-sufficiency. Production from the 2001 dry-season irrigated environment accounted for about 19% of total production for that year, compared with less than 3% coming from the irrigated environment in 1990.

Table 5. Levels of rice sufficiency (months per year) according to region and ethnicity.

Region	Ethnicity			
	Mon-Khmer	Tibeto-Burman	Hmong-Mien	Lao-Tai
North	6.2	7.0	8.2	11.5
East	6.3	–	7.8	6.5
Central	7.9	–	8.0	10.8
South	5.5	–	–	9.3
Average	5.9	7.0	8.1	9.0

Source: UNDP (2002).

Although the official statistics of the Ministry of Agriculture and Forestry indicated that national rice self-sufficiency was achieved in 1999 with the production of 2.1 million tons of paddy rice (Table 2), with further increases in subsequent years to in excess of 2.4 million tons in 2002, unofficially it is acknowledged that these figures are overestimates. It has also been long acknowledged that national rice self-sufficiency does not necessarily translate into regional, provincial, or household self-sufficiency. Rice surpluses of recent years in areas with double-cropping potential as a result of the expansion of irrigated rice cultivation have not necessarily alleviated the increasing chronic rice shortages of many upland areas. Recent studies on poverty and human development in Laos (ADB 2001, UNDP 2000) reveal that 90% of villages classified as poor throughout the country depend on swidden agriculture as their primary means of livelihood. Levels of poverty are closely linked to levels of food (primarily rice) sufficiency. Generally speaking, the level of rice deficiency is currently greatest within Mon-Khmer groups in upland areas and least in the Tai-Lao, who predominately inhabit the lowlands (Table 5). Rice shortages in the uplands generally average 3–4 months but can be as much as 8 months and are chronic; in the lowlands, they average 1–3 months and vary from year to year, depending on natural disasters, particularly drought and floods, and place to place, reflecting irrigation potential and the availability of land.

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Notes

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CHAPTER 3

Rice production systems of Laos

B.A. Linquist, B. Keoboualapha, Sipaseuth, and P. Inthapanya

The rice production systems in Laos can be classified into three broad ecosystems (Table 1 and Photos 3.1–3.3): irrigated lowland, rainfed lowland, and upland. Lowland rice (sometimes referred to as paddy rice) grows in bunded fields and the soil is flooded for at least part of the crop season. Water for rice production comes from either rainfall or irrigation. Upland rice grows as a rainfed dryland crop and is usually only grown during the wet season and is often associated with being grown in a slash-and-burn system on steep slopes.

The terms "upland" and "lowland," as used in describing rice production ecosystems, have no relation to the elevation or topography where the rice is grown. Indeed, lowland rice production systems can be found at over 2,500 m elevation in countries such as Bhutan. In Laos, lowland rice fields are found at over 1,000 m elevation in Xieng Khouang Province. Similarly, upland rice fields can be on flat fields at low elevations, such as those in Vientiane Municipality.

Lowland rice (both rainfed and irrigated) is common in the mountainous northern region and along the eastern border with Vietnam. This system will be referred to as montane lowland rice in this chapter (see also Chapter 25). It is distinguished as lowland rice grown in the mountains in small valley bottoms or on terraced hillsides. Although it is lowland rice by definition, the management practices in this system are sufficiently different to warrant separate discussion.

Table 1. Terminology for rice-growing environments found in Laos.

Ecosystem	Description
Irrigated lowland (paddy)	Rice grown in bunded fields and fields are flooded for at least part of the season. Irrigation water is used.
Rainfed lowland (paddy)	Rice grown in bunded fields and fields are flooded for at least part of the season. Water comes from rainfall.
Upland	Rice is grown in unbunded fields and water comes from rainfall. Rice is typically grown on sloping fields and associated with slash-and-burn systems.

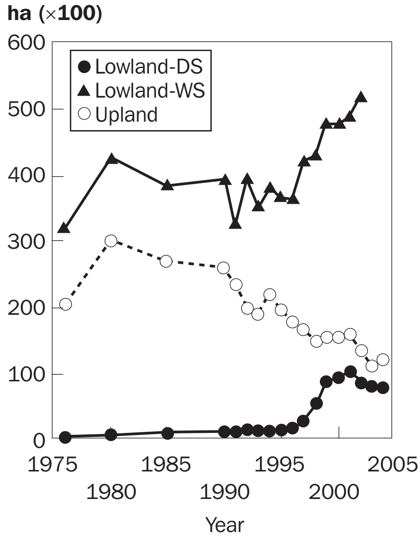

Fig. 1. Total area devoted to rice production in the lowland (wet season and dry season) and upland environments from 1976 to 2004.

Although three rice production ecosystems are recognized in Laos, production statistics collected and published relate to the following: (1) wet-season lowland rice (rainfed and irrigated), (2) dry-season irrigated lowland rice, and (3) rainfed upland rice. The statistics for wet-season lowland rice do not indicate the relative areas of rainfed lowland production and wet-season irrigated production.

Relative importance of production systems

Government statistics indicate that the total rice area in 2004 was 770,320 ha (Fig. 1). The most important system is wet-season lowland rice production, with over 550,000 ha in production. This area has been expanding annually since 1996. Dry-season irrigated rice production area increased rapidly between 1995 and 2001 from 13,600 to 102,000 ha. Since 2001, however, dry-season area has declined and, in 2004, 77,000 ha were in production. Upland rice area declined from about 300,000 ha in 1980 to less than 120,000 ha in 2004; however, some satellite imagery data suggest that the area under slash-and-burn production is actually increasing. Regardless, these statistics represent only the area planted to upland rice in a given season. Since most upland rice is grown in slash-and-burn systems, the total area devoted to upland rice depends on the fallow length. If the average fallow period is 3 years, then the total area under slash-and-burn would be close to 500,000 ha.

In the northern region, the upland rice production system is most important, although there is a large area of wet-season lowland rice (Fig. 2). In the north, the

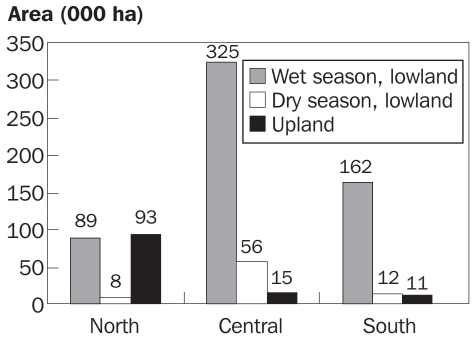

Fig. 2. Area of production systems by region (2004 data).

Table 2. Rice production statistics by environment for 2004.

System	Area (ha)	Yield (t ha^{-1})	Production (t)	Production (% of total)
Lowland (wet season)	575,520	3.43	1,976,000	78
Lowland (dry season)	76,840	4.45	341,703	14
Upland	117,960	1.79	211,200	8

Source: Ministry of Agriculture and Forestry, Vientiane, Laos.

province of Sayabouly has the largest wet-season lowland rice area (over 24,000 ha) but all the other northern provinces, with the exception of Phongsaly (which has 6,000 ha), have in excess of 11,000 ha. In the central and southern agricultural regions, the upland area is relatively small (a total of about 25,000 ha) and largely confined to the Lao-Vietnam border area. Wet-season lowland rice is the dominant rice system in these regions. Savannakhet Province, in central Laos, has the largest area of wet-season lowland rice (135,000 ha) for any single province. Dry-season irrigated rice is most important in the Central Agricultural Region, with Vientiane Municipality (21,000 ha) and Savannakhet (19,000 ha) having the largest areas.

According to government statistics, total rice production in 2004 was 2.53 million tons (Table 2). Of this, 2 million tons (78% of the total) was produced in the wet-season lowland environment, 0.34 million tons (14%) in the dry-season lowland environment, and 0.21 million tons (8%) in the upland environment.

The rainfed lowland rice production system

Annual cropping cycle

The annual cropping cycle begins in May or June, depending on the onset of rains, with the preparation of the nursery seedbed and the sowing of seeds for the nursery (Table 3). Seedlings are transplanted about 1 month after sowing; however, transplant-

Table 3. Seasonal cropping calendar for the different rice production systems in Laos.

System	Month											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Season	Dry season				Wet season						Dry season	
Rainfed lowland						Sow	TP			Harvest		
Irrigated lowland	TP[a]			Harvest		Sow	TP			Harvest		Sow
Montane lowland	TP			Harvest		Sow	TP	TP2[b]		Harvest		
											Sow[c]	
Upland	Slash		Burn; make fence and hut		Plant				Harvest			

[a]TP = transplant. [b]TP2 = transplant second time (double transplanting is practiced by some farmers). [c]A dry-season crop is planted only if irrigation water is available.

ing may be delayed if the onset of wet-season rains is delayed. Harvesting is during October and November, depending on the varieties and planting time. During the dry season, fields are often grazed by livestock.

Varieties

Before the release and distribution of improved Lao glutinous varieties in the mid-1990s, about 95% of the varieties grown in the lowlands were traditional varieties. These varieties were predominantly glutinous and photoperiod-sensitive. This situation changed rapidly in the latter half of the 1990s as farmers adopted the newly released varieties, and, by 2002, more than 80% of the lowland area in the Mekong River Valley was being sown to improved varieties. Laos has the highest per capita production and consumption of glutinous rice in the world, and although accurate data are not available, it is estimated that, in the 2002 production year, about 85% of the rice produced in Laos was glutinous (see Chapter 14). Further evidence on the preference for glutinous rice is that over 85% of the lowland varieties collected between 1995 and 2000 were glutinous (Appa Rao et al 2002).

Farmers sometimes grow up to nine different varieties in any given year, with the norm being four or five (Pandey and Sanamongkhoun 1998), although, with the increased adoption of improved varieties, there is a trend to growing fewer varieties overall. Choice of variety is based on available water, maturity time, yield potential, and grain quality. Early-maturing varieties (flowering in mid- to late September) are traditionally grown in upper terraces where water supply is less certain. Late-maturing varieties (flowering in mid- to late October) are typically grown in the lower terraces where water supply is more reliable, but where occasional submergence can sometimes be a problem (Schiller et al 2001). Further details on both the traditional and improved varieties grown in Laos can be found in Chapters 9 to 13 and Chapter 21.

Nursery management

Most lowland rice in Laos is transplanted as opposed to direct-seeded. Wet-season rice production typically begins in May or early June at the start of the monsoon rains with the planting of the rice nursery. Following sufficient rain, the seedling nursery is prepared by plowing and puddling using a harrow. This is often done by buffalo but increasingly small handheld tractors are being used (enough water is required to make the soil soft enough to plow, especially for buffalo). If farmers apply manure to the nursery, they do so prior to plowing; however, many farmers do not use manure or other forms of fertilizer in the nursery. Some farmers presoak seeds for a day or two before sowing. Rice is sown by broadcasting the seeds immediately after puddling. Nurseries occupy a small area (5–10% of the total area to be planted) and are usually fenced to protect them from livestock. Seedlings grow for about 30 days in the nursery, although farmers may transplant at any time from 25 to 40 days or longer depending on rainfall. Sufficient rainfall is required to plow the main field and prepare for transplanting.

Most lowland rice landscapes feature small huts in and around the rice paddies. These huts (*thieng na*), which provide a place to rest and eat while working in the field and to guard the crop, are usually erected around the time the nursery is established.

Field management

The main fields are first plowed 2 to 4 weeks before transplanting. Just before transplanting, when the soil is flooded, the field is plowed again and puddled using a harrow. In sandy soils, this is done immediately before transplanting, as the soil settles fast and becomes harder and more difficult to transplant the longer the time lapse between harrowing and transplanting. Transplanting is a labor-intensive operation and, in many cases, especially near urban areas, labor is hired for transplanting. Farmers typically transplant at a hill density of 16 m^{-2} using about 3 seedlings per hill.

Fertilizers are not used extensively in the rainfed lowlands. Until the mid-1990s, very little chemical fertilizer was available and use was very little in the wet-season lowland production system. The more recent adoption of fertilizer is largely confined to areas of lowland rice production along the Mekong River corridor in southern and central Laos. Fertilizer use is increasing, as is evident from survey information from southern Laos (Pandey and Sanamongkhoun 1998), which indicated that, in 1995, 60% of the farmers using fertilizer had only started using it in the two years immediately prior to the survey. The amount of fertilizer used and time of application often depend on individual farmers' financial resources. The most common fertilizers imported and available are 16-20-0 and 46-0-0 (urea), which represented 73% of the total fertilizers imported in 1999. Some farmers apply rice husks and manure to their fields but this is not a common practice. If they are applied, this is done before the first plowing.

Pesticide use is limited and has followed a similar pattern of adoption as for fertilizer (for more specific information on pests and their management, refer to Chapter

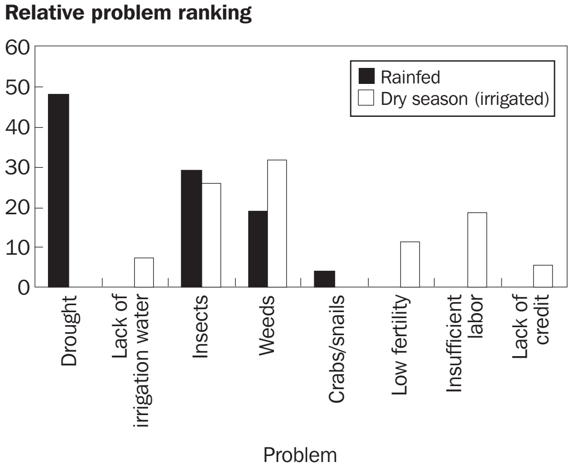

Fig. 3. Relative ranking of the top three problems identified by farmers in the wet-season rainfed lowland and dry-season irrigated environments. Source: Schiller et al (2001a).

17). Weeding is done manually once or twice during a season and, in the main lowland rice-growing area in the Mekong River Valley, is not normally perceived as a major production constraint (Fig. 3). Rice usually starts to mature in October, and continues through November depending on location, variety, and time of planting.

Harvesting and threshing

Harvesting is done manually and the harvest is usually bundled and left in the field for a few days to dry (Photo 3.4). Panicles may be left on top of the stubble straw to dry or be placed on an elevated pole or rack. Once dried, rice is often stored for a short period in the field before threshing by piling the cut rice neatly into a large round stack with the rice panicles in the middle of the stack to protect them from rain and rodents (Photo 3.5). Traditionally, threshing has been done manually, and manual threshing continues in the more isolated areas of Laos. However, in many of the larger lowland rice-growing areas, threshing is becoming increasingly mechanized.

Storage

How grain is stored depends on whether it is to be used for food or seed. Grain is usually stored when the grain moisture content is between 12% and 14%, and is always stored unmilled. Most farmers store grain in a wooden rectangular structure supported on stilts, which often carry physical measures for protection against rodent damage. The size of the grain stores varies, and depends on the quantity of grain to be stored. Some farmers put the grain directly in the store while others first bag the rice before storage. Another storage method is the occasional use of large bamboo baskets that are woven from split bamboo; the outer walls of these baskets are often plastered with mud or manure. The basket is usually placed on a platform and protected from rainfall by a temporary roof. These stores are situated close to the house. If the fields are far away from the village, a grain store may be built in the fields and grain carried to the home at regular intervals.

Seed rice is commonly stored in nylon bags and kept inside the grain store. Less common but occasionally used is the tying of panicles into bundles, which are then stored hanging from the roof. Only varieties that are difficult to thresh (nonshattering) can be stored in this manner.

Milling

Food rice is stored unmilled, as rice quality is better maintained when the rice is left inside the husk until required for consumption. When rice is needed for consumption, farmers will usually mill enough to meet family consumption requirements for 1 or 2 weeks. Traditionally, farmers milled rice in a mortar. This is still done in some of the more remote areas but increasingly farmers take their rice to a village-level rice mill for milling. Usually, the cost of milling at a rice mill is the bran from the rice, which the miller subsequently sells as a livestock feed.

Crop residue management

At harvest, farmers remove the panicle, leaving about half (depending on variety and farmer) of the rice straw in the field. This stubble straw is most commonly grazed by livestock during the dry season, but it may also be burned. The panicle straw, which is removed with the grain, is moved to a central location for threshing. In the case of the use of large mechanical threshers, the panicles are often moved to a location near a road, which provides access for the thresher; after threshing, the straw is often burned. Hand threshing is usually done either in the field or near the home, after which the straw is often stored for livestock feed. During the dry season, livestock graze freely on the straw residue left standing in fields. Little effort is made to collect and use any of the straw as a potential manure or mulch. Survey data from southern Laos in the mid-1990s revealed that only 11% of the farmers used manure, with application rates (mostly to nurseries) varying from 35 to 1,050 kg ha^{-1} (Lao-IRRI 1995). Rice husks following milling are often left at the mill, although in recent times there has been increasing use of them in areas of the Mekong River Valley, following recognition of their potential as organic fertilizer.

Labor inputs

Based on benchmark survey information collected in 1996 in a nonmechanized production system, a total of about 120 person-days per ha were required for rainfed lowland rice production (Pandey and Sanamongkhoun 1998) (Fig. 4). The main labor-intensive activities were winnowing and hauling (48 person-days), crop establishment (35 person-days), and land preparation (30 person-days). Land preparation was primarily done by men while the other two activities were done by both men and women. Manual weeding required less than 3 person-days per ha. With increased mechanization of both

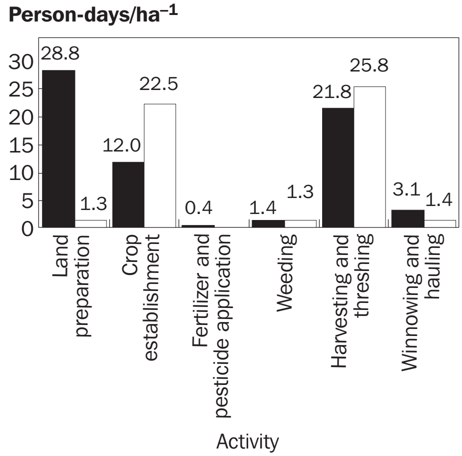

Fig. 4. Labor input in the rainfed lowland rice system. Source: Pandey and Sanamongkhoun (1998).

land preparation and threshing in the main lowland rice-growing area of the Mekong River Valley, the labor input has probably dropped considerably.

Constraints

The main production constraints identified by lowland farmers in the Mekong River Valley are shown in Figure 3. Drought is identified as the main constraint, followed by insect pests. Interestingly, soil fertility is not listed high even though this has been identified by Linquist et al (1998) as a main constraint. This probably reflects the fact that, at the time the survey was undertaken in the mid-1990s, farmers were less aware of soil fertility problems and potential yield responses to fertilizer inputs.

The irrigated lowland rice production system

Irrigation allows for double cropping. During the wet season, the cropping cycle is similar for the rainfed and irrigated lowland systems (Table 3). For the dry-season crop, the nursery is sown in December. The time of sowing is often determined by the availability of irrigation water. Transplanting is normally done in January, about 1 month after sowing. During crop growth, farmers are busier during the dry season than in the wet season as they tend to apply more fertilizer and weeds are a greater problem. Harvest usually takes place between March and May depending on location, varieties, and planting dates.

Although management practices in the irrigated rice system are generally similar to those in wet-season rice production, dry-season production differs in the following areas:

- Stubble straw (straw remaining after the wet-season harvest) is often burned following harvest to allow for easier and quicker land preparation. In the rainfed system, with only one crop grown per year, livestock typically graze the remaining stubble straw.
- Improved varieties are almost exclusively used. As in the wet season, glutinous rice is primarily grown. Most of the improved varieties planted are those that have been developed primarily for wet-season cropping. Although these varieties are generally suited to dry-season irrigated areas in southern and central Laos, often they have not performed well in the northern region, which experiences low winter temperatures, particularly during the period of seeding and transplanting in December and January.
- Generally, more inorganic fertilizer inputs are used for dry-season irrigated cropping than during the wet season; this largely reflects the lack of cropping risk associated with the known availability of irrigation water.
- Plants are usually transplanted using a closer spacing (25 to 44 hills m^{-2}).
- Weeds tend to be a more significant problem than with the wet-season crop.
- Some pests are also perceived as causing bigger problems in the dry season than in the wet season; these include a perceived higher incidence and damage from rice bug and brown planthopper.

The Montane lowland rice production system

Lowland (rainfed and irrigated) rice production is commonly practiced in the highland areas of Laos (in northern Laos, particularly in provinces adjacent to the Lao-Vietnam border). There are some large lowland rice areas (mainly in the northern provinces of Sayabouly and Luang Namtha) where lowland rice production practices are similar to those found in southern and central Laos. There are also considerable amounts of lowland rice production in narrow valley bottoms and along terraced hillsides (Photo 3.2). These areas are not extensive; many highland villages have only 1 to 10 ha of such lowland rice. Most farmers owning montane lowlands also have upland fields where they grow upland rice and cash crops. Although management in many ways is similar to that in other lowland areas, there are some significant differences.

1. Since farmers also own upland fields, the timing of the various lowland activities needs to fit in with their upland activities (Table 3).
2. Local varieties are more common in the montane lowlands.
3. Nurseries are in upland fields, adjacent to lowland fields (Photos 3.6 and 3.7). Having upland instead of lowland nurseries is primarily due to the high labor demand for upland fields and limited water availability.
4. Double transplanting is often practiced (see box, page 38).
5. Small irrigation schemes are common. Farmers typically form groups to make a weir from logs and stones. Canals are dug to carry water to paddy fields by cutting a canal out of the slope. Bamboo is often used to carry water over low areas to fields.

Double transplanting

Double transplanting is where farmers transplant twice: first from the upland nursery to a lowland nursery and then from the lowland nursery to the main field. In each nursery, rice is grown for about 1 month. Some reasons given by farmers for double transplanting are

1. To spread labor demand. Even though total labor may be higher, the labor is spread out. As mentioned earlier, many farmers also own upland fields and they need to balance their labor betwen these areas.
2. To reduce excessive vegetative growth, especially in good soils where traditional varieties (susceptible to lodging) are grown.
3. To reduce damage caused by crabs. Crabs are a problem in many lowland nurseries (crabs cut the stems of young seedlings); planting larger seedlings helps reduce this damage.
4. To cope with water shortages. Many lowland areas are irrigated from mountain streams that may dry up in the dry season. There may not be enough water early in the wet season to transplant into the main field.

6. Pest problems are often different, as montane lowland fields are often surrounded by forest or fallow vegetation that provide a good habitat for rodents and other pests.
7. Gall midge (*Orseolia oryzae*) appears to be a particularly common pest problem, especially in wet years.
8. Farmers rarely use fertilizer. Local varieties are not responsive to fertilizer and fertilizer increases problems with gall midge.
9. Dry-season production is limited because of inadequate irrigation water, low dry-season temperatures, and high susceptibility to pest damage (small cropped areas are often targeted by pests such as rodents and birds).
10. When dry-season rice is grown, farmers typically sow their nurseries very early (mid-November) before the onset of the lowest winter temperatures. They then transplant in early to mid-January when temperatures start to moderate.

Upland rice production practices

Upland rice production is practiced widely in northern Laos as well as in the eastern parts of central and southern Laos, which are also very mountainous. Upland rice production is practiced on slopes ranging from 0 to 120%. Upland rice is usually grown in slash-and-burn production systems where rice is grown for 1 or 2 years (but usually only 1 year), with the field then being allowed to return to a natural fallow. In some areas (5–10% of the area), a rice crop is followed by rice or other crops (Roder 2001); however, this is in response to population pressure and farmers are simply testing new strategies. Historically, this practice has been sustainable, but in recent times it has become increasingly unsustainable because of shortening fallowing periods as a result of increasing population pressure. The shorter fallows have led to increases in soil erosion and increased weed ingress (which has, in turn, resulted in significant increases in labor inputs required for weed control, thereby reducing the area capable of being cropped by individual households), with a resulting decline in fertility and rice yields. Another system observed in the north is what farmers call "garden rice," in which rice is grown in permanent fields, either successively or in rotation with other crops; however, this is practiced in a very small percentage of the area. A detailed discussion of upland issues and research can be found in Chapter 24.

Rituals and religion are intertwined with most aspects of slash-and-burn cultivation. Some of these traditions and beliefs associated with the different ethnic groups are described in Chapters 5 to 8.

Land use and ethnicity

One characteristic of the northern Laos uplands is their high ethnic diversity. Certain ethnic minorities are often blamed for causing environmental damage and forest destruction because of unsustainable land-use practices associated with slash-and-burn upland rice cultivation. Between 1991 and 1994, Roder (2001) conducted a survey to quantify differences in land-use patterns among various ethnic groups. The results of this survey did not indicate that the upland cultivation practices of any particular ethnic group were more unsustainable than for other ethnic groups. Variations in land use within the same ethnic group were generally larger than between ethnic groups. Some specific findings from this survey can be summarized as follows.

1. All ethnic categories are engaged in slash-and-burn cultivation to varying degrees, including some Lao-Tai, who are generally associated only with lowland rice cultivation. Conversely, members of the Mon-Khmer group (particularly the Khmu) and the Hmong-Mien group, more usually associated with upland cultivation systems, were found to have lowland rice fields when conditions allowed.
2. There are no consistent differences between ethnic categories with regard to rice yields, slope gradient of fields, labor input, weeding requirements, and fallow periods.
3. Some ethnic groups tended to have their villages at higher elevations and their villages were more remote. This is particularly the case for the Hmong-Mein and is believed to probably reflect the fact that (1) these groups moved to Laos more recently and had to use land that was not yet occupied and thus more remote, and (2) partly the preference of cultural isolation, cooler climate, and environments relatively free of malaria.
4. The Hmong-Mein ethnic group generally follows longer cropping cycles and their soils had higher organic matter levels, which may reflect the fact that (1) they are recent immigrants and are still working on land with relatively high fertility status, having gone through fewer cropping cycles; (2) the overall cooler climate (higher elevation) results in slower organic matter breakdown; and (3) wider crop diversity allows for longer cultivation by reducing the impact of weeds and pests.
5. The Hmong-Mein generally had higher crop diversity and maize was a more important component of their cropping systems.

Although there may not be marked differences in relation to land-use practices, diversity does exist in relation to upland rice production practices, some of which are discussed below.

Annual cropping cycle

The annual upland rice production cycle (Table 3) starts in January, when farmers slash the vegetation that has grown in their fields. In March and April, when dry, the vegetation is burned. Sowing takes place between mid-April and the end of May, depending on the rains and location. During the growing season, farmers weed their fields from three to five times (areas with shorter fallows requiring more frequent weeding). Harvesting begins in early September with the early-maturing varieties, whereas late-maturing ones are usually harvested by the end of October.

Field preparation

In January, farmers meet together to discuss and identify the areas to be cleared and cropped. Usually, farmers like to have their fields adjacent to those of other farmers, as this creates a system where they work together to protect the area from livestock and other pests. In January and February, the vegetation is slashed and allowed to dry. The time and effort spent doing this depend on the length of the preceding fallow. Large trees and other perennials dominate fields that have been in fallow for a long time, whereas fields that have been in fallow for only a short time are dominated by shrubs and annual weeds. In March and April, the dried vegetation is burned (Photo 3.8). This usually takes place in two steps: an initial burning and then a reburning when all the unburned vegetation is stacked and burned again. During this time, fences are also built around the field to provide protection from grazing animals (both wild and domesticated). Fences are usually made from wooden poles collected from the burned field area, although some ethnic groups, such as the Hmong, are known to make quite elaborate fences. A field hut (*thieng hai*) is also built during this time. As many upland rice fields are a long way from the village (often a 2- to 3-hour walk), the field hut is important as the farmers rest in it during the day, cook and eat meals there, and occasionally use it for overnight stays, especially close to harvest time when they need to guard the field from pests and wandering animals.

Planting

Sowing takes place in mid-April to May. Under upland rainfed conditions, there is no soil preparation but rather rice is dibble planted into the ash from the preceding burning of the vegetation in the area being cropped. Dibble planting requires making a hole in the soil about 5 cm deep with a dibble stick and then putting the rice seed into the hole. Different ethnic groups have different preferences and types of dibble sticks. The most common is a 2-m-long stick made of hard wood with either a point carved onto the end or a metal point attached to the end. A modification of this is a sounding dibble stick, which the Khamu sometimes use. As the holes are made with a sounding dibble stick, a sound is made to give a pleasant rhythm to the planters so they can work faster and the job will be less tiring (Simana and Preisig 1997). Finally

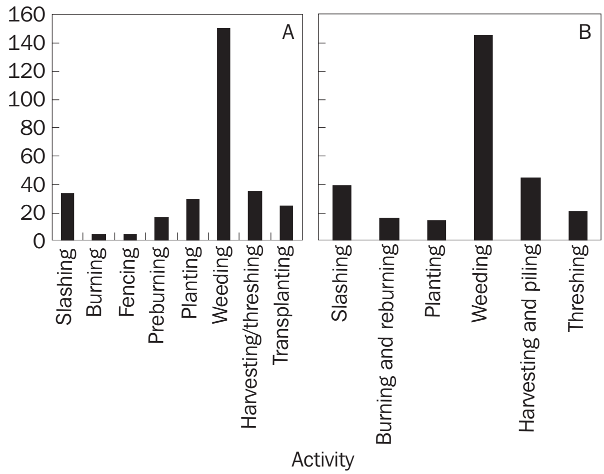

Fig. 5. Labor requirement (person-days ha^{-1}) for upland rice cultivation: (A) from household survey conducted in 1992 in the provinces of Luang Prabang and Oudomxay (Roder et al 1997); (B) from Pak Ou District, Luang Prabang Province, collected in 2001 (Lao-IRRI 2003).

is a short planting stick with a small, narrow, spade-like metallic blade attached to the wooden handle. Dibble planting usually requires two people, one making the holes and the other putting seeds into the holes, although one person can do the operation. Holes are usually spaced at a density of 10 to 16 hills m^{-2}, with 10–15 seeds being planted in each hole (Photo 3.9). The rice seed may sometimes be mixed with a pesticide to provide some protection against pests before germination. As upland rice is often intercropped with other crops, the seed of other crops is in some instances mixed with the rice seed before dibble sowing.

Weeding and crop management

Weeding requires more labor than any other activity—about half the annual labor requirement (Photo 3.10) (Fig. 5). Depending on the length of the previous fallow, a farmer may weed the field two to five times. All members of the family weed. Weeding may be done using only household labor or in a group whereby farmers exchange labor for weeding. In the first case, where only family members weed their fields, weeding needs to be done almost every day to provide adequate weed control, particularly in areas where the fallow period is short. Where group weeding is undertaken, a single field can be weeded in a few days. When weeding sloping fields, farmers weed by walking up the slope and in this sense they prefer steep fields, as they bend over less while weeding. Chapter 20 provides a more detailed outline of the ecology of weeds in the different rice production systems in Laos.

Rice is harvested in three ways:

1. Stripping the grain from the panicle by hand from the standing rice crop.
2. Cutting only the rice panicle using a small knife held between the fingers.
3. Using a sickle to cut the top portion of the rice crop.

Rice harvest and threshing

Rice is harvested during September and October depending on the maturity time of a variety. Some early varieties may be harvested before they are fully mature. This is especially the case if the farmers' rice supplies have been depleted. When harvested before maturity (during the dough stage), the grain is lightly roasted, fried, and then the hulls removed. This rice can be steamed and eaten as normal rice (*khao mao*) or used to make deserts such as "*khao hang*" (a desert with coconut milk and sugar). If a family has run out of rice from the previous season, this rice provides sustenance until the main crop is harvested.

Harvesting is done in different ways depending on ethnic group and rice variety. Three types of harvesting methods (see box) are recognized and each involves different methods of drying and threshing. First, rice can be stripped by hand from the panicles directly into a basket and hence there is no need for threshing. This type of harvesting is associated with rice varieties that have grains that are easily stripped from the panicle. The rice grain is dried on mats in the sun before storing. Second, a practice that is associated particularly with the Hmong ethnic group, is harvesting only the rice panicle using a small knife held between the fingers. These panicles are often taken directly to the village where they are separated from the grain using a mortar, trampling with feet, or beating with a stick. Third, and perhaps most common, is using a sickle to cut off the top half of the plant (similar to what is done in the lowlands). When harvesting the rice with a sickle, the panicles are tied together in bundles and left to dry for several days, most commonly on top of the remaining rice stubble, but also sometimes on an improvised platform or, as practiced in parts of Luang Namtha Province, hung on a large scaffold. As in the lowlands, once the rice has dried, it is often stored for a short period in the field before threshing by piling the cut rice neatly into a large round stack with the rice panicles in the middle of the stack to protect them from rain and rodents (Photo 3.5).

In the upland environment, almost all threshing is still undertaken manually; mechanical threshers are rarely used. Threshing is usually done by holding a bundle of rice together with two sticks that are tied together; the panicles are then beaten against a log slab or stone to dislodge the grain (Photo 3.11). After threshing, the chaff is removed from the grain. This is done in several ways, the most common being placing the rice in a large, flat woven basket and tossing it into the air to let the wind carry away the chaff. A practice associated with the Hmong is to build a platform 3 to 5 meters high and carry the threshed rice to the top and slowly drop it, letting the wind carry the chaff away (this is also seen in the montane lowland rice system—Photo 3.12). Following threshing, the grain is bagged and carried back to the village. Some farmers store the grain as “panicles” without threshing; this is only possible for varieties that do not shatter easily.

Storage

Rice is stored in many ways depending on whether it is to be used for eating or for the following year’s seed, and the methods used in the upland environment do not differ much from those used in the lowlands. Rice that is eaten can be stored in nylon bags and stored in the house, in a separate store on stilts or in large woven baskets covered with mud or manure. Often, rice stores are built on stilts with aluminum or smooth bamboo around the stilt poles to deter the entry of rodents. In some villages, these stores are outside of the village to minimize the loss of food reserves in the event of a fire within the village.

Seed rice is often stored in nylon bags. These bags may be put in the farmer’s house and stored above the cooking fire, the smoke from which helps minimize infestation by insects and other pests. Sometimes the bags of seed rice are buried in the rice that is being stored for consumption.

Milling

Methods of milling do not differ significantly from practices in the lowlands. However, as many of the upland villages are more remote, the use of manually operated mortars is much more common than rice mills. However, once villages have road access, one or two farmers will set up small rice mills to meet the needs of the village.

Varieties

Most traditional upland rice varieties belong to the tropical japonica variety group (Roder et al 1996). Upland farmers clearly differentiate between early, medium, and later maturing varieties and most households will plant varieties from each group. This allows them to harvest rice for consumption as early as possible, distribute labor requirements for harvest, and spread risk (Roder et al 1996). In addition, special varieties are sometimes grown for religious ceremonies, nonglutinous varieties are used for noodle making, and some varieties are suited to making alcoholic beverages. Most upland farmers grow two to five varieties, with each variety showing differences in maturity. Any given village may have up to 18 different varieties (see Chapter 10).

Most Lao farmers prefer glutinous rice varieties. However, a small number of ethnic groups grow and consume mainly nonglutinous rice, the most notable being the Hmong and Mien (Yao); originating from southern China, these two ethnic groups migrated to Laos during the 19th and 20th centuries. There are no known improved upland rice varieties being used in Laos. While variety preference varies, most farmers prefer upland rice varieties that are tall with thick stems and have long, large panicles and big grain.

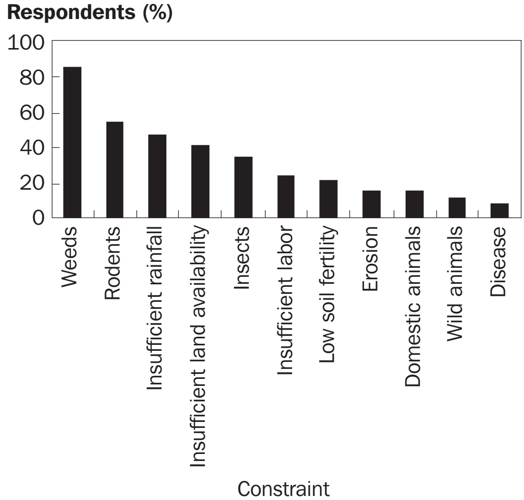

Fig. 6. Constraints to rice production in slash-and-burn systems (household survey conducted in 1992 with 129 correspondents from four districts in Luang Prabang and Oudomxay provinces). Land availability includes the constraint of short fallow and insect pests are mostly white grub. Source: Roder (2001).

Multiple cropping

Upland rice is rarely monocropped; maize, cucumber, pumpkin, taro, cassava, chilies, sesame, Job's tears, loofah, smooth loofah, sweet potato, long bean, peanut, eggplant, ginger, sweet-stalk sorghum (for chewing stalks), Italian millet, finger millet, yam-bean, pigeonpea, and sun hemp are often grown with the rice or along paths in rice fields (Photo 3.13). In some cases, seeds of these crops are mixed with the rice seed and planted at the same time as when the rice is dibble planted. Most of these crops are for home consumption (crops that are grown as cash crops are usually grown in a separate area, often as a monocrop).

Labor and tools

All labor in upland fields is manual and the only tools used are machetes, weeding blades, dibble sticks, harvesting tools (a sickle or small knife), and threshing tools. On average, upland rice slash-and-burn cultivation requires almost 300 person-days per ha (Fig. 5), with about 50% of the labor being devoted exclusively to weeding, whereas slashing, planting, and harvesting are the next largest consumers of labor (Roder et al 1997, Lao-IRRI 2003).

Problems and constraints

Farmers consider the main upland rice problem to be weeds, followed by rodents, insufficient rainfall and land availability, and insect pests (Fig. 6). Data were collected in the early 1990s and it was probable that by early 2000 the problems relating to land availability would have become more significant as a result of land allocation policies that started going into effect in the late 1990s, which restrict the land area that can be used for upland cropping.

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Notes

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CHAPTER 4

Climatic diversity within the rice environments in Laos

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Laos is a country with a natural beauty created by many rivers and mountains. More than 85% of the land area has an elevation of at least 180 m above sea level. Most of the rice-growing lowlands are located in the Mekong River Valley, in the central and southern parts of the country. Most of the northern region is mountainous, the mountains being a continuation of the Himalayan range, rising steeply from valleys, from where the majority of streams flow toward the Mekong River. The highest mountain, Phu Bia, at 2,772 m, is located in the north.

As most Laotians are farmers, their livelihoods are greatly affected by climatic variability, in particular by the occurrence of floods and droughts. Rice cultivation, the core of the life of most rural Lao, is dependent on the monsoons. Most rice is grown under rainfed conditions in the wet season, between May and November. The southwest monsoon rains during this period are heaviest during July and August, and usually last until late October. Up to 30 cm of rainfall can be received per month during this period, depending on the region. The northeast monsoons bring cool and dry conditions in November to February. During this period, the mountainous areas in the northeast of the country, with altitudes above 1,500 m, can experience nighttime temperatures as low as 0 °C. Water levels in the Mekong River can vary from 0.5 m (Pakse) to 12.5 m (Luang Prabang) between their April low and August peak (Van Zalinge et al 2003). Flooding of areas adjoining the Mekong River and its tributaries is common during the wet season, particularly in the central and southern parts of the country.

Data on climate, topography, and soils in Laos have been routinely collected by various agencies, during and after the period that the French administered present-day Laos as part of French Indochina. However, this information has, until recently, not been systematically processed, and its use for agricultural planning and management purposes has therefore been very limited. During the second half of the 1990s and early 2000s, several organizations, working in collaboration with the National Agriculture and Forestry Research Institute (NAFRI) within the Ministry of Agriculture and Forestry (MAF) of Laos, have worked on developing a database inventory for the country using available information on soils, topography, land use, and climate. This

Table 1. The response of the rice plant to varying daily mean temperature at different growth stages.

Growth stages	Critical temperature (°C)		
	Low	High	Optimum
Germination	10	45	20–35
Seedling establishment	12–13	35	25–30
Rooting	16	35	25–28
Leaf elongation	7–12	45	31
Tillering	9–16	33	25–31
Primordia initiation (panicle)	15	–	22–23
Panicle differentiation	15–20	38	–
Anthesis	22	35	30–33
Ripening	12–18	30	20–25

Source: Yoshida (1981).

chapter summarizes efforts to develop a series of agro-climatic maps for Laos focused on the rice-producing environments of the country.

A proper understanding of climatic variation across a country is essential in helping predict the weather pattern during periods of crop growth in a country like Laos, both in the wet season under monsoonal rainfall conditions and during the dry season in the irrigated environment. Although long-term climatic data are being used for predicting weather changes, the occurrence of drought in the rainfed cropping environments of Laos remains unpredictable. Rainfall, temperature, and solar radiation influence rice production through their direct effects on the physiological processes involved in growth and development of the rice plant, and indirectly through the influence on environmental factors that affect the incidence of pests and diseases. Climate and soil variation are the two most important factors that determine variation in yield throughout the region.

Temperature

Temperature and growth of the rice plant

Table 1 summarizes the response of the rice plant to varying temperature at different stages of growth. A mean temperature above 20 °C throughout the growing period is required for good germination, growth, and grain-filling processes. The rice crop can tolerate daytime maximum temperatures up to 45 °C and nighttime minimum temperatures as low as 7 °C. However, for seedbed seedling establishment, minimum temperatures in excess of 12 °C are required. The optimum temperature for panicle initiation is 22–23 °C, and for grain ripening 20–25 °C. Temperatures above 22 °C tend to accelerate the process of respiration and, as a result, the grain-filling period is reduced.

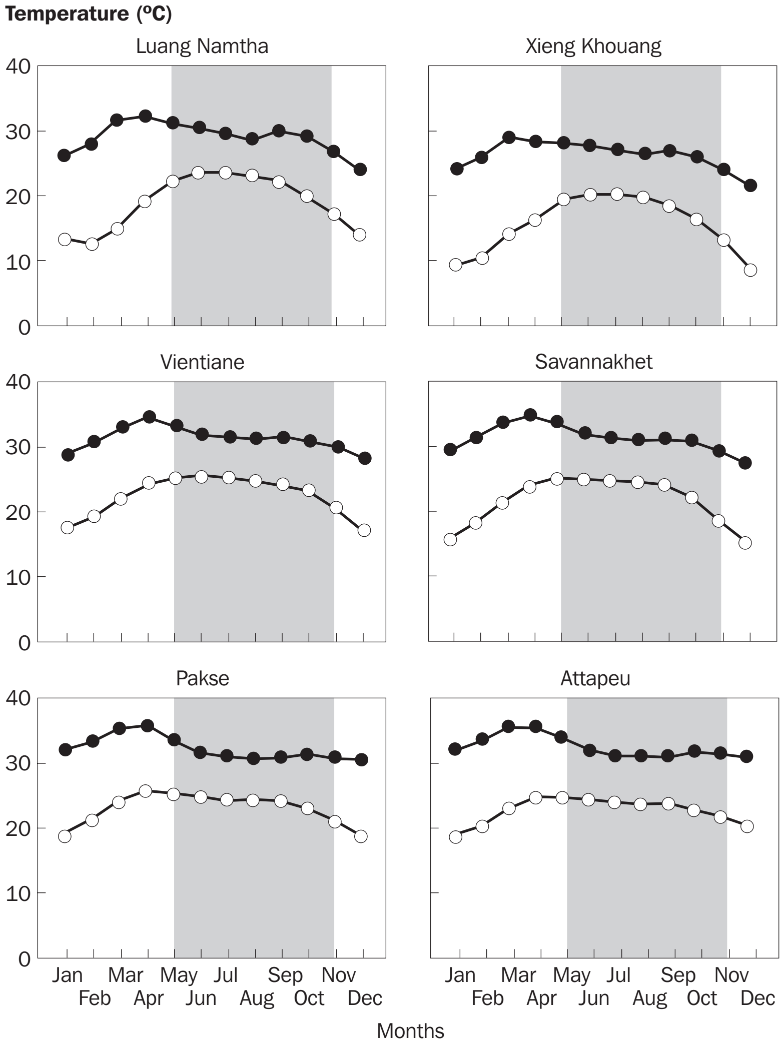

Fig. 1. Temperature distribution (monthly mean minimum and monthly mean maximum) in the wet and dry seasons in some rice-growing areas in provinces in the northern (Luang Namtha and Xieng Khouang), central (Vientiane Municipality and Savannakhet), and southern (Pakse and Attapeu) agricultural regions of Laos (the wet season is represented by the shaded area).

Temperature variation in Laos

The pattern of monthly mean temperature (minimum and maximum) distribution varies across central, southern, and northern Laos (Fig. 1).

In the central and southern regions, peak monthly maximum temperatures are recorded in April, immediately before the onset of the wet-season rains. Maximum temperatures increase gradually from their lowest of around 28–30 °C in January to

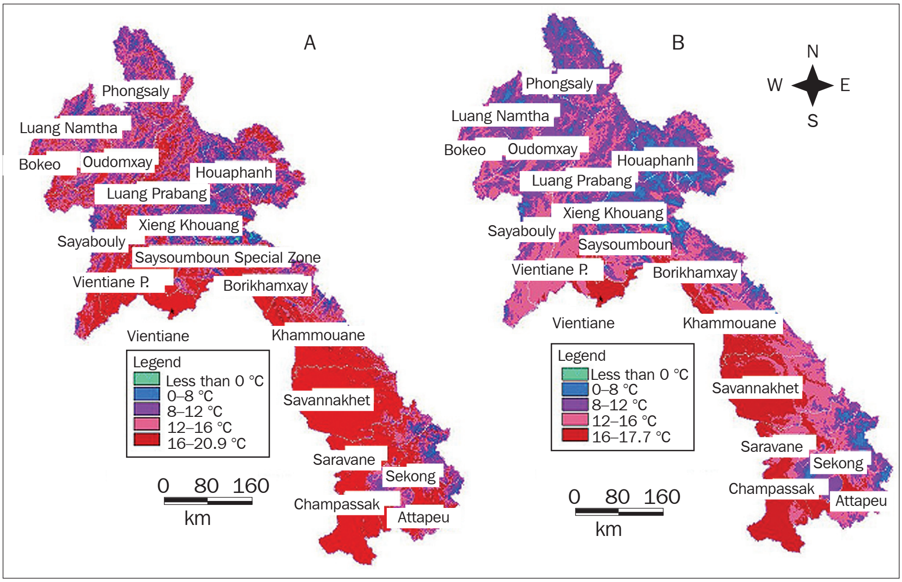

Fig. 2. Mean minimum temperature in November (A) and January (B) for Laos, predicted from altitude-temperature relationships.

about 35 °C in April. The temperature remains above 30 °C between April and October, and starts to decline from late October. Minimum temperatures also follow the same pattern, while the daily temperature variation becomes smaller (<10 °C) during April to August (Chanphengxay et al 2003).

Recent work on agro-climatic characterization reported by Inthavong et al (2001) has produced monthly minimum and maximum temperature maps for Laos. Digitized historical data on maximum and minimum temperatures were used to develop temperature distribution maps for each month. Altitude and temperature relationships were used to develop GIS-based temperature maps for the whole country. Examples of these maps showing the mean monthly minimum temperatures for November and January appear in Figure 2.

Temperature as a limitation to rice production in Laos

Generally, temperature is not a constraint to rice cultivation during the wet season. An exception to this general situation exists for flood-prone areas adjacent to the Mekong River in the provinces of Borikhamxay and Khammouane in the lower part of the central agricultural region. In this area, transplanting of the wet-season crop can be delayed beyond the normal time of late June or early July to August or September, with flowering occurring in December when the temperature is around 16 °C.

In contrast to wet-season cultivation, low temperature can potentially be a major production constraint for dry-season irrigated rice crops, particularly in some provinces in the northern agricultural region (Fukai 2001). In this region, for the coldest

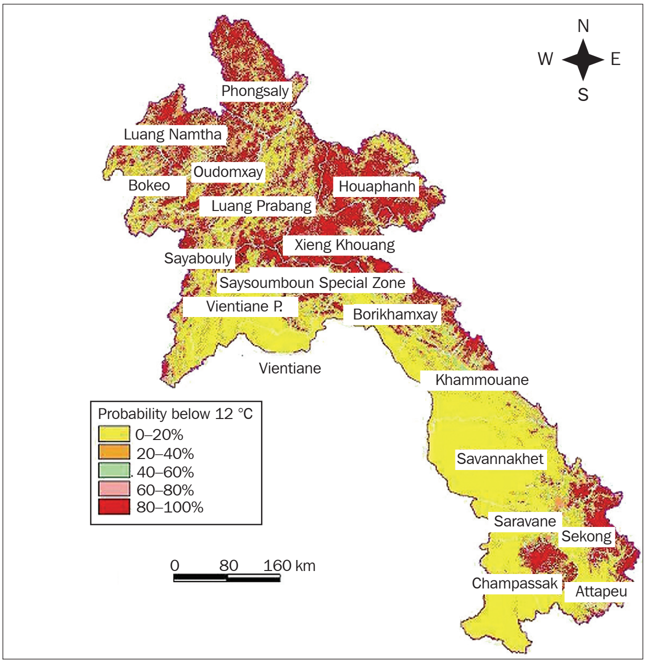

Fig. 3. Low-temperature probability map for a monthly mean minimum temperature of less than 12 °C during December throughout Laos.

months of December to January, mean monthly maximum temperature ranges from 22 to 26 °C, while mean monthly minimum temperature for the same period ranges from 8 to 12 °C. Dry-season rice crop establishment usually coincides with the period of lowest temperature. Seedling nursery establishment during November to January in some parts of the north can fail, as germination and seedling growth can be severely affected by low temperature, particularly at high elevation.

One method of quantifying the risk of low-temperature effects on seedling establishment is to estimate the probability of occurrence of critical temperatures during the period of seeding using historical temperature data. In formulating these low-temperature probability maps, a minimum monthly temperature below 8 °C was considered to be a severe limitation to rice establishment. Areas where the minimum monthly temperature is in the range of 8–12 °C, 12–16 °C, and above 16 °C were considered high, medium, and no low-temperature risk, respectively (Basnayake et al 2003). Temperature probability maps showing areas of the country potentially affected by low temperature are now available (Inthavong et al 2001). The higher altitude (>600 m) areas in northern Laos have been identified as high-risk areas, particularly for sowing in December and early January. Figure 3 illustrates the probability of monthly mean minimum temperature falling below 12 °C in December throughout Laos. There is a 80–100% probability of the mean minimum temperature being below 12 °C in some parts of the northern provinces of Xieng Khouang and Houaphanh. Other parts of these provinces show a less than 20% probability of having a monthly mean minimum temperature of at least 12 °C. Other provinces in the north that also show varying degrees of low-temperature effects on rice crop establishment and growth are Luang Namtha, Phongsaly, Oudomxay, and Luang Prabang. For the central and southern regions of the country, there is almost no risk of low-temperature effects on seedbed establishment in November to January for dry-season irrigated rice crops. However, there can be an exception to this at higher altitudes in some provinces (mountain areas in Khammouane and Champassak), where monthly mean minimum temperatures can fall below 12 °C (Fig. 3).

The temperature maps for Laos have been published (Inthavong et al 2001) and an interactive CD featuring these maps is currently available through the National Agriculture and Forestry Research Institute within the Ministry of Agriculture and Forestry of Laos.

Daylength variation across Laos

The life cycle of many plants is synchronized to the changing seasons. This relationship ensures that developmental transitions, such as the onset of flowering, occur under the most appropriate environmental conditions. Fluctuations in daylength (or photoperiod) provide the information used by plants to synchronize these developmental adaptations to the seasons (Garner and Allard 1920). Rice is a short-day plant and it progresses quickly toward flowering and reproduction in response to the shortening of daylength.

Daylength variation throughout the year in Laos is relatively small when compared with that of the rice-growing areas in many other countries. This reflects the fact that Laos is located near the equator. Generally, daylength ranges from 10 h 45 min to 11 h 15 min in different parts of Laos for December to between 12 h 45 min and 13 h 15 min in June (Fig. 4). Phongsaly (21°42′N, 1,000 m) in the north has the maximum daylength variation between January and June (2 h 30 min), whereas Attapeu in the south (14°48′N, 105 m) has the lowest (1 h 30 min). Vientiane (17°57′N and 178 m) has an intermediate daylength variation.

The short daylength in the wet season is conducive to flowering in many rice-growing areas of Laos. Generally, traditional rice varieties of Laos, which are usually highly photoperiod-sensitive, flower from late September to mid-October when daylength is shorter than 12 hours. Flowering of photoperiod-insensitive cultivars (into which category most improved Lao varieties released since 1993 fall) depends on time of sowing. If seedbed sowing is delayed as a result of early wet-season drought, to July or possibly early August, this would result in late flowering in November or December. However, photoperiod-sensitive cultivars that flower in mid-October (early) or early November (late) do not reflect any influence of time of sowing on flowering time. Photoperiod sensitivity is an advantage where the time of sowing needs to be adjusted on account of other resource limitations, such as lack of water availability. Early sowing provides a potentially long vegetative period, whereas late

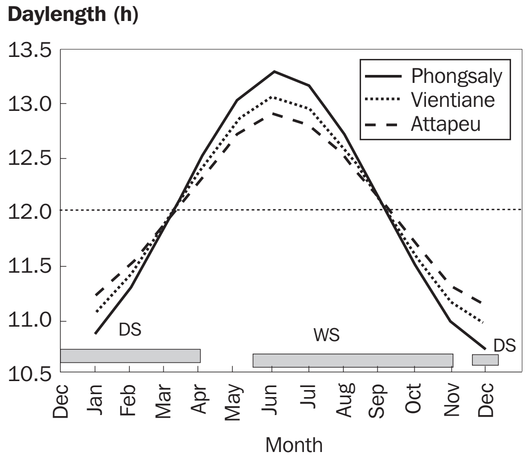

Fig. 4. Monthly mean daylength variation in three provinces (Phongsaly, northern region; Vientiane, central region; Attapeu, southern region) of Laos. The shaded areas indicate the normal growing periods for rice in the dry season (DS) and wet season (WS).

sowing shortens the vegetative period in photoperiod-sensitive cultivars grown in the wet season. Most wet-season rice-growing areas of Laos experience short days (<12 hours) during the flowering period. Dry-season crops flower in February and March. However, there is a risk to the sowing of photoperiod-sensitive rice cultivars in the dry season because daylength is too long for these cultivars to flower during this period of the year. Generally, photoperiod-insensitive cultivars are grown in the dry season.

Solar radiation

As with temperature, the solar radiation requirement of the rice plant varies for different growth stages. Low-intensity solar radiation generally reduces photosynthesis in crop plants. Reduced photosynthesis results in lower crop yields. Low radiation during the early vegetative stage generally does not have a significant effect on yield and yield components. However, low radiation levels during the reproductive phase can have a detrimental effect on spikelet number and subsequent grain yield. A yield reduction of more than 50% has been measured in response to 75% shading in the reproductive stage (Yoshida 1981, Monteith 1972). Low radiation during the ripening stage also reduces grain yield. On the contrary, varieties with a high yield potential can produce higher yields if daily radiation exceeds 20 MJ m^{-2} during the ripening stage.

Under tropical conditions, solar radiation levels are higher in the dry season than in the wet season. During the wet season, radiation interception by cloud cover is greater than in the dry season. Long-term solar radiation data for Laos are not available. The solar radiation information presented here is based on records of sunshine hours from several meteorological stations across the country for a period of 5 years (1996-2000).

The variation (weekly) in solar radiation across Laos (for two locations for each of the northern, central, and southern regions) is shown in Figure 5. In the northern region, the two provinces of Luang Namtha and Xieng Khouang receive an annual mean radiation of 18 MJ m^{-2} day^{-1}, with a range of 16 to 21 MJ m^{-2} day^{-1} for the wet and dry seasons, respectively. The central and southern regions receive mean annual radiation of 20 MJ m^{-2} day^{-1}, with a range of 18 to 24 MJ m^{-2} day^{-1} for the wet and dry seasons, respectively. Potential solar radiation ranges from 12 to 23 MJ m^{-2} day^{-1} in the north to 15 to 24 MJ m^{-2} day^{-1} in the south. Also represented in Figure 5 is the solar radiation that could be received without the interception effects of cloud cover during the year. Clouds mostly affect incoming radiation during the wet season, reducing the incident radiation level to 15 MJ m^{-2} day^{-1} in the month of peak rainfall, September. Generally, the potential effects on rice grain yield are greatest by a reduction in solar radiation levels during the last two months of growth, during the period of flower primordia initiation and maturation. For wet-season crops, this period of development occurs in September-October, when the solar radiation level can fall to less than 20 MJ m^{-2} day^{-1}. For dry-season crops, the incoming radiation level varies from 20 to 25 MJ m^{-2} day^{-1} in March and April, corresponding with the flower primordia initiation to maturation periods. In the absence of other constraints, dry-season rice crops should be able to yield more than wet-season crops on account of the difference in radiation levels between seasons. For wet-season crops, early-flowering cultivars (August) will generally result in lower yields than later-flowering (October) cultivars because of the impact of differences in radiation levels at the time of flowering. However, independent of the effects of solar radiation, yields of later-flowering rice crops can be limited by a lack of water in the rainfed lowland environment.

Rainfall

Water and the rice plant

Rice can be grown as a lowland crop with standing water as well as an upland crop without standing water, although genotypes generally differ in relation to the growing environment to which they are best adapted**.** The water requirement of the rice plant varies according to its growth phases. Generally, 200 mm of monthly rainfall for lowland rice and 100 mm of rainfall for upland rice are required during the establishment phase. For the vegetative stage, the crop requires a minimum monthly rainfall of 125 mm. At the ripening stage in lowland crops, no standing water is required, but the soil moisture content should be retained close to field capacity.

Interruptions to the regular monsoon rainfall can result in moderate to severe moisture stress for the rice plant. Moisture stress can cause the retardation of both root and shoot development, delay flowering or cause poor floral development, affect pollination and fertilization, and affect grain filling, all of which can affect final grain yield. Excessive rainfall can also cause severe problems in rice production. It can interfere with many farming operations such as seedbed preparation, sowing,

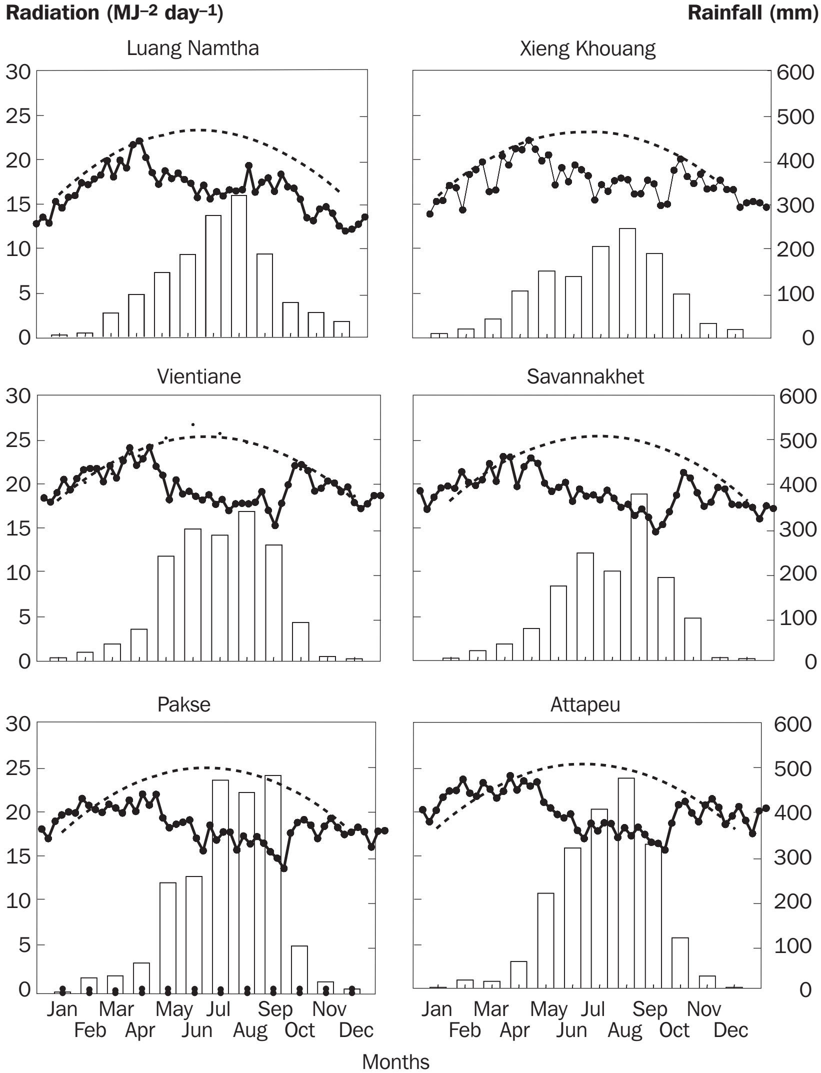

Fig. 5. Weekly mean incoming solar radiation and monthly rainfall across six rice-growing areas during a 12-month period. The dotted lines indicate the pattern of incoming radiation if there is no radiation interception by clouds during the rainy season.

Table 2. Rainfall distribution (mm) in selected provinces of northern, central, and southern Laos.

Region/province	Dry-season[a] rainfall (mm)	% rainfall	Wet-season[b] rainfall (mm)	% rainfall	Annual rainfall (mm)
Northern					
Phongsaly	251	16	1,329	84	1,580
Luang Namtha	258	17	1,272	83	1,530
Oudomxay	213	15	1,221	85	1,434
Luang Prabang	214	15	1,192	85	1,406
Sayabouly	224	17	1,060	83	1,284
Xieng Khouang	303	20	1,180	80	1,483
Central					
Vientiane	197	11	1,594	89	1,791
Savannakhet	197	13	1,286	87	1,483
Savannakhet (Seno)	120	11	1,011	89	1,131
Southern					
Saravane	197	9	1,908	91	2,105
Pakse	195	9	2,022	91	2,217
Paksan	467	14	2,893	86	3,359
Attapeu	252	11	2,041	89	2,292

[a]The dry season starts in November and ends in April. [b]The wet season starts in May and ends in October.

harvesting, threshing and processing, and seed drying. High rainfall can also cause flooding, with resulting yield reduction or crop loss. Further, continuous rain during the flowering period can affect fertilization and grain formation. Excessive rain can also favor an increased incidence of plant diseases and pests, resulting in lower crop yields. The frequent occurrence of both drought and flooding in many rice-growing areas of Laos has been summarized by Schiller et al (2001).

Rainfall in Laos

Annual rainfall distribution is highly varied across the northern, central, and southern agricultural regions of Laos. Provinces in the northern region generally receive less rainfall than the central and southern regions, with small variations (1,566 ± 247 mm annum^{-1}) across provinces. The northern provinces of Sayabouly and Luang Prabang have the lowest mean annual rainfall, with 1,284 and 1,406 mm, respectively. The highest annual rainfall is received in provinces in the southern region (2,237± 426 mm annum^{-1}), with a higher variation across provinces within this region than in other regions. The provinces with the highest annual rainfall are Saysoumboun Special Zone and Borikhamxay, with 3,231 and 3,107 mm, respectively. The proportion of total rainfall received in the wet season (north to south) varies from 84% to 90% across the three regions (Table 2).

The annual rainfall distribution for Laos is illustrated in Figure 6. The temporal pattern of rainfall distribution is depicted in Figure 7 for weeks 15 (second week of April), 25 (third week of June), 35 (first week of September), and 40 (first week of

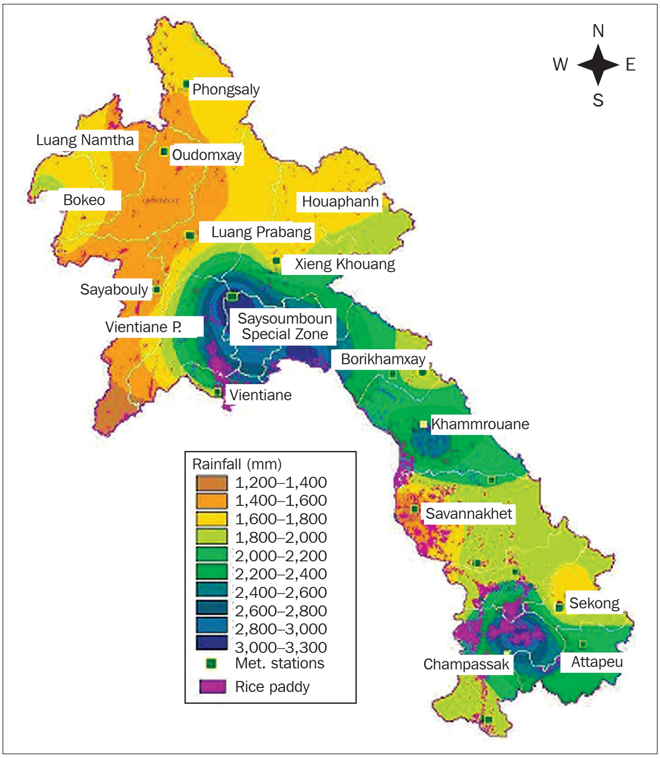

Fig. 6. Mean annual rainfall map for Laos generated with the interpolation of rainfall data.

October). Week 15 (mid-April, Fig. 7A) marks the beginning of the wet season. Within the main lowland rice-growing areas along the Mekong River, Borikhamxay and the northwestern part of Khammouane in the central region, together with Saravane and the northwestern part of Champassak in the south, receive good rainfall early in the wet season. In contrast, the western part of Savannakhet remains relatively dry at this time of the year.

By week 25 (late June, Fig. 7B), most of the area of central and southern Laos bordering the Mekong River receives about 50 mm of rain per week (50 mm per week is considered adequate for rainfed lowland rice). In contrast, in late June, most rice-growing areas of northern Laos still receive less than 50 mm of rainfall per week, insufficient for rainfed lowland rice cropping.

In week 35 (early September, Fig. 7C), rainfall registrations are high (more than 50 mm) throughout most of the country. Thereafter, rainfall decreases sharply and, by week 40 (mid-October, Fig. 7D), the southern part of Borikhamxay and Khammouane and Savannakhet in the lower central agricultural region receive less than 50 mm per week, while rainfall still exceeds 50 mm in some parts of Vientiane Municipality and Champassak in the south. In Savannakhet and Khammouane, in early October, there

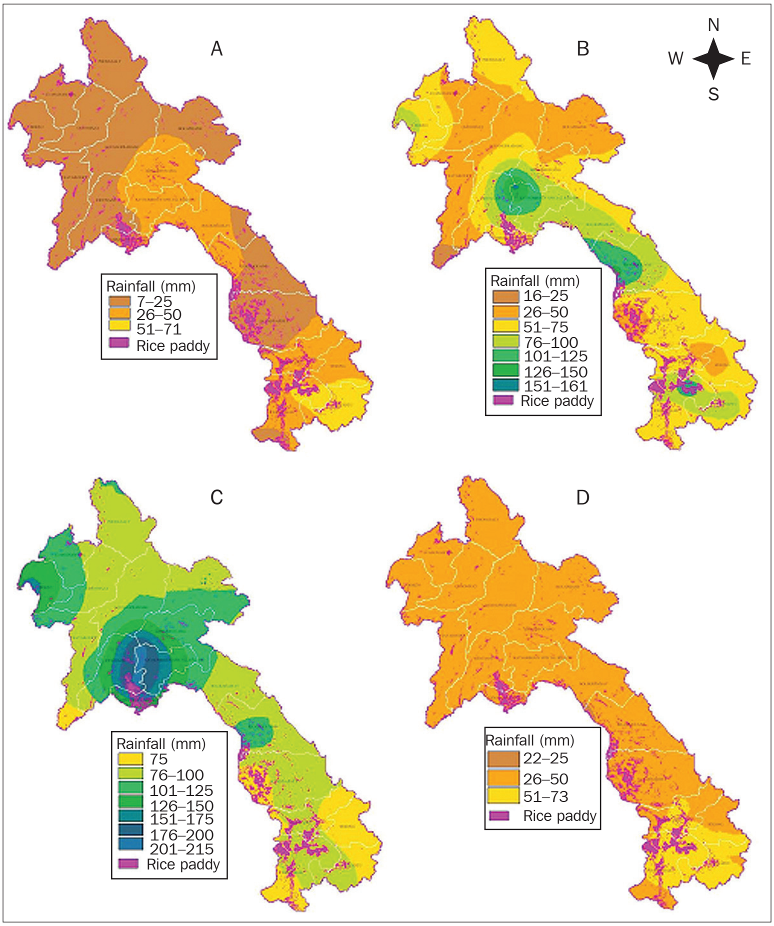

Fig. 7. Rainfall distribution maps for week 15 (mid-April), 25 (late June), 35 (late August), and 40 (early October) in Laos.

is a trend of increasing rainfall (from about 20 mm to 40 mm per week) from the west to the east in each province. There is little rainfall throughout the country from November to April. Full irrigation is usually required for dry-season rice cultivation during this time of the year.

Potential evapotranspiration and length of growing period

Potential evapotranspiration (PET) is a measure of the ability of the atmosphere to remove water from the plant and soil surface through the processes of evaporation and transpiration, assuming no limitation of water supply. The concept of PET was first introduced in the late 1940s and ’50s by Penman, and is defined as “the amount of

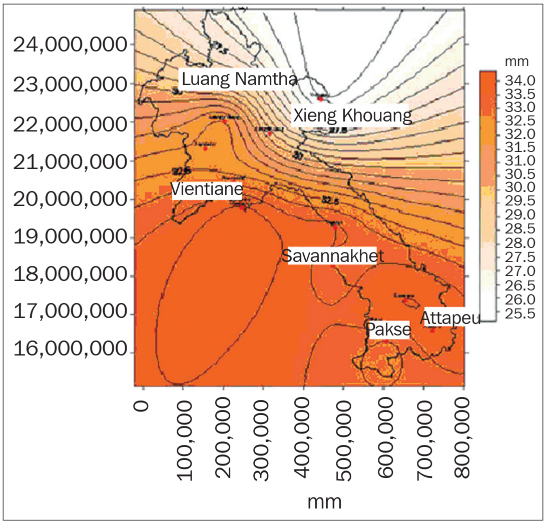

Fig. 8. Map of potential evapotranspiration (mm week^{-1}) in mid-October (week 40) throughout Laos. (X and Y coordinates are universal transverse mercator, UTM.)

water transpired in a given time by a short green crop, completely shading the ground, of uniform height, and with adequate water status in the soil profile." In the definition of potential evapotranspiration, the evapotranspiration rate is not related to a specific crop. PET is an important determinant of rice plant growth, as the effectiveness of rainfall depends upon the level of PET. If the PET is higher than the rainfall, an input of irrigation water is required for optimum plant growth.

The following factors are important in estimating potential evapotranspiration:

1. Potential evapotranspiration requires energy for the evaporation process. The major source of this energy is from the sun. The amount of energy received from the sun accounts for 80% of the variation in PET.
2. Wind enables water molecules to be removed from the ground surface by a process known as eddy diffusion.
3. The rate of evapotranspiration is associated with the gradient of vapor pressure between the ground surface and the layer of atmosphere receiving the evaporated water.

Systematic PET data are not available for most parts of Laos; the estimates presented here have been based on meteorological information for 17 locations where daily data on sunshine hours, maximum and minimum temperature, maximum and minimum humidity, and wind speed are available. Spatial interpolation using GIS was carried out on the point-based PET estimates to produce gridded maps of weekly PET (Inthavong et al 2004). Figure 8 shows the PET surface for Laos for week 40 (mid-October). In mid-October, the highest PET is recorded in the southern agricultural region (Pakse and Attapeu), where it reaches about 34 mm week^{-1}. During the same period, PET is as low as 25 mm week^{-1} in the north and northeastern parts of the country (Luang Namtha and Xieng Khouang). Therefore, water loss in the northern region is relatively lower than in the southern region late in the wet season.

In estimating the climatic water balance, rainfall and PET for each week were used for representative locations throughout the country. The importance of water balance relates to the definition of the "length of the growing period" (LGP) for crops, where the LGP is usually defined as the period within the year when rainfall exceeds 50% PET. For Laos, where rice is the major crop, the water balance estimates were based on 75% PET (rather than 50% PET, which is the usual PET level used by FAO for upland crops, FAO 1978) because lowland rice consumes more water than most other crops. The beginning of the growing season for wet-season cropping under rainfed conditions is defined as the time when weekly rainfall exceeds 75% of the weekly PET at the end of the dry period. The first instance when rainfall exceeds 75% PET is not considered as the week of the beginning of the LGP when at least two consecutive weeks receive less rainfall than 75% PET. The end of the growing season was defined as the time when the weekly rainfall falls below 75% of the weekly PET.

The weekly rainfall, 75% of the weekly PET, and length of the growing period for six locations in Laos are shown in Figure 9. At some locations during the wet season, weekly PET falls below the weekly rainfall for 1 or 2 weeks, reflecting potential drought conditions (e.g., week 22 for Luang Namtha). If this period lasts only 1 week, it is considered to be a continuation of the period of growth (i.e., water is not considered a constraint to growth). The weekly PET together with rainfall are comparatively lower at the beginning (week 12) of the wet season in the northern region relative to the central and southern regions. However, rainfall is insufficient to begin the season for rice until weeks 17–18 (late April to early May) in both the north and central regions. Conversely, for the southern region, although PET is higher than in the northern region at this time of the year (weeks 15 and 16 in Pakse), rainfall is adequate to begin the growing season. By weeks 39–40 (late September to early October), rainfall usually falls below the 75% PET level in some locations, including Luang Namtha in northern Laos, Savannakhet in the lower central region, and Attapeu in the south (Fig. 9), and the growing season ends. However, in the area of the Vientiane Plain in the central region, the growing season extends to week 41 (mid-October), with rainfall exceeding 75% of PET until this time.

In Laos, as in most tropical and semitropical areas of Asia, the LGP for wet-season lowland rice crops is a reasonably distinct period that roughly coincides with the period of the southwest monsoon rains. Also, the LGP as estimated from the climatic water balance is not affected or modified by low-temperature constraints that might further limit the period of crop growth. The mean weekly rainfall and PET were used as inputs for the development of a climatic water balance model (rainfall minus 75% PET) to generate the LPG surfaces for Laos (Fig. 10). The start of the growing period varies throughout Laos from early April to late June (Fig. 10A), while the end of the growing period ranges from mid-September to early November (Fig. 10B).

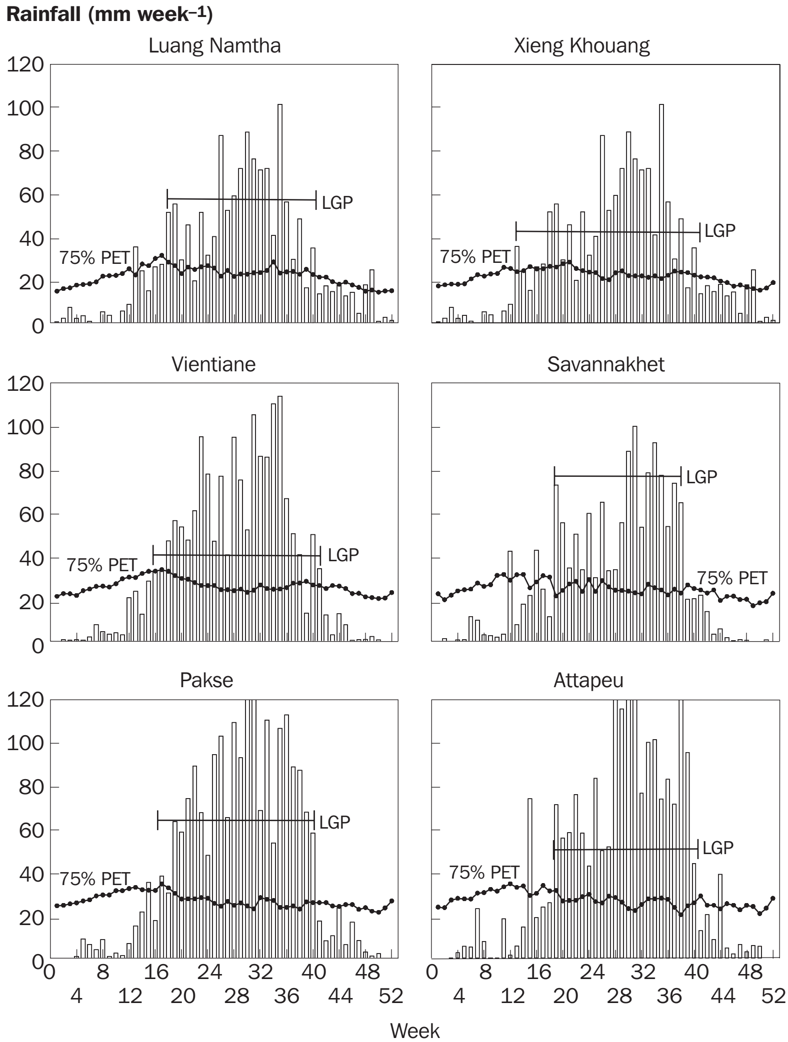

Fig. 9. Line graphs for 75% of the evapotranspiration (mm week^{-1}) and bar charts for rainfall (mm week^{-1}) in some lowland rice-growing areas in northern (Luang Namtha and Xieng Khouang), central (Vientiane Municipality and Savannakhet), and southern (Pakse and Attapeu) Laos. Horizontal lines indicate the estimated length of the growing period (LGP).

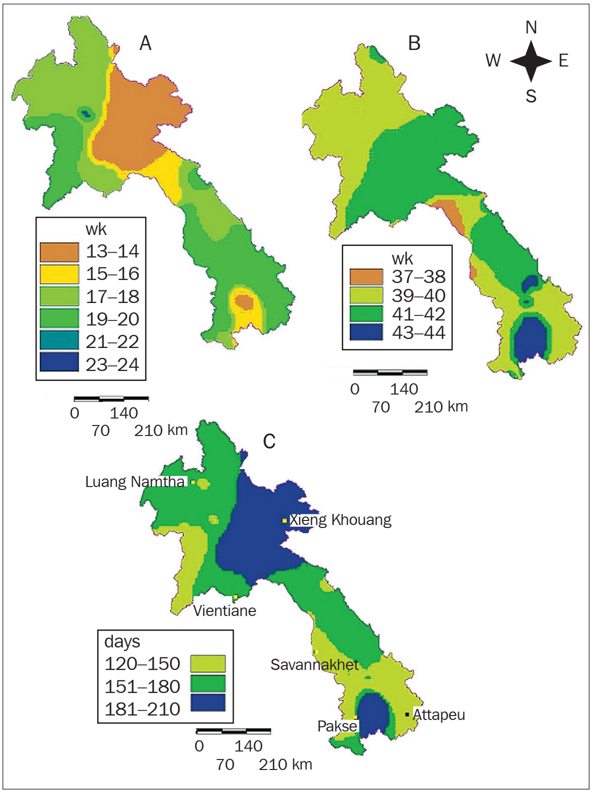

Fig. 10. Maps of Laos showing (A) first week, (B) final week, and (C) duration (in days) of the length of the growing period for wet-season rainfed lowland rice.

The LGP for wet-season rainfed lowland rice ranges from 120 to 210 days in the main rice-growing areas (Fig. 10C). The shortest LGP is in those provinces with the lowest rainfall—Attapeu in southern Laos, Savannakhet in the lower central region, and Sayabouly in the lower northern region. The areas with the longest LGP are in the rice-growing areas of Champassak near Pakse, and in the northeastern province of Xieng Khouang. Most lowland rice-growing areas in the upper north and northeast have an LGP of moderate length, from 150 to 180 days.

Conclusions

The rice production environments in Laos have enormous climatic diversity. In the main lowland rice-growing areas in the central and southern agricultural regions in the Mekong River Valley, the predominant rice production ecosystem, the rainfed lowlands often suffer from the effects of drought or flood, or a combination of both. Rice varieties can be developed for these areas that are adapted to the constraints imposed by LGP as determined by rainfall distribution, as well as showing improved adaptation to drought. Temperature is usually not a constraint to rice cropping in this environment, in either the wet season or dry season. However, low temperature can cause crop establishment failure for dry-season cropping in the northern agricultural region, particularly at higher altitudes. Recent studies and analysis of the agro-climate have provided a better understanding and delineation of the potential climatic limitations to rice production in different parts of the country; however, these studies need to be supported by further analyses (and incorporation of other factors, particularly soil-related information) and further field studies to allow more accurate mapping of potential constraints in the different agricultural environments. The results of the current analyses can be used in both rice breeding and crop management programs to better stabilize yields in many areas, as well as provide a basis for yield improvement.

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Notes

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CHAPTER 5

Rice-based traditions and rituals in the Mekong River Valley

Hatsadong, K. Douangsila, and P. Gibson

The Mekong River Valley (MRV) area of Laos occupies the central and southern parts of the country and primarily consists of the provinces of Vientiane, Khammouane, Savannakhet, Champassak, Saravane, Sayabouly, and Vientiane Municipality. Approximately 93% of the Lao population lives in this area (Hook et al 2003). As is the case elsewhere in Laos, rice cultivation is the main agricultural activity in the MRV. The MRV accounts for the majority of lowland rice production in the country, in both the rainfed lowland and irrigated environments, contributing about 74% of national rice production (MAF 2004). Until the early 1990s, traditional rice production practices prevailed in most of the MRV, with more than 90% of the lowland rice area being planted to traditional rice varieties, there being little by way of inputs of commercial fertilizers and very little use of chemical pesticides. There was also almost no mechanization of production until after 1995.

In general, farmers in the MRV produce sufficient rice to meet family needs, within given labor and resource constraints; the MRV is also the most favorable area for rice cultivation in Laos. Poor farmers in the area are generally those who have to cultivate poor soils, or those not having draft animals or sufficient paddy land. Relatively rich farmers are those living on fertile soils, usually immediately adjacent to the Mekong River and its tributaries or near the larger provincial towns where they have potential access to markets and off-farm employment. In years of good rainfall, self-sufficiency in rice is achieved; in years with poor rainfall, rice and food deficits often prevail.

The people of the MRV are mainly those with Tai-Lao ethnicity. They speak Lao and as many as 80% are engaged in lowland rice cultivation, although slash-and-burn upland cultivation is practiced in some hilly areas, mainly in the lower central and southern agricultural zones. The vast majority of farming households in the MRV prefer to grow and consume glutinous rice. Rice not only provides the major food source for the population but is also the basis of many of the cultural and social traditions of farming families in this region. In addition to ritualistic traditions, the majority of traditional cultural practices revolve around the cultivation and consumption of rice. These include traditional dances based on the cycle of rice cropping, and the performance of plays and songs associated with rice. Typically, dances taught to children, as well as those performed by professional dance troups, will include group movements set to music and reflecting communal planting, harvesting, and threshing of the rice crop. The wording of one of the most well-known traditional and patriotic farming songs, *Yin sabaai saonaa* ("The Contented Rice Farmer"), is an example of this rice-based association with contentment in life. The words to this song are as follows:

The Contented Rice Farmer

We are rice farmers' children,
We take plows and buffaloes to the fields,
We look for food in the forests,
We look for food in the forests.

After sunset, we go home,
Everyone in our village is very happy and contented,
Very happy, very contented.
In our village, there is rice and there are fish in the rice fields,
When the wind blows, we have fresh air,
Contented, contented farmer; contented, contented farmer.

In the afternoon, we ride wild buffaloes,
We sing songs, dance, and play the "khaen."[1]
We urge everyone to come together to play, work, and develop the nation.
Contented, contented farmer; contented, contented farmer.

The direction of our lives is a happy thing,
In the fields, our skin becomes dark, but we are still happy to work for our nation,
To work to fight hunger and poverty,
Contented, contented farmer; contented, contented farmer.

We are proud to use our work to develop our nation,
We have buffaloes as powerful friends,
Our leaders direct us on the right path,
Contented, contented farmer; contented, contented farmer.

In researching this chapter on the rice-based traditions and beliefs of lowland rice farmers, interviews were conducted with farmers living in areas broadly representative of the lowland rice-farming areas in the MRV. The majority of the information was gathered in Saythany District of Vientiane Municipality, Kong District of Champas-

[1]A traditional Lao wind instrument made from bamboo.

sak Province, and a village in Nasaythong District of Vientiane Municipality, where the current inhabitants are descendants of families who were relocated to the area from Xieng Khouang Province during the 19th century, and who carried with them the rice-based traditions and beliefs of their former abode. The farmers interviewed were mainly village elders, whom it was recognized were likely to have the most vivid knowledge of rice-based traditions and beliefs. Not all the rituals described are currently still being practiced by the younger generations of farmers.

Spiritual and ritualistic practices are important to most Lao people, and lowland farmers in the MRV engage in many rituals and ceremonies associated with all aspects of the rice-cropping cycle. Most ceremonies involve a belief in *pi*, powerful, invisible beings of the spirit world. Most Lao have traditionally believed in various forms of *pi* that are thought to live in the trees and forests, and other plants found in the forests, mountains, fields, and streams; also in their homes and bodies (when both alive and deceased), and sometimes in some kinds of animals. The ceremonies and rituals of MRV farmers have been practiced and passed down through many generations of farming families. Many are believed to have originated in the Hindu traditions of India; others have their origins in the animistic, pre-Buddhist era of Laos. Some have combined aspects of Buddhist-animist rituals and ceremonies.

The traditions and rituals specifically associated with rice in the MRV are many and varied. It is beyond the scope of this chapter to comprehensively document all these rituals and beliefs, or to establish conclusively their exact origins. Rather, the chapter aims to document the main rice-based rituals as they have been traditionally practiced by the Tai-Lao in the MRV. These rituals are presented in the sequence of the normal cropping cycle for rainfed lowland rice.

Ceremonies prior to the start of the rice cropping cycle

In May to early June (the sixth month of the Lao lunar calendar[2]), communities in the MRV (and in northeast Thailand) celebrate the *boun bang fai* or "rocket festival." Traditionally, this pre-Buddhist festival can last up to three days and is held in order to prompt the heavens to initiate the rainy season and to bring much-needed early rain to allow the planting of the wet-season rice crop. Projectiles consisting of bamboo (or, in more recent times, aluminum) tubes filled with gunpowder are fired high into the air over the fallow fields to gain the particular attention of *Phaya thaen* (the protector of paradise who resides on the frontier between "paradise" and Earth). The first rocket to be fired is to honor the local spirit of the host village, whereas later rockets are fired in a rocket competition (Fig. 1). It is believed that a successful rocket festival will ensure sufficient rainfall for the coming rice cultivation season. During the festivities, pigs

[2]The traditional Lao calendar is based on the movement and phases of the moon. There are 15 days in the waxing moon and 14 or 15 days in the waning moon. Some months (the 1st, 3rd, 5th, 7th, 9th, and 11th) have 29 days; others (the 2nd, 4th, 6th, 8th, 10th, and 12th) have 30 days. The Lao lunar year therefore has 354 days, unlike the 365 days in the European (solar) calendar.

are often slaughtered, and drinks, particularly *Lao lao* (rice whisky) and *Lao hai* (rice wine), flow freely with people repeatedly toasting each other's health.

In Kong District in Champassak Province in southern Laos, specific to this festival is the exhibiting of erotic images such as naked wooden puppets with enlarged sexual organs that are meant to represent fertility in general and fertility of the rice crop in particular. However, these erotic exhibitions are not common to all areas in the MRV. Pongkhao (2005a) states that although traditionally, the objective of the festival was to ostensibly create favorable growing conditions for the rice crop during the coming rainy season, it has now come to mean a lot more than that and is seen as a means of building harmony between villages as people from a number of villages congregate for a large celebration. The same traditions associated with the annual rocket festival are also widely practiced in neighboring northeastern Thailand.

Traditions associated with land preparation and transplanting

Before transplanting the main wet-season rice crop, villagers have traditionally first transplanted seven bundles of seedlings around the "field hut" (or *hor*), which is usually located at the edge of the rice field of individual families. This ritual, referred to as "*ta haek*," includes making an offering of cooked chicken, alcohol, and fruit to the resident spirits, while chanting prayers requesting that the spirits protect the forthcoming rice crop. Villagers believe that, if these seedlings grow well, the main rice crop will also grow well and give a good grain yield.

The most auspicious day to begin land preparation is believed to be the first day of the sixth month of the Lao lunar calendar. In some districts, before seeding the nursery plot, many farmers plow the main field along its diagonals and along its levees in a ritualistic operation known as *haek na*. Only after the rains fall is the rest of the plot prepared and planted according to usual lowland cultivation practices. Following preparation of the main fields, an auspicious day is then chosen for transplanting the main rice crop. Generally, it is believed that planting on a Thursday will ensure good, abundant grain, planting on Wednesday will ensure abundant leaves on the rice plants, and planting on Saturday will ensure an abundance of tillers. Most farmers believe, therefore, that Thursday is the most auspicious day for transplanting rice. A small planting of 10–15 hills may also be undertaken prior to full transplanting of the main plots. These hills will receive special care and attention during the growth phase of the rice crop. It is believed that maintaining these practices will ensure a good relationship with the spirits near the rice fields and is necessary to ensure good rice yields and that those farmers who do not follow these practices may suffer pest attacks, disease attacks, and other problems resulting in lower yields.

Rituals performed during the period of growth of the rice crop

During the growth stages of the rice crop, villagers go into the fields to perform weeding, bund maintenance, and other necessary tasks. However, little by way of rituals is performed during this period, apart from the days of *wan sin yai* (the 15th day of each Lao lunar month) when no work should be undertaken in the rice fields; if work is done on this day, it is traditionally believed that it can result in a high probability of bringing about misfortune for the farm household. Each evening, before returning to their homes from their fields, many lowland farmers request the spirits to protect their crops from disease, pest attacks, and other dangers. These requests are made in simple, respectful Lao language.

At the milky stage of grain development, farmers in Saythany District of Vientiane Municipality have traditionally selected a small number of beautiful immature panicles to prepare *khao mao*, which is prepared by threshing and drying immature rice grains, which are then mixed with sugar and grated coconut to prepare a sweet that is then offered to the *phi ta haek* (the field spirits), together with one cup of rice alcohol. These offerings are placed in the field hut (*hor)* and it has traditionally been accepted that, unless this ritual is performed, the villagers cannot later consume the grain produced from their rice fields.

Rituals associated with harvesting of the rice crop

Villagers choose an auspicious couple of days for harvesting their rice crop, according to tradition and in relation to the lunar calendar. It is generally believed that harvesting should not commence on either the 2nd or 12th day of the month. Before harvesting the main crop, some villagers harvest the plants around their field hut until they have a handful of grain; these grains are then counted. If the total number of grains amounts to an even number, the main crop can be harvested on the first day selected. However, if the total number of grains forms an odd number, harvesting has to begin on a day other than that first selected. Villagers believe that selecting single grains or pairs of grain (even or odd numbers) represents a balance between high and low yields. Pairs of grain (even numbers) indicate a high yield, whereas single grains (odd numbers) reflect a low yield.

Before the harvest of the main crop begins, the seven bundles of plants that were transplanted around the field hut at the commencement of planting are harvested, tied into a bundle attached to a wooden pole, and placed in the center of the area to be used for drying and threshing of the main crop.

Traditions associated with threshing the rice crop

When all the rice has been harvested and moved to the drying area, a ritual is performed whereby villagers return to the rice fields to request the spirits of the fields to send any uncollected grains or panicles to the rice threshing and drying area. This is performed by the men of the village while the women prepare the rice storage area. In the fields, the men place their hands together in a traditional *nob* (prayer-like positioning of the hands) and make the following request of the *nang kosuk* (female rice spirit):

"Nang kosuk, we invite you to come back with us to the rice store.
Glutinous rice (or nonglutinous rice), come to the store!
Nang kosuk! Send the uncollected grains to the rice store!
Come! Come with us to the rice store!
Nang kosuk! Come with us to the rice store!"

At this time, the villagers then physically collect any remaining grains or panicles in the paddy field, and carry them to the drying and threshing area. In the rice-drying area, the bundle of panicles that was earlier placed at the center of the drying area is placed on the top of the threshed grain for a later ritual. On completion of threshing and before the rice can be taken to the rice mill, the traditional, semi-Buddhist *baci* ceremony must be held. Offerings of cooked chicken, alcohol, banana, sugarcane, and taro are made. This offering of thanks to the spirits of the rice fields includes the chanting of prayers in Pali, and the lighting of incense sticks and candles. Rice from that harvest cannot be milled or eaten until this *baci* has been held.

The *baci* ceremony[3]

This most popular of Lao traditional ceremonies involves the ritualistic tying of holy cotton threads to ensure blessings of the spirits on specific persons, activities, or places (Fig. 2). It is believed to restore the natural order of things and bring communities closer together. The ceremony originated in the Hindu tradition and began to mix with Buddhist traditions in Laos 500 years ago. It is performed by a *mor phon* who is usually an elder who has spent some time as a Buddhist monk. The *mor phon* and invited guests sit around a *baci* centerpiece, which is an elaborately decorated flower arrangement. A long chain of cotton threads is placed in the hands of guests connecting them to each other and to the centerpiece. The *mor phon* then lights candles on the centerpiece and begins to chant Buddhist scriptures in the Pali language.

The guests clasp their hands together in respect and those familiar with Pali prayers participate in various points of the chanting. On conclusion of the chanting, holy, scented water is sprinkled over the guests and uncooked rice grains are thrown in the air. At this point, special guests may be presented with an offering bowl containing cooked chicken and other simple foods. The special guests must hold aloft the offering bowl in their palms and drink from cups of Lao rice wine. It is believed that this will ensure that they have sufficient to eat and drink in the future.

Following this, the *mor phon* and other guests tie cotton threads on guests' and each other's wrists. These cotton threads as well as the centerpiece have been prepared by the women of the group in advance of the ceremony. The threads used in the *baci* ceremony are usually white as Lao people believe that white represents innocence, friendship, and kindness. However, recently, other colors such as red, yellow, and black have been introduced to the ceremony. Red threads are believed to represent bravery, yellow can symbolize faith, and black can mean sympathy for a person's sadness or

[3]Adapted from The Vientiane Times, April 2005.

loss. Before tying on the threads, a knot is tied in the strings. This, it is believed, firmly ties the guests' souls to their bodies.

While tying on the threads, good wishes are offered to the recipient, usually along the lines of "bad things go out," "good things come in," or "wish you good health, long life, and happiness." The form of these good wishes is very flexible and may be offered in any language. The recipient then raises his or her right hand to chest level to show respect for the person who ties the string. During this process, the *mor phon* and special guests will be encouraged to drink more ceremonial glasses of Lao rice wine or similar alcoholic drink.

On conclusion of the ceremony, the *mor phon* and guests will usually move to a nearby area to eat, drink, and engage in other, nonritualistic activities.

With the recent and widespread adoption of mechanized threshers throughout the MRV, the traditional rituals associated with the harvest and threshing of the wet season's rice crop are now rarely practiced.

Rituals associated with storage of the rice grain

Before moving the rice to the storage area, the symbolic bundle of rice panicles that had been placed on the heap of drying rice is taken to the store and placed high up on the front of the building above the entrance. After that, all rice can be moved from the drying area and placed in storage. When all the rice has been placed in storage, the *mor phon* will go to each family's rice store to pay respects to the *nang kosuk* (female rice spirit) and chant from standard Buddhist scriptures in the Pali language.

When the rice is moved from the store to the mill, rice containers must be filled from the bottom of the heap and not vice versa, as the latter is believed to bring about bad luck. While the rice is in storage, if there is a sound of thunder in the area, rice cannot be taken from the store, nor can the door of the rice store be opened until three days have passed. Ideally, the door of the rice store should be opened on the third day of the third month of the Lao calendar.

When preparing the rice for storage, villagers divide the harvest into two components. One component is placed into large containers for family consumption. The other is put aside for the *boun koun kao* ceremony. This important ceremony is widespread throughout all areas of the MRV and continues to be practiced by young and old alike. Each farming family takes the proportion of their threshed rice they have set aside to be ceremonially donated into a "rice bank" located in the village temple. The amount each family donates to the rice bank is up to the individual family, but, generally, wealthier families donate more. On an auspicious day, a *boun koun kao* ceremony will be held within the grounds of the local temple, during which at least four monks must be present. All villagers are expected to attend the ceremony and participate in the chanting of Buddhist prayers in the Pali language. The senior monk will bless the rice and the villagers, and sprinkle the donated rice with scented holy water. Assuming that there is sufficient rice for village consumption, this donated rice will later be sold and the proceeds administered by the village council for the benefit of the local community, such as temple construction and maintenance of village schools, roads, etc.

Other rituals associated with growing the rice crop

Ritual associated with the clearing of new land

In the past, when a new area was selected for an expansion of rainfed lowland rice fields, the villagers had to first perform rituals to seek the approval of the forest spirits before they could prepare the land for rice cultivation. The ritual involved in this process often varied from village to village and between the different areas in the MRV. However, in all instances, its objective was the same—to ensure that the local spirit chief (*Phum* in Saythany District and *Pi lak ban* in Nasaithong District, of Vientiane Municipality) is agreeable to the land being cleared for rice cultivation. As part of the ceremony, in most areas, the villagers first prepare a *khanhar* or *khanpaed*. The *khanhar* is an offering of five pairs of candles and flowers, whereas the *khanpaed* consists of an offering of eight pairs of flowers and candles. A small field hut (*hor*) is built in a small part of the area to be cultivated. Villagers then call on nearby spirits to come and stay in the *hor* to help protect their crops. The villagers hold the *khanhar* or *khanpaed* offerings above their heads and make requests to *Mae-thorrany* (the spirits that live in that area). Although this ritual is mainly associated with gaining the approval of the spirits for the clearing of new land for rice cultivation, requests are often also made to these same spirits to protect the rice crop from pests such as birds and rodents, and, in general, spiritual support to ensure that the rice crops are bountiful. These requests are made in simple, respectful Lao language and may include recitations such as the following:

> *"Honorable Pi lak ban! Honorable Mae-thorrany! We would like to use this land.*
> *We respectfully request permission from you to allow us to do this.*
> *We will use it for some time and then return it to you.*
> *Please allow us to prepare the land for rice cultivation and protect our crop from all bad things.*
> *Also, please protect us and our families from illness and other bad things.*
> *All this we respectfully request from you."*

There is no standard form for these requests and they are not made by monks or shamans but by laymen and women farmers. The candles, flowers, and offerings of glutinous rice cake are placed inside or nearby the *hor* for the benefit of future spirit residents, and small baskets of farmyard manure may be placed at each corner of what will become the main paddy field.

Drought-breaking ceremony—*hee nang meaw* (procession of the female cat)

Rice cultivation in the MRV is primarily rainfed based rather than irrigated. The soils are predominantly sandy and extended periods without rain can have a devastating effect on crop yield. Drought is a common occurrence in this region and farmers in the rainfed lowland environment of the Mekong River Valley consider drought as their most consistent production constraint (Khotsimuang et al 1995). Traditionally, when faced with such conditions, the villagers in this part of Laos and northeast Thailand have conducted a special ceremony called the *hee nang meaw* (procession of the female cat). In the ceremony, villagers construct a bamboo, wooden, or metal cage into which they place a female cat. They then carry the cage (and the unhappy cat) through the village in a procession, while playing traditional drums and gongs, making as much noise as possible in order to gain the attention of the spirits. Villagers not in the procession but who line its path vigorously throw water over the cat, while loudly calling on the spirits to do the same, that is, produce rain for the rice fields. This ritual, once common in most areas of the MRV, is well remembered by village elders but is now rarely observed.

Paying respect to the buffalo

Buffaloes play an important role in lowland rice cultivation and, on completion of harvest, a special *baci* ceremony is sometimes held to pay respect to these animals. In some areas, as part of this ceremony, glutinous rice cake, flowers, and a pair of candles are tied to the horn of one buffalo. In addition, a handful of cooked rice is mixed with salt and presented to the buffalo for consumption. This occasional ceremony is performed by individual households.

Other festivals relating to rice or in which rice plays an important role

Postrice harvest and other festivals, traditions, and ceremonies are numerous and are summarized in Table 1. Two of the largest and most important are the "fire boat festival" (*Boun lay heua fai*) and the "boat-racing festival" (*Boun song heua*). These festivals are held every year some time after the completion of the rice harvest. During the morning, boat-racing competitions are organized, temporary stalls and restaurants are set up along the river bank, and there is much revelry. In the evening, small ceremonial "fire boats" are decorated with candles, incense sticks, white rice, and flowers before being ritualistically set adrift in the river. During both these events, people enjoy eating rice products, drinking rice alcohol, and listening to music while also making rice offerings and other offerings to the *Naga* spirits of the Mekong River and tributaries. Offerings to the Nagas include cooked or uncooked white rice, rice alcohol, cake, fruits, and leaves.

Other rituals in which rice plays an important role

During funeral ceremonies, fried rice is traditionally thrown on and around the coffin of the deceased person. Many Lao people believe that this inspires the soul of the

Table 1. Important festivals (Boun) associated with rice in the Mekong River Valley of Laos.

No.	Festival name	Time festival held	Objective	Rice processing/preparation	Activity/ceremony
1	Boun Khoun Khao (maintaining the paddy festival)	December	To celebrate the success of rainfed rice production, to wish the producer family success, and to establish a rice bank to be used for the benefit of the village.	The newly produced sticky rice is prepared as *Khao tom* (rice-coconut-banana/mungbean boiled in banana sheets), *Khao lam* (rice-coconut cooked in bamboo canes), and *Khao poun* (vermicelli in fish or chicken-coconut extract-spicy sauce).	Construction of an elevated plateau of paddy in the postharvest operation area. The plateau is covered with bamboo or cyprus woven sheets. Monks are invited to sit on these and give benediction, receive offerings, and eat rice.
2	Boun Khao Chi (grilled rice festival)	February	To celebrate the success of the rainfed rice production for the second time. To acknowledge the spirits of ancestors who passed on knowledge of rice production.	The cooked sticky rice is taken in clumps, skewered with long, thin bamboo sticks, and grilled while marinating with egg and pork fat.	The ceremony is conducted in the temple where villagers come to assemble and invite monks to receive offerings of food and give benediction.
3	Boun Bang Fai (rocket festival)	Sixth month of the Lao lunar calendar (approx. May to early June)	To encourage the spirits to provide rain for the coming wet-season rice crop.	Preparation of rice cakes and candies, slaughtering of pigs, and consumption of Lao rice whisky and Lao rice wine.	Firing of rockets high into the air to attract the attention of the spirits living on the frontier between Heaven and Earth.
4	Boun Ho Khao Padabdin (wrapped rice presentation on Earth festival)	End of August	For the deceased parents and relatives. To transfer the benediction as their spirits reach heaven.	*Khao tom* is wrapped in separate small units that are then attached together.	In the early morning at about 3–4 o'clock, the prepared offerings are distributed on the stupas and around the temple. In the morning, a ceremony is performed in the temple to present offerings to the monks who give benediction.
5	Boun Ho Khao Salak (gift offerings to the ancestors festival)	Mid-September	(Same as above.)	Same as above plus the preparation of meat and fish as a complete set of offerings.	(Same as above.)

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Table 1 continued.

No.	Festival name	Time festival held	Objective	Rice processing/preparation	Activity/ceremony
6	Boun Khao Sampapi (rice mixed with everything festival)	End of September	For good health and long life, to transfer benediction to deceased relatives, and to receive personal benediction.	Rice flour is prepared and mixed with coconut oil, sugar, and different medicinal plants for longevity. The whole mixture is boiled together to obtain a concentrated preparation that is ready to serve.	The preparation of rice and other offerings is conducted in the temple. The finished products are offered to monks and distributed to each family in the village and can be given to friends.
7	Boun Khao Phanh Kone (festival of 1,000 rice pieces)	End of September	To present to the sacred spirits in the universe with the spirits of the deceased persons and to establish good relations between the two.	Cooked sticky rice is taken in small clumps (1,000 pieces) and skewered on fine sticks that are placed into small stupas made with banana leaves. These stupas are prepared as a receptacle for offerings.	The ceremony is conducted in the temple. At night, people walk around and celebrate. In the morning, offerings are presented and people receive the Buddhist precepts from the monks.
8	Boun Tieak Khao (dispatching rice festival)	Any month	To transfer benediction to parents and relatives who are recently deceased, and to lead their spirit to happiness.	*Khao tom, Khao nom* (cake), *Khao pat* (rice flour + coconut extract + sugar + green-leaf extract), and vermicelli (*Khao poun*) are prepared and offered.	Relatives and friends come to contribute offerings for the deceased. Monks are invited to give benediction and receive offerings from the families.

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Table 1 continued.

No.	Festival name	Time festival held	Objective	Rice processing/preparation	Activity/ceremony
9	Boun Tak Batevo (alms bowl ceremony)	August-October	To offer to the monks the new rice prepared at different stages: milky stage (*Khao mao*), late milky stage (*Khao hang*), and maturity stage (*Khao mai*), after the monks have just finished the 3-month rains retreat.To get benediction and transfer it to ancestors' spirits.	*Khao mao, Khao hang* (immature rice), and *Khao mai* (new white rice) are prepared and offered.	The ceremony is conducted in the village temple.
10	Boun Song Heua (boat-racing festival), Boun Lay Heua Fai (fire boat festival)	Full moon, 11th lunar month (after the end of Buddhist Lent)	To celebrate the end of Buddhist Lent and provide entertainment at the end of the planting season. To offer respect to the Nagas (mythical river serpents) and ask for blessings from ancestors.	Offerings to the Nagas include cooked or uncooked white rice, rice alcohol, cake, fruit, and leaves.	During the day, boat-racing competitions are organized. At night, small ceremonial flower boats are set adrift on the river.

dead person to leave the coffin, thus making it lighter to carry. However, Phouthonesy (2005) suggests that this ritual encourages people to accept that the person has passed on and that, like the fried rice, cannot be expected to grow again in this world.

Variations and changes in the rituals in recent times

The extent to which rice-based rituals are adhered to and the depth of the belief in spiritual phenomena such as *pi* vary greatly among the Lao people in the MRV. The Lao generally tend not to be dogmatic about their religious beliefs and accept a wide variety of adherence to ritual and custom. In recent times, many people have performed the rituals associated with rice, and other rituals, without necessarily having an unwavering belief in the existence or influence of spirits of the fields and forests. One lowland rice farmer, educated in the Buddhist tradition, has expressed the current level of belief in the following terms:

> *"Even for those farmers who do not believe in the existence of spirits, the performance of rituals can have many potential benefits. In these cases, the benefits of ritual do not accrue to the rice crop, to the spirits, or even to the ancestors of the person participating in the ritual. Rather, the benefits accrue to the person participating in the ritual. Participation in ritual is a way of controlling the mind. It is similar to the meditation and chanting practices learnt in the Buddhist temples. Those farmers who practice the rituals are better able to control their minds than those who do not participate in rituals, and persons who can control their minds are better able to endure life's misfortunes and challenges."*

It can be expected that, as a result of the combination of improvements in the general education standards of the Lao people living in the MRV, combined with the increased adoption of improved rice production technologies, belief in, and the conduct of, many of the rice-based rituals will show a steady decline. This is already apparent in many areas, particularly where land preparation and threshing have become mechanized, at the same time as improved varieties have been adopted. Farmers can also increasingly be expected to plant their crops according to optimum dates recommended by researchers and extension workers, rather than on dates that are astrologically or ritualistically determined. These changes, as well as increasing migration of the young people of rice-farming families to urban and periurban areas, and exposure of the rural people of Laos to other beliefs and rice-growing practices, through improvements to infrastructure and telecommunications, can be expected to lead to an irreversible decline in the practice of the rituals and traditions that have been an integral part of these communities for centuries.

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CHAPTER 6

Rice-based traditions and rituals of the Kmhmu'

Suksavang Simana and Elisabeth Preisig

The Kmhmu'[1] are one of the major ethnic groups of Laos, considering themselves as indigenous people of the northern part of Indochina. The Kmhmu' currently living in and around Laos number around 700,000, with the majority living in Laos, where they represent abut 11% of the population (613,893 in the 2005 census). Kmhmu' are also found in areas adjacent to Laos: in Vietnam (about 56,542 in the 2001 census), in the Sipsoong Phanna area of China (3,000), and in Thailand (10,000). In Laos, the Kmhmu' are found throughout the northern region (where they make up as much as 20% of the population), with the highest concentrations in the provinces of Luang Prabang (47%) and Oudomxay (59%). In spite of minor regional cultural and linguistic differences, all Kmhmu', wherever they may live, always understand themselves to be members of the same ethnic group.

The Kmhmu' language belongs to the Khmuic subdivision of the northern Mon-Khmer branch of the larger Austro-Asiatic language family and is subdivided into a number of regional dialects that form two larger dialect categories.[2] Within each dialect group are additional subgroups corresponding to family descent lines *(smta')*, each of which follows its own particular rituals and traditions, dictated by the totemic ancestry and passed down through the patriline.

In traditional Kmhmu' villages (Photo 6.1)) and families, life is generally organized according to customs of the larger regional subgroup (or dialect group) one belongs to, and the totemic ancestry *smta'* of the family's clan. The Kmhmu' social structure and their entire traditional system of beliefs are characterized by the ancestral lineages named after their totem-plant or totem-animal, and their intricate network of relationships of exchange, expressed through cooperation, mutual respect, and support. Furthermore, the Kmhmu' pay respect to natural phenomena and the powers of the universe that may hinder or facilitate their daily life and struggle for survival based to

[1]Alternative spellings are Khmu, Kammu, Khmou, Khamou, and Khơmu.

[2]The larger dialect group includes about two-thirds of the Kmhmu' people and is spoken in the provinces of Luang Prabang, Phongsaly, Xiengkhouang, Houaphan, Vientiane, and Bolikhamxay, and parts of Sayabouly. The second group is divided into several more distinct dialects called Kmhmu' Lue, Kmhmu' Khvèèn, Kmhmu' Rook, and Kmhmu' Khroong, found in parts of the provinces of Oudomxay, Bokeo, Luang Namtha, and northern Sayabouly, as well aṣ China and Thailand.

a large extent on producing enough rice to eat. Traditionally, community-related and clan business affairs are conducted by a council of elders, and decisions are reached by consensus, with both men and women participating in the decision-making process. Currently, a political system operates alongside the council of elders.

Most Kmhmu' adhere, in varying degrees, to their traditional animistic[3] worldview, according to which there is a world of spirits and a world of humans. Spirits *(hrôôy)* have an influence on people's lives, and it is accepted that people become spirits when they die. These spirits may live in the natural environment. Each living person also has a sum of personal spirits or "spirit-souls" *(hmmaal)*, in the absence of which it is believed that the person can get sick and may die. To restore the body involves calling back the personal spirit-souls by family, friends, and community, sometimes with the help of a spirit specialist *(mo môn).* Furthermore, it is believed that, just like people, other beings or bodies such as the traditional Kmhmu' bronze drum-gong *(yaan)*, important plants such as the rice plant, or particular animals such as the tiger, may also be animated by such personal spirit-souls.

The first-generation patrilineal ancestors are respected as house-spirits *(hrôôy gaang),* who are in turn expected to protect the family in their daily lives as well as their belongings, crops, and animals. In the Kmhmu' worldview, the human world is believed to be the model for the spirit world. What works in the human world is thought to work similarly in the invisible world. So, what feeds the people and their preferences is also thought to satisfy and feed the spirits as well. *Rice, as the most important food for people, is therefore, in all its forms, the choice food for all versions of spirits as well, including raw and steamed rice, as well as various rice-alcohols.* So, rice culture and the traditional beliefs of the Kmhmu' are closely interrelated and play an important role in the every-day lives of the people. In addition, dreams also play an important role in relating the human and spirit worlds.

Rice cultivation by the Kmhmu'

The Kmhmu' are mostly upland subsistence farmers. Traditionally, they have lived in relatively remote mountainous areas where little land was usually suited to wet- rice cultivation. Where paddy-type rice cultivation has been undertaken by the Kmhmu', this development is relatively recent, in response to the national government's policy encouraging the adoption of more sustainable forms of agricultural production.

The staple food of the Kmhmu' is glutinous rice, which they grow in their upland "swiddens." This is complemented by whatever grows and lives wild around the rice fields, in the forest, and in the waters, and can be gathered or hunted as needed for their own use and survival. Together with upland rice, some corn, tubers, taro, cotton, hot peppers, eggplant, sesame, sorghum, pumpkins, cucumbers, beans, and Job's tears are grown. These are planted around the edges of the rice fields, over stumps,

[3]During the last 100 years, a small percentage of Kmhmu' have become Christians, others are Buddhists having received education in the temples, while many, under modern influences and the revolution, have given up most of their traditional spirit beliefs and rituals.

or in separate plots or fields according to the crop, available work force, and regional traditions. Predators of the crops are hunted and eaten if edible. These include bamboo rats, mice, squirrels, birds, monkeys, and whatever other animals are trying to eat the crop. In times of famine, the Kmhmu' dig for wild tubers and eat other food from the forest to survive. Around the villages (which may vary in size from about 20 to 80 or more households) and around their houses, they also plant small areas of herbs, vegetables, and bananas, and raise domestic animals such as water buffalo, cattle, dogs, pigs, chickens, and sometimes goats and horses. Traditionally, domestic animals were raised not so much for regular meat consumption as for feeding the spirits in times of sickness and calamity, and for ancestor veneration or for use in other rituals along both the life cycle and planting cycle. The choice of animals raised was related to the believed preference of the spirits that were to be pleased. In more recent times, many Kmhmu' raise some domestic animals to generate income.

The importance of rice to the Kmhmu' households and community is reflected in one of the old Kmhmu' sayings:

> *"Making rice fields is eating rice, and eating rice is EVERYTHING; not enough rice means that there is not enough of ANYTHING."*
> *"To eat rice means to be alive*
> *but to not eat rice means death."*

The most important activity of the Kmhmu' is therefore the work in their rice fields. Individual Kmhmu' households usually plant several varieties of rice. The names of the rice varieties are taken from trees, bamboo or grasses, silver and gold, "winged" white, black, yellow, etc., and are qualified as soft, nice and soft, or robust, fragrant, growing anywhere, good for alcohol but hard, ritual black rice with long grains or round grains, small or big grains, etc. The names given to particular varieties are meant to be flattering as if to suggest how the rice should grow nicely and beautifully. Small areas of black rice are usually grown to meet the needs of some of the rice-based rituals of the Kmhmu', for which black rather than white rice is often used.

Traditions and rituals of the Kmhmu' associated with upland rice cultivation[4]

In the past, the Kmhmu' believed that rice had a soul or a personal spirit similar to that which is believed to be associated with humans. The rice spirit-soul was also thought to be capable of getting angry and cross. If the rice spirit-soul stayed with the owner and master of a field, then it was believed that the owner could plant a rice crop and

[4]The sacred activities for fertility, just as other rituals, are not usually open to outsiders to attend for fear of trespassing and consequences thereof, and are therefore often unknown even to neighboring ethnic groups. However, during the Kmhmu' harvest festivals, *greh*, nowadays often performed as village festivals with a folkloristic note, ritual and other instruments as well as field tools used during the planting cycle are displayed and demonstrated in an artistic way for the pleasure of officials, guests, and the community.

be assured of a good yield. However, if the rice spirit-soul became angry and was staying elsewhere (other than in the householder's field), the owner of the field would not get a good harvest. For this reason, the rice-field owner was obliged to love the rice and the rice seed that was planted. Furthermore, he had to store his rice properly, so that not one grain would fall on the ground and be wasted. If he didn't take all the necessary precautions, he would fear that the rice spirit-soul would become angry and leave. This is why, every year, the Kmhmu' perform two or more rice spirit-soul blessing rituals during which they call the rice spirit-soul home, first before the rice gets planted and one or more times when it is harvested.

The rice-planting cycle of the Kmhmu' usually starts in February, after the celebration of the traditional year passage rite and harvest festival, followed by the annual rest, family-related activities such as weddings or other rituals, and the undertaking of repairs to, or the building of, a house. Tools are also prepared for use during the next planting season.

Taboos and spiritual considerations in the choice of a field

The selection of a field is a most important activity that takes place in January to February, depending on geographic location. It includes not only the examination of the natural conditions, such as the environment, the soil, sun exposure, rain, moisture, etc., but also the supernatural conditions such as spirits living in the area, and the working conditions in the field. For this complex activity, the Kmhmu' form solidarity groups *(thung hré')* of family members and friends that will help each other throughout the planting cycle with work that must be done collectively.

In choosing a field site, several taboos and beliefs are adhered to. In some areas, the Kmhmu' are taught not to select a rice field site from where their own cotton field would be visible. If a farmer has more than one field, the separate fields should also be out of sight of each other. Farmers should also not be able to see the fields of their siblings (fields of family members may be close together, as long as they are out of each other's sight).

Ritual related to the selection and marking of a new field

The evening before it is planned to go, examine, and select new fields, a jar of rice wine is opened and the house-spirit is notified of the plan by the recitation of the following words:

> *"Master, father and mother, we are breaking open wine*
> *for you to consume and we let you eat this rice.*
> *The month in which to make our field and its divisions has already come.*
> *Tomorrow is the day to go to examine the field and the divisions.*
> *Watch over the path of the fields and the walkways of the paddy.*
> *Don't be critical and scared. Yes!*
> *Accident spirit don't pass by; devouring spirit,*
> *don't shine on us (=target with a signal).*

May our dream show signs of a good spirit-soul
or else have a pleasant meaning,
so we can see that we will get rice and be fortunate with animals."

The fields are then examined on the nominated day by a team of Kmhmu' men and, when an appropriate field has been chosen and agreed upon for the family, the following prayer is recited:

"Yes, we are the Tva'- family (prayer by fern clan family).
I would like to start clearing this place for testing,
on a day that is auspicious for lush rice and perfect animals.
In case we can't proceed, we will understand it:
If whatever spirit passes by, will signal it and manifest itself to us.
If it is good and we can go ahead with clearing, we will know:
If whatever spirit passes by will signal this by being quiet and by not manifesting itself.
Make our dream good and perfect,
meeting the rice spirit-soul and perfect animal spirits.
May we dream of a very good and perfect omen,
Such as of the luck bringing rice spirit-soul and the perfect (quiet) animal spirit-soul."

After reciting this prayer, a small part of the land selected is cleared as a basis for checking with the spirits as to the suitability of the land. If, during the time of clearing, no calls of particular animals or birds are heard (the birds or animals that were asked to remain quiet in their prayers), the members of the household return to their home to sleep on the choice that was made. If, during the following night, members of the household dream of the rice spirit-soul in a positive way, it means that the family may proceed with the clearing of the remainder of the field on the first auspicious day, according to the Kmhmu' calendar for work. If, however, the dream is about something that is regarded as taboo, or not good, or if a bad omen is observed (such as fly eggs or other inauspicious signs), the site must be abandoned and another area of land selected.

On the day that the family is to proceed with clearing, those who are to be involved in the clearing work should not have any problems with their hands and legs such as open wounds or other injuries. As the clearing and subsequent burning can potentially be dangerous, the elders of the group will seek the consent and protection of the spirits, preparing an offering tray with food gifts, trying to form a pact with them, with the following words:

"We are the Tva'-family!
We will engage in the work.
We will enter the fields and clear them and their divisions
and then we will cut the trees and the logs.
Watch over our feet and over our hands so they will have no injuries!
When the time has come (harvest time), we promise to make a meal for you!"

Clearing and preparation of fields for planting

Clearing the land in readiness for planting is a collective activity of the Kmhmu', with the different families of the "field working group" helping each other. By working together, the clearing can proceed rapidly and, as a result of the social interaction on these occasions, is enjoyed by all participants. Both men and women participate in the work of clearing. The initial clearing of the field (*hrwam*) can take between one and two "10-day weeks" (the traditional Kmhmu' week, *vèèng*, has 10 days, each day being assigned special duties and taboos). After the clearing of small trees, branches, and undergrowth is completed, the women usually engage in other activities while the men use axes to cut down (*kool*) any large trees. The felled trees and vegetation are then left to dry so all can be burned on a day that is very hot and preferably when there is also a breeze. Burning (*guuc*) is carried out according to traditional passed-down methods. If the burning is done well, the work of field preparation that follows will be easier. Women and children generally do not participate in the burning, as it is regarded as being too dangerous. After the initial burning, the whole family then works together to collect and burn any remaining debris, leaving a clear but rough seedbed that is covered with ash, which, in turn, provides a source of nutrients for the rice crop that is planted in the area. The quality of the cleaning up and preparation of the seedbed, called *puur*, is important, as it also affects the ease with which the subsequent hand weeding of the rice crop can be undertaken.

In ordinary (most) years, there are no important rituals to perform, or special customs to observe, during the process of clearing, burning, and cleaning up of the fields being prepared for the wet-season's rice crop. An exception exists for those family households that have constructed a new family house of the type that is also the residence for the house-spirit *(gaang tè')* in the previous dry season. These families have to prepare two additional ritual meals in the field to honor their house-spirit *(hrôôy gaang)*. One meal, called *mah pnggwl,* is prepared just after the fields have been burned, but before the final burning of the remaining debris. The second meal, called *mah tmbri',* is prepared when the rice is well established and about knee-high. Detailed descriptions follow in a later section of this chapter.

Rituals associated with the planting of the rice crop

The Kmhmu' have many different traditional ways of planting their upland rice crops, reflecting the geographic conditions and their traditional belief that putting the seeds into the ground may cause offense to the rice spirit-soul. Rituals that are followed by individual families reflect their particular totemic ancestry and beliefs. The actual method of planting the fields may also vary among different regional groups.

Ritual miniature rice field and blessing of the rice seed. On account of their dependence on rice as their staple food, the Kmhmu' consider and respect rice as something of utmost importance. So, when the time of rice planting approaches, they still think and worry that when they abandon the rice seeds in the earth, the rice spirit-soul might become angry and leave. Therefore, to please the rice spirits, before planting the main rice crop, a small ritual garden or "miniature rice field" *(mat rèèk)* is prepared and planted with a small quantity of seed of each variety of rice to be grown in the main field.

The "mat rèèk" *or ritual miniature rice field.* The miniature rice field *(mat rèèk)* is prepared on the first day selected for dibble planting by the male head of the household that owns the field. This miniature rice field usually does not exceed about 4 m^2 in area, with a symbolic giant rice plant made from bamboo planted in its middle, and other symbols related to rice cultivation arranged around it (Photo 6.2). The *mat rèèk* is made in the following way: a *tala* bamboo stalk of about two full double-arm-stretches in length is cut and its top end beveled off so it looks pointed like a rice leaf. The third internode down is slit lengthways several times and then expanded with bamboo sticks to make it resemble a large, full, round rice grain. At some distance up from the base of the bamboo stalk, a hole is pierced, through which a rope is then pulled to represent a double phallus pointing in two directions. Finally, a loosely woven bamboo disk *(thèlè)* is attached to the stalk to mark it as being taboo or sacred. The bamboo stalk, symbolizing a giant rice plant, stands firmly planted in the ground in the small field. On the ground around the base of the bamboo stalk, miniature water channels are made to represent the channeling of water into water containers placed at the base of the stalk. At the foot of this giant imitation rice plant, some small symbolic rice-wine tubes are sometimes placed too. To complete the ritual rice plot, split bamboo is used to make a fence around it. The bamboo stalk in the garden symbolizes giant rice plants that the Kmhmu' farmers wish the rice in their main field to take after. The water channels and the bamboo water containers below symbolize the rainwater needed for the rice to grow. The symbolic phalluses are supposed to scare off the "foamy-grasshopper-widow-spirits" and "insatiable consuming spirits," which might want to steal the rice. The fence around the little field is to indicate to the animals of the forest, which might want to come and eat the rice that is planted, that they should stay out of the field. All is symbolic for the main field.

The blessing of the rice seed with chicken blood (baak smlah hngo'). For the ritual action of initiating the planting season, the mother of the household (*ma'gaang*) has to get herself ready, wearing new clothes and a new headscarf, a silver bracelet, and necklace, before carrying the family seed-rice to the field in a back-basket. After arriving in the field, she places the back-basket with the seed in the center of the field.

When the father of the household has finished preparing the ritual miniature field, the mother will take a silver bracelet, a silver necklace, and their talisman (*prnèèt*) (consisting of a small bagful of items such as special stones with special powers, that are used to attract the spirits) and place them all inside a small basket (*bèèm*). She then adds a small quantity of seed of each variety of rice to be grown to the offerings already in the small basket. Once this is done, she slits open the beak of the chicken, intended for the sacrifice, letting its blood run over the rice seed, the talisman, and the silver items. This is what is called *baak,* to "smear" (sacrificial blood on) the rice seed. While the blood is applied to the rice seed varieties, the mother recites (*a bor*) the following prayer:

"Please, spirit-soul of unthreshed rice (hmmal hngo'),
spirit-soul of cooked rice (hmmaal mah), don't be angry or cross.
Today is the good and perfect, and long-awaited day.
The other people (jè') far around also say this is the one,
and the holy man in the cave also believes it's a good day today
to start planting the rice seed.
Let every grain sprout and every root grow fast!
Oh, yes!
If there are no runners, go and get some from the elephant grass.
If there is no mother-plant (ma'), go and ask for one from the tall "cèèp" grass.
Grow and sprout in a hurry, stump and tree!
Would anyone forget the apple of his own eye?(=descendants)"

After communicating in this manner with the rice spirit-soul, the spirit-soul of cowrie[5] and money *(hmmaal kmuul ksôông)* is addressed as follows:

"Oh, yes, we are pouring blood on cowrie (shells) and money and talisman.
May the rice we plant and the rice we eat be lucky!
Climbing up the slope above the village,
may we meet the nest of the bronze drum-gong yaan (= treasure).
Climbing up the slope above the houses,
may we meet the silver stack.
May we get bundles of silver and bags full of silver "six-alloy" (nam hrôk).
May we get good silver like they have in (Kmhmu'-) Rook country (= pure),
Chinese and Vietnamese white silver.
May goodness turn towards us.
We implore, we implore you!"

Following the offering to the rice spirit-soul, a tray-table of food is prepared and served to the participants in the ritual. After this ritual meal is finished, the mother of the household *(ma' gaang)* goes to initiate the planting work by taking some seed of each variety of rice the family will plant, dibble planting a small area of each in the ritual miniature starter field, while reciting the following blessing:

[5]Although cowrie shells (*ksôông*) are not used as a form of currency anymore, reference to them is often made when talking about money and wealth in a poetic way.

"Oh yes, a good and perfect day—a beautiful day—it is today
for initiating the planting of this rice!
May each germ sprout and every root grow!
If there are no runners, go ask for some from the elephant grass.
If there is no plant, go and ask for one from the tall grass.
Grow, sprout, explode, stump and tree!
We are initiating the planting this new year on this cleared field.
No one should forget his own eyes or nose (=offspring)."

When this ritual initiation of the planting is completed, the mother of the family will scoop out rice seed into each of the belt-baskets that are to be worn by different female members of the household and others assisting in the planting of the family's rice field. She then still has one more ritual to perform. For this, she lights a special foul-smelling torch made with a grease-soaked rag or with the bark of a rotten tree, sits down in the field, and again addresses the spirits:

"Hey, let's not have any devouring and the consuming spirits,
nor any "foamy-grasshopper-widow-spirit" come in.
Come and help us plant the rice, the food we need most.
From now and forever, keep them away!"

The smelly torch is then discarded and the dibble planting of the rice in the main field can then commence and it is usually completed within two or three days as a collective effort by family and friends.

Dibble planting of upland rice

Depending on the region, the Kmhmu' use different tools to dibble-plant their rice fields. Some regions use long, wooden planting sticks *(groong cmool)*, while others use a shorter planting stick *(clè),* or diggers with a small, narrow, spade-like iron blade. Dibbling done with the long, wooden planting sticks requires two people working together, one (usually a man) taking the lead while punching seed holes in the ground, with the second (usually a woman) following behind to drop seed into the holes (Photo 6.3). Dibbling with a short *clè* digger can be done by one person making the holes with one hand, while dropping the seeds into the hole with the other. In some areas with relatively flat, smooth terrain, such as the plain of Xieng Khouang, people also use a special kind of long dibble stick called a "sounding-stick," so named because of the musical sound it makes when being used. The sounding-sticks (*groong wwyh*) are usually used along with the ordinary long dibble sticks (also called "dumb-sticks," *groong sluut*). The musical dibble sticks are ancient ritual instruments, which, in the past, were used not only to make the work of dibbling proceed quickly according to their rhythm but also to call rain for the fields at the same time. The choice of dibble sticks depends on both the type of land and the regional ritual traditions of the Kmhmu' planting the rice.

Feeding the field-spirits

Traditionally, the Kmhmu' also feed the area-spirits of the fields while they cultivate their rice crops. This is usually done twice. The ritual of "closing the seed hole" is the first of these rituals, the purpose of which is to make a pact with the spirits living in the field area, asking them to keep and protect the rice seed that has been placed in the seed holes. In turn, the farming household promises to prepare another meal for these spirits once the rice is being harvested. This promised meal will represent a second offering to the field area-spirits at harvest time. Both events are commonly referred to as "feeding the field-spirits" *(liang hrôôy hré')*. For each of these rituals, an elder or an older member of the family with a knowledge of the prayers and rituals presides over the ceremony.

Ritual of "closing the seed hole" (first feeding of the field-spirits)

In preparation for the ritual of closing the seed hole, a temporary platform *(raan)* is constructed beside the ritual miniature rice field (Photo 6.4). A bamboo stalk is then used to make a symbolic giant arched rice stalk. Thin, narrowly split bamboo bands are woven into rings and a chain; a woven cricket and a woven fish are then attached to the ends of the bamboo chain, which, in turn, is suspended from the top of the arched stalk. On the ceremonial bamboo platform are placed four pieces of wood, cut into the shape of silver bars, together with two skirts and two double-arm-span lengths of cloth. Also added to the platform as offerings are plates of traditional delicacies such as chewing bark, tobacco, betel leaves, areca nuts, and lime. Underneath the platform are placed a silver bracelet and a necklace, together with an open jar of rice wine (to attract the invited spirits and let them smell the rice-wine vapors). Three prayers are then recited. The first prayer (in a type of ritual Lao-Thai language marking the distance) calls upon these spirits to receive the gifts:

> *"Oh spirits (hrôôy) of the soil, of the termite hills,*
> *of the region and of the surroundings!*
> *Owners of the country, owners of the place where we live*
> *and of this very piece of land here!*
> *Protect this field and this section of field, take care of it.*
> *Care for the gardens of the Tva' family and of their house.*
> *Now, oh, do not let the mice bite the shoots off*
> *and the animals scratch them out;*
> *don't let the first leaves die or the top leaves droop."*

Such words are spoken while feeding the area-spirits of the field and the spirits of people known to have died in the area, calling them by name, one by one.

For the second prayer, a chicken is cooked and then offered to the spirits. When they have eaten (acceptance of offerings is determined by divination), a third prayer of thanks is recited. These prayers can differ, depending on the reason for which the spirits are called upon. To ensure that everything is done correctly, other signs are

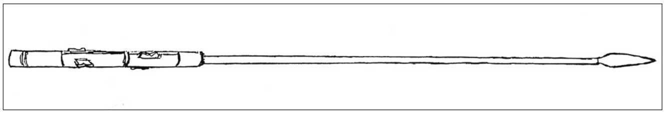

Fig. 1. Musical dibble stick *(groong wwyh).*

examined, such as the shape and look of the feet of the cooked sacrificed chicken once it is boiled. This is all done in a way similar to when making offerings to other spirits such as the "spirits of the country and the paths" or the "spirit of the graves."

Rituals calling for rain during, or following, dibble planting

When the dibbling work is completed, special rituals to call for rain are sometimes performed by some of the Kmhmu' subgroups such as the Kmhmu' Rook in Oudomxay Province and the Kmhmu' who live in the mountainous areas of Sam Tay District of Houaphanh Province. Some subgroups do not have separate rain-calling ceremonies, while others use musical dibble sticks during planting to simultaneously call for rain to assist the germination of the newly planted rice crop.

The musical dibble sticks of Xieng Khouang Province. In the past, the Kmhmu' of Xieng Khouang Province made musical dibble sticks *(groong wwyh)* for use on days when they called on other members of the community to help with the planting of their rice fields (Fig. 1). The fields in which such dibble sticks were used had to have smooth terrain. They could not be used on steep slopes. As the season for planting the rice crop approached, all Kmhmu' households in this part of Laos would make musical dibble sticks, making one, two, and sometimes three per family. On the day when they were called upon to help with the planting of someone else's rice fields, the men and household heads would shoulder their own musical dibble stick and go to the fields. Planting would commence with those carrying the dibble sticks moving in a line across the field, making seed holes by hitting the ground with the sticks, while at the same time producing "the rhythmic music" for everyone to work by. Behind the men would follow the women and children, dropping rice seed into the holes. Sometimes between 10 and 20 of these musical dibble sticks would resonate with their *"bring bring"* vibrating sounds being carried over the fields and echoing through the air. The sounds created by the musical dibble sticks were believed to ascend to the place of *Lord In* and *Lord Thèèn* of the heavens, who, upon hearing them, would then respond, sending rain down on the fields of newly planted rice.

The termite-hill-drum (groong wwt) of Sam Tay District, Houaphanh Province. The Kmhmu' in some remote mountainous areas of Sam Tay District of Houaphanh Province near the Vietnamese border used to perform another rain-calling ceremony using a type of "earth-drum" or "termite-hill-drum" (Fig. 2). This drum is built using a cavity in the ground such as an earth nest of termites. The cavity (about 40 to 60 cm in diameter) is covered with a woven bamboo screen or thin layer of bark, which serves as the drum membrane, its edges firmly attached to the ground with wooden

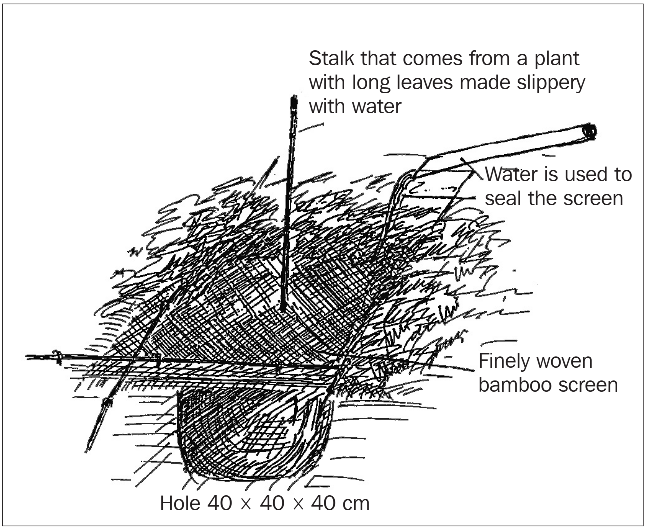

Fig. 2. Earth-drum or termite-hill-drum *(iit iing)*.

pegs. A leaf-stalk of the fragrant *dru* plant[6] (*Phrynium capitatum*), knotted and then run through the center of the screen, provides a string that can be pulled, rubbed, or stroked, causing the screen to vibrate and the cavity beneath in the ground to resound with loud, complaining *wwt wwt* sounds. This instrument has therefore been given the Kmhmu' name *groong wwt* ("plaintive stalk"), but it is also called "*iit iing*" (a name reminding of its sound).

The occasion for making and playing the earth-drum or termite-hill-drum was usually at the beginning of the season, if rain was late in arriving, or later, around the time of making offerings to the field-spirits, when the rice was about knee-high. So, in an attempt to induce the rain to fall, an earth-drum was made and played, "making earth and sky vibrate to its thundering sound." Upon hearing it, the "spirit of lightning" *(hrôôy cndrayh)*, also called "dragon spirit" *(hrôôy pryoong)*, was expected to get annoyed and angry, finally pouring rain down on the thirsty land, thereby allowing the rice seed to germinate and the plants to grow and provide the people with rice grain to eat.

The rice-kldoong of the Kmhmu' Rook of Hun District, Oudomxay Province. The Kmhmu' Rook from Meuang Hun of Oudomxay Province have a yet different tradition for calling for rain. This tradition is based on an orchestra of four to six people who play paired bamboo resonator tubes (*kldoong*), while being accompanied by other percussion instruments such as a long foot-drum or button gongs. The orchestra produces, in a rhythmic way, an unusual combination of percussion and droning sounds. Each Kmhmu' Rook village usually has its own special interesting type and size of

[6]The leaf of this plant is also used as the fragrant wrapper of traditional rice cakes.

bamboo *kldoong* that produce their own unique sounds (Photo 6.5). Each bamboo resonator tube pair has a special name according to the role in the rhythmic playing of the orchestra. The names of larger tubes are preceded by "mother" and the smaller ones by "child."

On the final day of rice planting, the *kldoong* are made from *r-haang* bamboo and already beaten on the way home from the fields. Once arriving at home, the planters take rice wine and a pig to the house of the respected brother of the mother's family *(éém)* to eat and drink and celebrate there.

That evening, the whole village would gather and beat the *kldoong* and listen to their playing, drink rice alcohol, and have a good time together. In the old days, the villagers also dressed up two people like forest spirits, using forest palm leaves to clothe them and transforming and painting their faces so they would look like fierce animalistic spirits with pointed heads and long teeth. In addition, the two monsters would have a big, frightening-looking symbolic phallus bound on a string from their waist. The young and old men would play the *kldoong* while the women would try to splash water over the players to indicate that it was female heavenly angels and spirits that were responsible for making the rain for the rice crop. The two forest spirit-monsters would dance around the players trying to keep the women and girls away from the *kldoong*-playing men using their frightening giant phallus to chase and scare the womenfolk away. Just before the end of the *kldoong* playing, the women would take water and throw it on the players and declare:

> *"There shall be rain and thunder and splashing water.*
> *Water shall splash on the chestnut flowers, and on the flowers of the lôôñ*[7] *fruit,*
> *come to our village, so be it please!"*

Everybody would then loudly call out and shout their approval together.

The period of growth of the rice crop

During the period of crop growth following planting, no special rituals or customs are observed until the crop approaches maturity. The only exception to this, as mentioned earlier, is for households that have constructed a type of house called *gaang tè'* in the preceding dry season, and who will need to offer a special meal, called *mah tmbri*', to their house-spirit at the time when the rice is about knee-high in order to lift a food taboo. However, during this time of growth of the rice, two or three weedings are undertaken, mostly done by the women using a special bent hand-hoe called *vêêr*. The men protect the field area against incursions of forest animals that might damage the precious ripening crop by using diverse traps and scaring devices and by hunting and so also keep the family supplied with meat to eat.

[7]A tree species whose wood is highly regarded for construction purposes.

The harvest and threshing of the rice crop

In connection with the harvest of their rice crop and subsequent storage of the grain, the Kmhmu' maintain many different customs and traditions related to their beliefs and respect for their house-spirit *(hrôôy gaang)*, the spirits of the fields *(hrôôy hré')* and the land *(hrôôy pté')*, and among others the many wandering spirits *(hrôôy hyaap, hrôôy boor)*.

The Kmhmu' rice harvest under upland conditions starts about early September and, if additional paddy fields are planted, it can last until December (depending on the climate, the maturity time of rice varieties, and field type). Harvesting is a collective activity in which many people of the "field working group" as well as other friends and family members participate. Harvesting requires a lot of preparation, as the family whose field is to be reaped is responsible for equipping and feeding all participants, including providing a supply of rice wine. Harvest time is a happy time of working and being together, of courting, singing, and sharing stories with each other.

The rice crops of the Kmhmu' are harvested in different ways depending on the rice variety and the region. The so-called "sickle-rice" *(hngo' kiiv)* is, as the term suggests, cut with a sickle and then stacked in round rice-stacks with the grain-filled panicles pointed to the center of the stack, where it will be left to dry. When dry and ready for threshing, it is threshed by beating the grains off the panicles using a special L-shaped threshing stick, or by beating the rice bundles onto a slanted threshing board similar to that traditionally used by the Lao of the lowlands. In recent times, there has been increased used of threshing machines. The *kiiv*-rice may also be harvested by hand-stripping *(hoot)* the grains directly from the panicles into the belt-basket, which is carried in front around the waist of the harvester. Hand-stripped grain is considered softer when cooked. In northeastern Laos, in Sam Tay, other varieties known as *taan*-rice are harvested using a special hand-held cutter *(hèèp)* that harvests just the panicles with enough stalk attached to allow for binding them into bundles. As *taan*-rice does not shatter or lose grains easily, it is first stored in a temporary drying-rack-wall built in the field, and is allowed to dry while the rest of the rice is harvested. After the harvest, the *taan*-rice bundles are carried to the village and stored in the permanent family rice storage-house at the edge of the village.

Rituals during the time of harvest and threshing of the rice crop

Prior to and immediately after the rice harvest, a variety of traditions are observed by the Kmhmu'.

Ritual of starting to eat new rice. When the new rice starts to ripen, the Kmhmu' perform the "starting to eat new rice" ceremony *(rèèk mah hngo' hmmé')* in order to begin eating the new rice. For this ritual rice harvest, an auspicious time and day have to be chosen. On that day, no rice should be accidentally spilled by anyone, lest the "never satisfied spirits" *(hrôôy hyaap)* and the "consuming spirits" *(hrôôy bôôr)* be attracted. On the appointed day, the mother of the household carries her back-basket, takes a wooden torch *(cndôh h'é'),* and walks up toward the rice field until she arrives at the last path, which branches off leading to her own field. There, she, or whoever is with her, will build an arch over that particular path. Two long wooden sticks are planted into the ground on each side of the path and then bent toward the middle of the path to get an arched top. A palm-leaf or some other type of leaf is used to finish the arch. A torch that burns by means of a grease-soaked cloth (and spreads an unpleasant smell) is fastened onto the arch. The mother then addresses the spirits with the following words:

> *"Hey, spirits (hrôôy), if you want to eat, there's grass there!*
> *Don't you try to follow me and get our first new rice!*
> *I'll enter into the archway now and leave you behind!*
> *We don't allow you to pass here and go on any further!"*

On finishing this warning, she passes through the arched gate carrying her back-basket. When she arrives at the center of her field, she reaps some of the almost ripe rice, in all a quantity contained in about two sheaves of ten bundles. If it is *taan*-rice, she cuts the heads using the hand-held rice-cutter, and, if it is sickle-rice that easily shatters, she strips the grain directly from the panicle into her small belt-basket. She then carries this first portion of the new crop home, where she prepares a special kind of ritual "first rice"[8] *(mah pr'wp)*.

The same evening at home, a chicken is killed as an offering to the honor and well-being of the members and descendants of the family line. The *pr'wp* rice is served and the house-spirit is notified that the first new rice has already arrived and will presently be sampled and tasted. After the tasting, the house-spirit is expected to be eager to come and watch over the rice crop, preventing wild animals and pests from destroying or eating it. A jar of rice wine is opened and some of the alcoholic rice and husk material is lifted out with two flat sticks, and offered to the house-spirit to taste also.

Feeding of the field-spirits at harvest time. At the stage when about half or two-thirds of the rice has been harvested, the second ritual food offering to the spirits of the fields is performed. It takes place on an auspicious day and requires a pig, two chickens, and two jars of rice wine. The day before, the villagers and all members of the extended family are notified and invited to join the final stages of the harvest and the ritual meal. The ceremony for the second feeding of the field spirits uses an enlarged version of the ritual platform (*raan*) that was used earlier for the ritual of "closing the seed-hole." On top of the platform are displayed several items, including two token silver bars made from wood, a carved wooden rhinoceros horn, and a wooden elephant tusk. Various items of clothing and pieces of cloth are also placed on the platform, together with many offering plates decorated the same way as for the "closing of the seed-hole" ceremony and containing chewing bark, tobacco, betel leaves, areca nut, and lime.

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[8]*Mah pr'wp* is rice that is harvested before it is quite ripe. Before it is eaten, it is presteamed within the husks, then dried above the fireplace and only after that pounded and steamed again. The flavor is nutty and the color light brown.

When the villagers and relatives arrive at the field on the appointed day, they all join in the final stages of the rice harvest. Only the close friends of the mother and father and the village elders, including the performer of the ritual, remain at the platform near the field hut in order to attend the ritual of feeding the spirits of the fields *(liang hrôôy hré')*. After the offerings are laid out on the platform and the rice wine is opened, the performer of the ritual lights a beeswax candle, places it next to the platform, and recites the following prayer (in a mix of ritual Lao-Thai and Kmhmu' languages marking the distant relationship to these spirits):

"Oh how beautifully yellow and ripe are the rice plants!
Oh, we will cut them off, may we be very lucky from now on!
Now the rice has come, it has arrived!
Spirits of the region, owners of the land,
of the area and of the plots of land,
keep your guard over the field as true noble owners of land.

After the prayer, divination *(knè')* is used to consult the spirits. A pinch of rice grains is placed into the hollow hand and checked as to whether the number of grains is even or odd. If the grains of several consecutive pinches are an even number, this is regarded as a sign that the spirits have accepted the gifts. The pig is then killed and cooked, and presented as an offering to the spirits, with more prayers. The rice wine is then opened and the spirits are first invited to taste it. A special wine-serving set consisting of a water container *(rngbaang)*,[9] a ladle *('muay)*, and a buffalo horn measure *(nééng)* is used for measuring and serving the rice wine. The elder conducting the ceremony recites a prayer while taking hold of a bunch of bamboo drinking straws, raises them up toward the platform, and motions to the different spirits, inviting them to come and drink. After that, he raises the buffalo horn that is used to measure water into the rice-wine jar, as if offering drinks up to the spirits, urging them to drink well and plenty.

Following this feeding of the area-spirits *(hrôôy A-vông)*, the grave-spirits *(hrôôy rmaan*, representing the people that died while in this area and were buried here and are now watching over it) are fed. This is done on a smaller, separate ritual platform or altar that is erected and decorated in a similar manner, next to the first one. For this additional ritual, the requirements are two chickens and two bamboo tubes of rice wine, together with an assortment of clothes, a bracelet, a necklace, some ancient cowrie shell money, silver money, and other items. As the spirits of the graves of the dead are fed, they are addressed with the following words in the Kmhmu' language:

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[9]The water basin was originally made from a half of a big gourd *(plé' gôôk)* and the ladle from a half of a smaller type of bottle-gourd.

"Spirits of the graves, spirits of the water-barriers,
you that are the keepers of these surroundings,
feed yourselves and your own.
Don't feed on the food of the regional spirit (A-vông).
Eat by yourselves, drink by yourselves!"[10]

Ritual of the "rice-mother calling the rice-child." On the same day as conducting the ritual of feeding the field-spirits during the harvest, yet another ritual, the "rice-mother calling the rice-child" *(ma' hngo' k'eey koon hngo')*, is performed. The people who have been working together on completing the rice harvest are now called to return. When they arrive, the mother of the household that owns the field prepares what is called the "rice-child" *(koon hngo')*. For this, she gathers two or three panicles of each variety of rice that she herself has planted inside the ritual ministarter-field *(mat rèèk)* with the symbolic giant bamboo rice stalk that was established before the planting of the main field. She puts these rice panicles in her small waist-basket. Inside the basket are already a silver bracelet, a silver necklace, and the family talisman objects. The whole basket is now referred to as the "rice-child *(koon hngo')* (Photo 6.6)." The mother of the family then takes a chicken, boils it, and pinches off some of its soft comb and tail, then calls the rice spirit-soul *(hmmaal hngo')* to come and receive the food offering *(sngkhvan hmmaal koon hngo')* while reciting the following words:

"Rice-child,[11] *don't you ever forget your own body or face again!*[12]
From now to the twelfth month the new rice of the field will be dry.
We want to take the rice-spirit to go and cut off rice, oh, yes.
We will bless you, will pour blood on you, and wash you,
will keep feeding you and serving you food to eat
and drinks to drink in abundance."

This blessing ceremony for the rice child requires a chicken and a jar of rice wine. The rice wine is then set aside for only the womenfolk to drink. The mother of the family is now referred to as the "rice-mother" *(ma' hngo')*. Following the offering to the rice-child, food is served to all people attending the harvest. After people have eaten, jars of rice wine are served for everyone to drink in the traditional way. The festive mood carries on well into the night, with the harvesters chanting poetry they have composed themselves, wishing each other well and telling their personal stories. After the ceremony, the rice-mother carries home the small waist-basket (containing the rice panicles she placed in it before, and which now represents the rice-child) and keeps it in her house[13] until the day when the rice harvest is officially brought into the

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[10]This prayer to the grave-spirits is all in the Kmhmu' language.

[11]Both field rice and cooked rice are invoked in reduplication (*koon hngo', koon mah*).

[12]That is, "remember your duty."

[13]The attractive gifts that were first in the basket when she collected the rice-child are put there only for the ritual and are removed afterward and stored in safety.

"rice storage-house" *(c'ô')*. Then she moves the rice child to the rice storage-house, where the small basket with the rice panicles is tied to hang down from the main roof-beam (*phraang gaang*). Tying the rice-child basket to the roof-beam in this way has the meaning of storing and safe-keeping the spirit-soul of all rice: field rice as well as cooked rice (*hmmaal hngo', hmmaal mah*).

Feeding the rice spirit-soul before threshing. On the first day of threshing before the actual commencement of threshing, the mother of the household again has to kill a chicken and offer it to the rice spirit-soul. Enacting the role of the mother of the rice-child, she climbs on top of the rice stack *(knduur koong hngo')* to perform this blessing of the rice spirit-soul (*sngkhvan hmmaal hngo'*) before pulling from the top of the stack the first rice bundles that will be threshed to ritually initiate the threshing (Photo 6.7).

Rituals related to the transportation and storage of the rice harvest

Seed of each rice variety is always kept for planting in the following year. The grain to serve as seed is carefully selected and sorted, with seed of different varieties being stored separately. The rice that is to be kept for family consumption or sale and the seed-rice is stored in the rice-house *(c'ô')* (Photo 6.8). If the rice fields are close to the village, the rice-house will be in the village; these rice-stores are often at a distance from the family houses as a precaution against the loss of their food in the event of a fire in the village. If the rice fields are a long way from the village, a rice-store may be constructed there, with the rice then being carried to the village for consumption as needed. With recent improvements in roads and transportation in some areas, vehicular transportation of the rice crop to villages is increasing. Specific rituals are also followed relating to ensuring the safe-keeping of the rice during storage.

Feeding the rice spirit-soul before transporting the harvest home. Once the rice is threshed and winnowed, a chicken is killed and its blood poured on the rice as an offering and blessing to the rice spirit-soul (Photo 6.9). This action is called *baak sngkhvan hmmaal hngo'* (smearing-blessing the rice spirit-soul)**.** The rice is then transported home to the rice-house. This work continues until all stacks are threshed and the grain is stored in the granary.

Calling the rice-soul home to the rice-house. On the occasion of transferring the rice into the storage house, the following prayer is recited by the father of the family that owns the rice, in order to call the rice spirit-soul *(hmmaal hngo')* home:

> *"Oh, we call the rice spirit-soul to go home to the rice-house,*
> *to the roof-beam of length, to the roof-beam of width.*
> *Hey, return home to create, to repair, so we will have a long life.*
> *Be elevated, be raised (in status) rice spirit-soul!*
> *Hey, "white rice" that has long panicles, return, return to me (male[14]) today.*

[14]In this prayer, the person praying uses the Lao word for "young man" *(laang)* for himself, so it must be done by the father of the family: if it is the mother, she would replace *"laang"* with *"naang."*

"Vaay" rice, with long panicles like banana stalks, come home to me (male) today.
"White rice," I (male) will smear (bless) you on the threshing mat,
and you, "vaay" rice, in the basket.
I (male) will store and keep you for the village: they are all waiting to get some.
I will store and keep you for the village,
for the young generation of the family and of the house
is waiting to have something to chew.

The fathers sit in the corners by the fireplace
and the mothers in the corners of the bedroom.
I myself will sit here to contemplate and chew.
The room is not bad.
The house looks full from the outside,
it's stuffed full up to the rooftop, full, ready to burst,
the rice is filling up every space.

The village will have something to chew
and everybody will rush trying to chew it first.
The rice plant will sprout for me in all its strength;
the leaves will be sprouting nicely, wide and spread out.
The "black rice" is like the young man and
the "white rice" like the young lady.
Rice-soul, rice-spirit,
come to the rice-house under the roof.
Hey! When my basket will be suspended on the ladder,
pounding rice in the foot-rice-husker is a pleasant thought.
It is a beautiful sight like seeing a handsome young man,
just perfect and strong.
Slowly kick the husker, slowly step down, slowly step,
slowly observe from afar.

Return, come and eat, soul of rice, spirit of rice.
Coming home at day time, it is good;
coming home at night time, it is fine.
Staying up there,[15] you will fear rats;
staying on the ground, you will fear the "koon dèèn".
So come home and stay in the rice-house here,
under the beams, with the roof overflowing with rice.
Rice-spirit-soul, come home and eat!"

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[15] In the fields.

Other rice-based field rituals connected with the family's house-spirit

The ritual meal for the house-spirit. In those years in which a family has built a particular type of new house (called *gaang tè'*) to be the home for themselves and also for the spirits of their dead parents, that family has to perform two additional rituals during the planting season. A first ritual meal (called *mah pnggwl*) is celebrated when the fields are burned (which is a time of special vulnerability for those involved). If there is sufficient time, this ritual meal is prepared on the same day as that on which the burning takes place. If there is insufficient time on that particular day, the meal can be prepared and the ritual performed within two to three days after the main burning *(guuc)*, but before the final cleaning up of the fields *(puur)*.

First, a small hut is constructed not far from the village, on the path that leads to the farmer's field. Two narrow offering trays, resembling the ones used to feed the house-spirit at home are made, one from a half of a small bamboo tube and one of woven bamboo strips, and then attached to an inside wall of the hut. A jar of rice wine, a chicken, a bamboo tube of sweet fermented rice, and a rice-basket full of black rice are prepared and carried to the hut, where a ritual meal takes place around three or four o'clock in the afternoon. The rice wine is opened and placed near the ancestor-feeding-trays. The father of the house takes the chicken, cuts its beak, and applies the blood first to the woven upper shelf, which stands for the direct patrilineal ancestors, reciting the following words:

"Now the grandchildren, the children, and the younger siblings
have burned the fields and their divisions already.
We want to let you know, our mother and father,
who are our house-spirit.
Tomorrow or the day after, we will go and clean up our field divisions.
Please do watch over us, over our hands and feet.
Don't cause any thin leeches to get in our nostrils,
nor anything to hit or hurt our eyes.
Slanted tree, don't point at us; twisted serpent, don't bite us.
Father, mother, house-spirit, now you can't say that we haven't told you."

After smearing the upper tray, he lets some of the chicken blood run into the bamboo tray underneath. This second application of blood is to represent the symbolic feeding of deceased in-laws and any dead children of the family. The following words are recited at that time:

"So that there be fields,
watch the field divisions and the separations of the wet fields.
Please don't let the mice bite, or the animals dig out the rice!"

Then the chicken is cooked, and some of its soft meat is first offered to the spirits, followed by the meal for the family and the customary drinking of rice wine. The family then returns to its home.

The ritual of eating new leaves. Later in the growing cycle, during the time of weeding when the rice has grown to about knee height, and the pumpkin leaves and bean leaves (which are usually planted along with the rice) have put out long shoots, some shoots of these plants as well as of some specific wild fern types are collected and cooked in a soup to use in the ritual of "eating new leaves" *(mah hla' tmbri')*. When conducting this second field ritual in honor of the house-spirit, the old hut on the way to the field and the offering trays (earlier built for the first ritual meal in the fields and designated to the house-spirit, *"mah pnggwl")* are repaired and used again. The ritual of eating new leaves requires in all two chickens and two jars of rice wine. In the evening of the selected day, one jar of rice wine and a chicken are taken out to the hut and offered to the spirits while reciting the following words:

"This is the meal of freshly-harvested leaves and greens,
cooked to eat around the table.
From now on don't say you didn't hear us tell this to you,
or that we didn't let you know anything, our father and mother, our house-spirit.
We will eat of the leaves and greens, of the fern stalks and fern leaves.
We will cook them back at home and then bring them out here to eat on the tray.
Now the rice is already quite big and tall!
Watch over us all, go and watch over all
so that the mice won't bite,
or the animals dig up the harvest.
The first leaves: don't let them die;
the top leaf: don't allow it to droop.

We prepare for you to eat, plenty of stems and leaves of the fern,
mid-way to the water channel, on the way to the fields.
After eating, take your responsibility and watch over all:
the children, grandchildren, the younger siblings,
the nephews and nieces who will work the fields and go trapping,
who are doing all the work,
and who make things happen."

The ritual meal itself is celebrated in the same way as the earlier meal for the house-spirit. The only difference is that, on this occasion, the first leaves and new shoots of vegetables also grown in the rice fields are cooked and served along with the chicken. After the food is eaten, the offered rice wine is drunk. The family then packs up everything and returns back home where a second chicken is killed and another rice-wine jar opened and offered there to the house-spirit to taste first. The chicken is cooked and pumpkin leaves and the young shoots of other plants are also added. After the chicken is cooked, some of the food is offered to the house-spirit on the family's spirit-feeding trays to taste, while saying:

"Don't forbid or taboo (sri') from now on (in the year)
that we offer you to eat new leaves and greens,
new pumpkin leaves, and new daisy leaves (hla' hmbrèèt)!"

From that time on, the leaves of the various plants can be cooked and consumed again. Before this ritual is performed, traditionally the Kmhmu' concerned with the described ritual duty were not allowed to cook any leafy food in the private room of their house, nor offer any such food to the house-spirit in his residence *(lôôk),* which is also where rice is cooked.

End-of-harvest and Kmhmu' New Year celebrations

After the harvest is brought in, the Kmhmu' people celebrate yet another ritual connecting both their ancestors and rice. It is a type of passage rite of rice cycles, or yearly cycles, and at the same time a thanksgiving celebration for the blessings of the year that has passed, which some people equate with their traditional New Year celebration. However, this very important celebration was traditionally not on a particular date, nor was it celebrated by all Kmhmu' around the country or even in one village on one specific day.

Rice-cycle and year-cycle passage rite

In times past, the months of December and January of every year were observed as taboo (*sri'*) for work, in memory of the famous Kmhmu' ancestor and hero Cheuang. During this time, the Kmhmu' had to offer food sacrifices and prayers to the spirit of Cheuang, who, as a child, was also called Ñi and who is regarded as the Kmhmu' people's mighty ancestor leader and the source of all knowledge. So, in December or January, after the rice harvest has been brought to the rice storage-house, a *greh* ceremony or *vwayh* ritual in honor of the spirit of Cheuang and Ñi must be performed. Traditionally, these activities did not involve the whole village or community, as is commonly the case in more recent times. Whichever household or family completed its harvest first was the first to celebrate its individual family *greh;* households that finished their harvest later celebrated their *greh* later. The *greh* celebration is simply a ritual ceremony with a meal during which the family formally concludes or "takes down" the old year and welcomes or "puts up" the new year. The *greh* celebration does not have to be elaborate but needs to be celebrated every year, sometime in either December (Cheuang) or January (Ñi). (January is considered the birth month and December the death month of Cheuang.) To return to the fields for preparation of the succeeding year's rice crop, without first having celebrated the *greh* on completing the harvest of the previous year's crop, is regarded as being very inauspicious.

The *greh* ritual touches on a great many aspects of the life and culture of the Kmhmu', such as preparing and serving food, planting fields, harvesting and storing the rice crop, and raising various kinds of animals. It also relates to the digging up *(grwayh)* of various kinds of tubers, thereby reminding the Kmhmu' people of how they have survived in times of famine without rice. Furthermore, *greh* is a ritual of thanksgiving for all things that have contributed to the productivity of their fields.

Finally, in this ritual, all the personal spirits *(hmmaal)* are called for each person, to return home, and the spirits of their deceased parents, who now rank as beloved house-spirits *(hrôôy gaang-'naam pang),* are fed while asking them to look after their offspring and their belongings, including animals and valuables, in the year ahead.

During the *greh* ceremony, the father of the house cuts open the beak of a chicken and smears some blood onto the knees of the family members, starting with the smallest child and ending with the oldest member. The father gets his knees smeared last by his wife. All valuables belonging to the family such as cowrie, money (silver) and any talisman, the rice-child, and field tools are also smeared with chicken blood, as are any animals such as cows or buffaloes (if not directly, then on a pictorial representation of them) to feed their personal spirit-souls. This is how each family concludes, or "takes down," the old year, and then opens, or "puts up," the new year. Many prayers are recited in which the house-spirit is honored, praised, and begged to keep protecting the family and belongings throughout another year.

The *greh* celebration, whether conducted as a large or small ritual, in one or another regional variation or family totem tradition, is always a very important event in the lives of most Kmhmu' people and there would be fears of repercussions in case of an omission of this ritual duty.

Art in greh. The communal *greh* celebrations have both ritual and social components. The ritual component takes place around a richly decorated bamboo pole from which flowers, fruit, tubers, and field tools are hung, and under which various instruments, traps, rice wine in jars and in bamboo tubes, and different kinds of rice cakes and steamed tubers are displayed (Photo 6.10). During the communal celebrations, which have become fashionable in the last 15 years, the people sometimes carry out various artistic performances of which they are proud and display artifacts and wear costumes that have now mostly become folklore. Among the field tools are sometimes included the musical dibble sticks that were used for planting rice in some areas and these can also be used in a rice-planting dance. Cymbals, button-gongs, stamping tubes, and whatever percussion instruments the family may have are also played during the second more social part of the *greh* celebrations. In the provinces of Oudomxay and Bokeo, the Kmhmu' also play their bamboo resonance tubes (*kldoong*) in orchestras of four to six players, in the same way as when they play them to call for rain after the completion of dibbling work. Well-off Kmhmu' families may display their bronze gong-drum *(yaan*) and have it played along with the other percussion instruments during the feast that marks the celebration. Other instruments that may be part of the *greh* ceremonies are bamboo stamping tubes, bamboo dulcimers, gourd fiddles, flutes and pipes of many types and sizes, and finally bamboo humming forks, all of which may be played to accompany the *teem* poetic singing or as part of musical groups.

Rice alcohol in Kmhmu' rituals

Every ritual in Kmhmu' society uses rice alcohol of some sort. Probably by the nature of its volatility and smell, alcohol has become thought of as an especially appropriate form of rice to attract spiritual beings, just as it is enjoyed by the Kmhmu' people celebrating. Alcoholic rice preparations create a special joyous atmosphere, which, it is believed, the spirits would like to be a part of. Furthermore, rice alcohol links and unites people of a great many social and ethnic backgrounds, breaking down social barriers that otherwise cannot be easily trespassed. Beyond that, rice alcohol passes the barriers between the material and spiritual world and is used in facilitating and sealing pacts and important contracts in family and society.

The Kmhmu' drink mainly two types of rice alcohol: rice wine *(buuc kdong, buuc sa),* which is either kept in sealed bamboo tubes *(tông)* or earthenware rice-wine jars *(kdong)*, and the stronger, distilled rice alcohol, or brandy *(buuc siav)*, made from rice wine. A third kind of alcoholic preparation is a sweet fermented rice *(buuc sthô')*, reserved for very special purposes.

Rice wine is consumed when a house is built, when magic is performed, when a wedding is celebrated, during healing rituals, and when feeding the spirits of the ancestors of the Kmhmu'. Rice wine is also used in blessing rituals called *hmmaal*, be it for the personal spirit *(hmmaal)* of a person, rice, important possessions such as the bronze drum-gong, or an animal such as a buffalo that is newly acquired and brought into the family. It is also served to welcome one's respected or close family members and dependents when they call to socialize and discuss family affairs (Photo 6.11).

Preparation of rice alcohols

Rice wine. Rice wine is made from glutinous rice and husks. The rice is steamed and then, after some fermenting agent has been mixed with the rice and husks, it is fermented, first in banana leaves and then in sealed earthenware jars. After three more days, the rice wine is ready to drink, but the alcohol level and quality increase if the wine is stored longer. Following precise traditional recipes maintained by families, different flavors of rice wine are produced, from bitter to sweet. The fermenting agent used by the Kmhmu' is also home-made from glutinous rice. Just like all handling of rice in general, the production of the fermenting agent, as well as the production of the various kinds of rice-based alcohol, is considered a feminine duty. The mother of the household is responsible for always maintaining a supply of "fermenting agent patties" (*jwa pdô'*) of each of the strains and rice-wine flavors the family has the tradition to keep and produce (Photo 6.12).

Rice brandy. Rice alcohol or brandy (*buuc siav*) is made from rice wine and is produced by distilling the rice wine a second time, using a simple home distillation technique. Although the Kmhmu' drink some rice brandy, it is not as popular as rice wine. Many Kmhmu' make rice brandy strictly for ritual purposes. It is generally not consumed in the same way or as frequently as rice wine. However, in some northern provinces such as Luang Nam Tha, Oudomxay, and Phongsaly, this type of alcohol is also served to guests to welcome them and announce them to the house-spirit.

Sweet fermented rice. A sweet fermented rice porridge (*buuc sthô*) is both consumed by the people and used in offerings to the spirits. The Kmhmu' like to eat sweet fermented rice porridge during heavy clearing work and when they are felling trees in the fields, as they regard it as a good source of needed energy for such work. It is also often used for ritual meals for the house-spirit held outside the village, or when magic is used to solve problems.

To prepare sweet fermented rice, black glutinous rice is preferred together with a sweet strain of the fermenting agent. Black rice, when fermented, is regarded as being more delicious and nutritious than white rice; it is also regarded as being more attractive. In producing sweet fermented rice, the rice is first cooked like ordinary glutinous rice. After cooling, the appropriate amount of fermenting agent is added. The rice is then put into a jar or bamboo tube, which is covered with a leaf and allowed to ferment for about two days before it is ready to eat.

Conclusions

The rich inventory of the Kmhmu' rice-based rituals and traditions described above provides glimpses into the rice culture of the Kmhmu' people, who are not concerned only with planting a cereal and eating it as a staple food. Rice is totally intertwined with every aspect of Kmhmu' everyday life, involving their worldview, beliefs, and kinship system, in fact, with their entire intangible culture as well. This is expressed throughout the life cycle of the people, the year cycle, and life cycles of nature and vegetation, with which rice in some ways interrelates. It could be said that rice, the sustainer in all its forms and functions, together with the house-spirit and the totem of the family*,* constitutes the life line of each clan, representing, in a way, an intertwined centerpiece of the Kmhmu' culture, linked to their survival and perpetuation.

Everything in the life cycle of the Kmhmu' involves rice, not just as food but as a grain people plant and eat to have life. Rice is more—it represents life beyond the physical body whose health is believed to depend on a life element or spirit-soul. This is manifested in the many rituals in which rice is given to feed the soul-spirit of the person to return life and health starting from the day the baby is born up to the effort of feeding the spirit-soul when it is trying to leave the person's body at death. Furthermore, rice is considered as if it were a person itself and is believed to have a spirit-soul just as people do. This is reflected in the ritual of the rice child, in which rice is symbolically adopted as a child of the human family and thereby socially bonded with the Kmhmu' society that depends so much on rice. But, beyond this dimension, rice also constitutes the medium of contact and flow of forces between the living and the dead, between the spirit world and the human world, which is considered essential for the survival of the society in its environment.

These are among the reasons why the planting and subsequent care for the rice crop until it can be eaten and planted again are of such great importance for the Kmhmu'. This involves not only their whole human being but also the cooperation of their extended family, and the protecting ancestors. The work of making rice fields, apart from the heavy physical effort and attempt of keeping predators away from the crop, is accompanied by a constant spiritual concern of maintaining appropriate relations or distance with potentially harmful or helpful spirits in order to protect themselves and their field. At the same time, every effort is made to protect and please the rice spirit-souls in order to not lose any rice. In this effort, each family seeks the help of its respective house-spirit, representing the first ascending patrilineal ancestors (or, if not following the old traditions, of whomever they consider and respect as the spiritual power the family respects and depends on). It is considered to be the house-spirit's duty to help his descendants to get a rice crop so they will survive and be able to continue their family line.

For all these reasons, changes in the lifestyle of the Kmhmu' people reflect strongly on their rice culture and the underlying system of beliefs that link the food chain, kinship, life and death, health and sickness, and their entire culture, including respect, privileges, and duties in society and well-being in life after death. Changing habits and patterns of livelihood (such as the adoption of new production techniques, the planting and production of cash crops such that part of the household rice needs can be purchased, or accepting work outside their traditional culture or changes in role patterns) can have profound implications for the Kmhmu' in their struggle for survival and a hopefully brighter future. Too many changes, changes that come too fast, or changes too great in the patterns of livelihood, especially if they happen involuntarily or by accident, can result in a deterioration of culture, and of the established social order, leading to an identity crisis for the ethnic group. As demonstrated throughout this chapter, Kmhmu' livelihood, family traditions, worldview, and rituals in their traditional way of life are all intricately interrelated, forming a well-rounded culture owned by this distinct society in its distinct social, geographic, and historical setting. Although culture as such is subject to constant transformation, as old components get lost and new ones need fitting in, time and thought are needed if the change is to become a positive, harmonious experience that enhances the development of the society that owns the culture.

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CHAPTER 7

Rice-based traditions and beliefs of the Hmong

Pheng Sengxua

The Hmong are among the most recent ethnic groups to arrive in Laos. The late 18th century to as recent as the early 20th century saw the migration of the Hmong-Mien (Yao) and Tibeto-Burmese–speaking peoples from southern China, tightening administrative controls in their Chinese homeland being behind this move (Batson 1991, Quincy 1995, UNDP 1997). The Hmong initially generally settled at higher altitudes in the more mountainous areas of northern and northeastern Laos, and later in upland areas as far south as the provinces of Sayabouly and Borikhamxay (Dommen 1995, UNDP 1997). In addition to their movement into Laos, during this period there was also a significant movement of Hmong into northern Vietnam and also into northern Thailand and adjacent mountainous areas of Myanmar (Quincy 1995). In the 1995 census, the Hmong-Mien ethnic group was estimated to represent 7.5% of the population of Laos, with the Hmong comprising the larger component of this group. The Hmong comprise three subgroups—Striped Hmong, White Hmong, and Black Hmong. The three subgroups are similar, with the main basis for the subgroup classification being differences in their traditional clothing. Linguistically, 85–90% of the language is common among the three subgroups, with differences in traditions and beliefs and family relations being relatively small.

The Hmong are animistic in their beliefs, with a strong tradition in shamanism and spirit worship. As with other ethnic groups with ancestral and traditional links with the land, the Hmong have many traditions and beliefs that are associated with the main crop that sustains their lives—rice. This chapter describes some of the rice-based traditions and beliefs of the Hmong in northern Laos. Although the practice of these traditions (as with other traditions) is in decline, the elders of most Hmong villages in Laos still have a strong belief in them, whereas, in more remote communities, they are often practiced in the traditional way.

Agriculture and the Hmong

Relative to many other ethnic groups that have lived in the upland environment in Laos, the Hmong have practiced a more integrated form of agricultural production, in which livestock have always been an important component, in addition to their cropping activities. In their traditional upland environment, most Hmong households and communities have been relatively self-sufficient. Within their own communities, food self-sufficiency is generally regarded as reflecting diligence and hard work, whereas households with insufficient food are often regarded as being "lazy." In the areas from which they originated in southern China and since their arrival in Laos, the focus of the upland cropping activities of the Hmong has been based on "swidden" cultivation (slash-and-burn, shifting cultivation). Although rice has always been the main crop grown for food production in such systems, other crops are also grown, particularly maize, which is used mainly as an animal feed (being used particularly for pig production). Although in the period since the 1980s, and particularly in the 1990s, there has been resettlement of some Hmong in lowland areas of Laos, as part of the policy of the government to stabilize upland areas where increased population pressure has resulted in past slash-and-burn agricultural practices being no longer sustainable (Roder 1997), in the early 2000s the majority of Hmong in Laos were still engaged in their traditional agricultural production practices in the upland environment.

The Hmong and rice

As with all other ethnic groups of Laos, rice is the primary crop and food of the Hmong. However, unlike most other ethnic groups in Laos, the Hmong have always preferred to grow and consume rice with nonglutinous rather than glutinous endosperm, that is, nonglutinous rice rather than glutinous ("waxy" or "sticky") rice. Rice self-sufficiency within Hmong households is regarded as a reflection of both the industriousness and "wealth status" of a household. Within the Hmong community, a general perception is that those households with insufficient rice to eat are lazy and poor. Unlike in most other ethnic groups in Laos, rice is not only the most important food of the Hmong themselves, it is also an important feed for some animals, particularly poultry and horses (from 5% to 10% of the household's rice can sometimes be used for domestic animals). Rice has also often been used as a form of currency for the Hmong. Of particular importance, rice is also regarded as the basis for unity, harmony, and generosity within and between the Hmong communities. Rice is also an essential component of the various social and animist-based traditions of the Hmong. The average annual per capita rice consumption of the Hmong in Laos is believed to be greater than 300 kg of unmilled rice.

Rice and the traditions of the Hmong

In the traditional upland cropping cycle, from the time of commencement of preparation of the upland rice fields through sowing to the final harvest of the rice crop, unlike many other ethnic groups that live in both the upland and lowland environments of Laos, the Hmong do not adhere to many special traditions and/or beliefs that involve the performance of rituals to ensure the success of the crop. However, following the harvest of the crop and during the period preceding the start of cropping-based activities for the following year, the Hmong follow several traditions and rituals to ensure the protection and productivity of the next season's rice crop and/or as part of which thanks are expressed to the various spirits for the productivity of the preceding year's crop.

The Hmong believe that the success of their rice crops is dependent on the support of the spirits of their forebears or family members who have passed on—parents, grandparents, brothers and sisters, children, etc. They therefore believe that it is important to offer rice from the first harvest of the rice crop to the spirits of these deceased family members before any living members of the family can consume any grain from the new rice crop. The ceremony of "eating the new rice" is performed when the earliest (first) maturing variety is almost ready for harvest. Initially, 20 to 30 kg of this crop is first harvested for the conduct of the ceremony. The ceremony usually involves only immediate family members, and is conducted by the household head, who, for Hmong households, is normally the oldest male member of the household. The mother of the household first cooks the rice and then places it on a bamboo platter in the center of the main room of the house; a bowl of soup and a piece of meat are placed near the rice. The mother then invites the head of the household to perform the ceremony. He takes up a position near the rice, while also being near the main door of the house. He first takes the piece of meat and, while tearing it into small strips, recites the following words:

> *"Myself and members of my family have harvested new rice to eat; we therefore invite our father and mother to come and eat some of the new rice; we also ask the spirits of our mother and father to protect all living members of the family—to keep them free of all forms of illness and injury."*

After reciting these words in the name of the spirits of the deceased mother and father of the household, the household head will then offer the ceremonial meal of rice to the spirits of deceased uncles and aunts (citing their various names), while at the same time asking the uncles and aunts to provide protection for the living members of the family and to also help ensure bountiful harvests from their crops and animals (following the same format as the request made in the names of the spirits of immediate parents).

Following the invitation to the spirits of the elders to come and eat new rice, separate invitations follow to the spirits at three other levels to participate in the eating of the new rice. These are in the order of

- Level 2: Invitation to older sisters, older brothers, younger brothers and sisters, and any children who have passed on.
- Level 3: Invitation to the household spirits.
- Level 4: Finally, the head of the family will take a spoon of the new rice and walk out of the house through the main door to invite the various spirits that live outside of the house to come and consume some of the new rice.

At all levels, in addition to the invitation to participate in the consumption of new rice, the various spirits are asked to keep members of the household healthy and free of problems, while also ensuring that bountiful harvests from the crops and animals are forthcoming in the following seasons.

The Hmong New Year and rice

The Hmong New Year falls in January of the Lao calendar. Hmong ceremonies associated with the New Year are an integral part of Hmong culture and are celebrated by all Hmong families and communities. As the time of the New Year approaches, each family spends a considerable time in food collection and preparation of sufficient food to last a period of 15 to 20 days of celebration. In addition to the usual nonglutinous rice, some of the food products prepared for this occasion are based on glutinous rice. Although the ceremony is performed as part of the Hmong culture wherever they are, traditionally the ceremony has been to "celebrate" the productivity of the preceding cropping season. The ceremony is also used to call the spirits of departed family members to return to the family home, and to call the spirits for the return of the production of any crops that may have been lost during the preceding cropping season, together with the return to their "pens" of any livestock that may have died or have been sold during the previous year. Individual households may kill a pig or a cow during the ceremonies associated with the New Year in order to properly entertain members of the extended family, as well as close nonfamily friends. However, the timing of the killing of such animals usually follows traditions relating to the offering of chicken sacrifices (the killing of a pig or a cow often has to take place three days after making offerings of chickens to the spirits of the fields, the spirits of the ancestors, etc.). For a three-day period associated with the sacrifice of the chicken, all forms of work have to cease apart from the feeding of the farm animals and food preparation. One or two days before chicken sacrifices are made, the head of the family either leads or has other family members go to the fields that were used for cropping in the previous season. They take with them a chicken and three incense sticks, and perform a ceremony to call "home" any production that might have been lost in the preceding season. In subsequent spirit-related ceremonies held in the home of each Hmong family, the household head undertakes a ritual cleaning of the area around and within the house, while reciting "*today I sweep the dirt away—things which are not good in the year past are also to be swept away*." On completing the ritual cleaning, the various spirits (spirits of the deceased family members, spirits of the animals, and spirits of the various plants that have significance for the family) are called to the home to join the ritual meal. In asking the spirits to join the ritual meal, their protection of the family from illness and misfortune is sought, and assurances are sought for future crop yields and animal production. After these rituals, members of the immediate and extended family, together with close friends, are invited to share a sumptuous meal for which a pig or cow might have been killed.

Finding a location for a new house

The process of locating a suitable site for the construction of a new house for any family is very important and follows strict traditions, in which rice also plays an integral part. After a family head has tentatively selected a piece of land for the construction of a new home, a hole 20-cm deep is dug, and, after flattening the base of the hole, a 2–3-cm wooden peg is placed at the center of the base of the hole. A number of grains of uncooked rice are then aligned with the peg, the number of grains used being the same as the number of members in the household who would be scheduled to live in the house. The hole and its contents are then covered overnight. If, on inspection the following morning, the rice grains have been undisturbed, the site is regarded as being suitable for the construction of the family home. However, if any of the grains are missing or have been displaced overnight, the site is regarded as being unsuitable, and a new site has to be found and the same ritual performed involving the rice grains.

Other traditions and rituals involving rice

Death-related rituals

Apart from the use and involvement of rice in many rituals relating to the well-being of the living, and which have the potential to benefit a family, when a member of a Hmong family dies, rice also plays a prominent role in the rituals related to the deceased family member. In the first of these rituals performed on each of several days before the burial of the deceased family member, a rice meal is prepared and offered to the spirit of the deceased three times each day. Then again following the burial of the deceased, a meal of rice is offered to the spirit of the deceased each morning for three successive days. Then, 13 days after the burial of the deceased, rice and other foods are prepared and again offered to the spirit of the deceased.

Spirit-related offerings

On many occasions during the year, food offerings and sometimes chicken sacrifices are offered to the various spirits that form the basis of the animistic beliefs of the Hmong. Some of these ceremonies and offerings are in honor of family ancestors, while others are in honor of the spirits that are believed to be associated with the various things, living and nonliving, that combined make up the environment in which the Hmong live. Offerings are also often made as part of efforts to cure various ailments and ensure productive crops and healthy animals. In all these rituals, rice is an integral part of the offerings made.

Rice and family goodwill

Rice is also used to reflect good manners, love, and respect among the members of the Hmong community. When family members or friends travel long distances to visit each other, an integral part of the welcome offered is a meal, the main basis of which is rice. If, on the return journey after making such a visit, the visitors have to travel for 4 hours or more, it is customary to prepare a meal composed primarily of rice, to be consumed on the return journey. Even though the food provided for consumption may be rather simple, the act of providing it is regarded as reflecting a high degree of good manners and respect for visitors.

Rice, for the Hmong, is not only regarded as being important for the maintenance of an individual's health through being the primary component of all food consumed, it also plays an important psychological role, on account of its various spirit-related uses. Further, an abundance of rice within individual households is regarded as an important measure of the industriousness of individual families and the members of that family group.

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CHAPTER 8

Katu traditions and rituals associated with rice

N.A. Costello

The Katu people number 52,000 and are found in Vietnam and Laos. Approximately 14,700 live in Laos, so they represent one of the smaller ethnic groups in the country (Sulavan and Costello 1994). They are currently found in the provinces of Sekong, Saravane, and Champassak. Those in Vietnam are found mainly in the province of Quang Nam, with a small number of villages in Thua Thien Province. The areas where the Katu live in Laos and Vietnam are adjacent. The Katu language belongs to the Katuic branch of the Mon-Khmer language family. The Katu are generally an isolated group inhabiting the more mountainous areas. Formerly, most of the Katu of Laos lived in Kalum District of Sekong Province, in areas inaccessible by road and where it could take up to 8 days of walking to reach their isolated villages. In the early 1970s, under a government policy encouraging a move from swidden agriculture to wet-rice cultivation, thousands of Katu moved to lowland areas in the districts of Thong Vaai, Lamam, and Thatheeng in Sekong Province and Lau Ngaam in Saravane Province. However, by 1979, many had returned to the more mountainous areas on account of not having the resources and knowledge to undertake the wet-rice cultivation required in the lowlands. During the mid-1990s, the government once again encouraged their return to lowland areas in Lau Ngaam in Saravane Province and Thatheeng in Sekong Province. In neighboring Vietnam, during the 1990s, many Katu were also encouraged to move to lowland areas, mainly to the district of Hien in Quang Nam Province, where they currently cultivate a combination of lowland rice (both rainfed and irrigated), upland rice, and coffee.

The Katu have a wealth of customs, traditions, knowledge, and folklore relating to astrology, medicine, and other sciences (Costello 1993, 2003, Sulavan and Costello 1994, 1996). They are animists, and are the only ethnic group in Laos that, in the past, conducted human sacrifices. The whole fabric of Katu society is intermeshed with the environment. The Katu people believe that they must live in harmony with the world around them—other people, animals, birds, trees, stones, water, traditions, and their many spirits. When this harmony is disrupted by the breaking of taboos and traditions, which displeases the spirits, actions have to be initiated to restore the equilibrium with their traditions and the spirits.

Rice is the staple food of the Katu and they have always preferred glutinous rice, consuming nonglutinous rice only when glutinous rice is unavailable. When rice cultivation is undertaken in the traditional swidden upland systems, many traditions and beliefs must be strictly adhered to to ensure good yields, but also in the interests of maintaining the equilibrium between the people and the many factors that the Katu believe influence their daily lives. All Katu traditions, beliefs, and taboos are passed down orally, mainly by the male elders of a village, although less important ones may be passed down by the head of a household. This chapter describes some of the important traditions, beliefs, and taboos that govern how rice is cropped, together with other traditions and beliefs in which rice plays a significant role.

Origins of the Katu

The Katu talk about their origins in Laos in ancient times when the Mon-Khmer people were called Koom (later called Kroom) and had two leaders called Kunmeng and Kunchuong. During that time, the Lao (then called Lava) and Koom people both lived in the lowlands. However, fighting erupted between the two groups of people in which many villages were destroyed in large fires. The Koom (Katu) subsequently fled to the mountains, taking with them their written records on animal skins. The Katu maintain harmony in society through the principle of dominance and compliance, referred to idiomatically as "fire" and "water." In their historical conflict, they refer to the Lava (Lao) taking the part of "fire," while the Koom took the part of "water" (Sulavan et al 1995). To this day, if a group or individual takes the dominant side (fire), the other must be compliant like water. The Katu in Vietnam also believe that their ancestors lived in coastal areas but were driven into the mountains by lowlanders.

Rice cultivation by the Katu

Traditionally, for centuries, the Katu in both Laos and Vietnam practiced swidden cultivation of rainfed upland rice in steep mountainous areas such as those found in Kalum District of Sekong Province in southern Laos (Sulavan and Costello 1994). The traditional swidden can be up to 3 hectares in area for each extended Katu family, and is generally in areas whose fertility is reflected by the presence of large trees. In addition, each extended family will often have a second smaller swidden closer to the village, where smaller trees indicate a prior history of earlier swiddens. The Katu villages are usually located near rivers, whereas the swidden fields may be up to 3 km from the village, depending on the population pressure and earlier history of swiddening. In Kalum District of Sekong Province, the Katu practice swidden cultivation on the banks of the Sekong River, and in areas near the Vietnamese border. The usual practice is to cultivate a field for 2 years before abandoning it. However, in steeper areas (near the Asaap, Trool, Arnge, and Arngoop rivers in the same province), cropping takes place for only 1 year before the fields are abandoned to allow regeneration under a period of fallow. The fallow period can be up to 25 years in duration. Unlike in much of northern Laos, where the period of the traditional fallows has declined to less than 5 years (Roder et al 1995), the Katu have generally been able to continue to maintain long fallow periods because of their isolation.

In northern parts of Kalum District and also near the Paai River in the same district, where there is flatter ground, wet-rice cultivation and dry-seeded lowland rice cultivation are practiced. In areas of southern Dak Chung District in Sekong Province, the Katu have developed four cropping programs—swiddens, wet rice, permanent dry rice, and gardens. The dry-rice cultivation system of the Katu does not require the use of buffalo or ploughs (both of which are required for wet-rice cropping and which are relatively uncommon in areas that the Katu have traditionally inhabited). Permanent dry-rice fields have been cultivated for generations at the edge of a village, or on flat ground far from a village. In these systems, water is diverted from a waterfall or river to the fields through a series of interconnected bamboo pipes, which can stretch for more than a kilometer, or through hand-dug channels. Another method is to construct a series of terraces in the field, in which the water flows from the top to the lower terraces. In the districts of Thong Vaai and Laman of Sekong Province, where the Katu have resettled in lowland areas in accordance with government policy since the early 1970s, the Katu have more diverse cropping practices. In addition to increased wet-rice cultivation and permanent dry-rice cultivation, they are increasingly involved in coffee production and the cultivation of alternative cash crops such as peanut.

Maintaining harmony with the spirits and swidden rice cultivation

The Katu beliefs and relationships with their many spirits are closely bound up with, and reflected in, the way they undertake rice cultivation in their traditional swidden production systems (Costello 2003, Sulavan and Costello 1994). Maintaining a good relationship with the spirits near rice fields is essential for the harmony of the whole Katu society. This is regarded as being more important than having good crops. Because the traditional rice fields are deep in the forest where many spirits dwell, the Katu are very careful about the way they conduct every aspect of work related to their fields, knowing that they enter the domain of the spirits, who will cause sickness if offended. The people must appease three groups of spirits: (1) the *dyaang* that dwell in the forest, trees, water, and villages, and watch over people and provide for them; if the Katu people do not make sacrifices to them, they do not give good crops or health; (2) the *saq*, which are the local spirits of individual trees, water, and mountains; and (3) the *brau* local spirits and *brau* spirits of the dead, which become displeased when people go near them in the forest. All these spirits, when displeased through the breaking of established taboos, are believed to make people sick by capturing their soul from the top of their head. Animal blood sacrifices are required to appease offended spirits and restore to health persons who have been made ill by displeasing.

Rituals for choosing land for a swidden

Before deciding on a section of forest for a swidden, the Katu must make sure that the *dyaang* spirits are happy for them to work that section (Sulavan and Costello

1994). They clear a small area, about 5 by 20 meters, on which they construct two bamboo arches. Then they dip unbroken kernels of long husked rice into water and ask the spirits not to let the rice kernels break. If they break, the Katu will not make that section of land into a rice field. Following the selection of a piece of land that has not brought the disfavor of the spirits, then they make signs and plant them every 10 meters in the field to claim the land, calling on the *dyaang* spirits to allow them to clear that land. They ask the *dyaang* and *saq* local spirits to give them good dreams. That night, if they dream a good dream, they continue to clear the field. However, if they have a bad dream, they abandon that section of land, afraid that the spirits would capture their souls and make them sick.

The Katu are very careful when clearing a firebreak around a swidden because they are afraid of the fire spreading and burning the forest where there are spirit houses built by the Katu to honor the spirits of the forest, *saq* local spirits in trees, and *dyaang* spirits. Also, the Katu want to prevent the possibility of the fire spreading to the village and the storage houses especially built for the rice at the edge of the village. Under customary law, the burning of other people's property results in a large fine being levied, while offending the spirits in the forest would result in the spirits making the person sick, thereby requiring a sacrifice to be made to restore that person's health.

Taboos associated with the preparation and burning of swidden fields

Burning felled trees for rice swiddens is dangerous work that takes 3 months to complete and is undertaken in the period immediately before the onset of the wet-season rains (Sulavan and Costello 1994). It is taboo to visit other villages during this period, for to do so may result in the breaking of taboos or traditions, which could result in the spirits giving sickness or poor crops. When the people are clearing their fields in preparation for cropping, they are careful to avoid all potential accidents. If a tree should happen to fall on someone, it is regarded as a bad omen and that person must abandon that particular field.

The Katu are continually afraid of burning *dyaang, saq*, and *brau* spirits in the forest. They also have to please *dyaang Abom*, the spirit of the weather, and *dyaang Apool*, who gives good crops. If people have bad dreams during the burning season, they have to appease the spirits they have dreamed about, and they would be afraid to undertake any burning on the following day. They also must be careful that the fire does not spread to other parts of the forest where spirits dwell, and where people have constructed shrines to the *saq* and *brau* spirits, where they make regular offerings. The Katu also observe many other taboos in order to avoid bad luck and the displeasure of the spirits. On the days they burn fields, it is taboo for visitors to enter a house or village where people are burning because they are afraid that, if the visitors travel a long way, the fire will also spread a long way. Any visitors who have entered a village cannot leave during the days of burning.

Following the completion of the burning phase of preparation of the rice fields, certain rituals must be followed to appease the *dyaang* spirits of the sky and the ground, who may have been harmed by the fire. A wood pile is made and fenced in, and a ritual appeasement of the spirits is made by one person. Every household in the village then brings an iron pot stand and scatters rice, calling on the spirits, begging for favor, and worshipping them. Each household also brings a bamboo tube of steamed glutinous rice that is offered to the *dyaang Apool* spirit to eat. Then the people also eat. One person performs a ritual to *dyaang Apool*. This person pours water on a sample of rice and the people wait to see if the rice swells; if it does, it is regarded as a sign that there will be a good rice crop.

Rituals associated with planting the rice crop

When the Katu finish planting the rice crop, they shout three times, saying, "We are relieved and happy because the work is finished" (Sulavan and Costello 1994). They call on the rice to be relieved and happy and not to become twisted but to sprout well. The whole village then holds a ritual to the spirits, the ritual being called "the ceremony for blessing the fields." People go to the fields, taking with them bamboo tubes of rice fish, and stay in shelters in their rice fields for 10 days. During this time, they make bamboo arches and wooden images of the various *dyaang* spirits, including the spirits of the ground, the forest, and the water. They conduct the same ritual for each spirit, holding the bamboo arch in the left hand, then hitting it on a tree stump while saying to the spirits, "Everything bad avoid us, go away. You spirits who stay in the fields and do not allow the rice to be good, go away." Then they hold the bamboo arch in the right hand and say to the spirits, "Give good corn and rice, do not allow people to be sick. Let people be kindhearted and speak soft words with people and with the rice and corn."

After completion of planting, there is also a ritual to the *dyaang Apool* spirit of corn and rice, called "the ceremony for blessing the village." The whole village catches fish, which they steam in bamboo tubes, and each household puts one tube of glutinous rice inside the communal house for men. The villagers call on the spirit *Apool* to give the village a comfortable life with lots of rice, corn, animals, and riches. Then they cut a piece of bamboo with hanging fronds and dip it into water on a dish. The bamboo is then held in the left hand and shaken, while calling on *Apool* to "Give us everything good to use." The bamboo is then held in the right hand, dipped in water, shaken, and thrown. If the bamboo sticks to something, this is regarded as a good omen and indicates that the spirits are pleased. The people then call out three times, split the tubes of fish and glutinous rice, and divide them among the whole village. They then call on the leaders and elders of the village to eat and drink *phardiin* alcohol together.

Taboos associated with the period of cropping

The Katu have many taboos during the months when they do cultivation work (Costello 2003, Sulavan and Costello 1994). If someone in a village dies while the rice is growing, it is taboo to work in the fields because it is believed that the rice may also die. This taboo applies for 2 to 3 days after the death of a baby, and for 4 days after the death of an adult. Areas in the forest that are taboo are marked with signs—small trees placed in the walking paths. Taboos are marked near graves, spirit shrines, and sacred areas where spirits dwell so that people will not go near them. When a person disobeys an important tradition or goes near a taboo sign, that person is fined. The fine may be paid with a person given as a permanent servant, or through a payment in kind, such as a water buffalo or pig. A person who does not pay a fine can be killed, thereby showing the importance the Katu place on maintaining harmony with the spirits in the forest where the rice fields are.

Rituals for harvesting

Before beginning harvesting of rice, the Katu observe taboos and traditions to ensure that the spirit of the rice, called the "mother of the rice," will return from the fields to the village, and remain there at the end of the harvest. They do not want her to flee from the fields. On the day the rice harvest is to commence, each family goes to the rice field, taking with them a chicken, a bracelet, a shirt, and a belt to perform a ceremony and offer the clothing items to the spirit of rice to wear. In the field, four rice stalks are bound together, stood up, and offered to the rice spirit. One "back" basket of rice is then harvested and carried back to the village, where the chicken is cleaned and boiled. The shirt is hung up in the top corner of the house. The family then offers the chicken to the spirit of the rice to eat when she comes. There are also taboos to be observed during harvesting. On the first day of harvesting, the people do not bathe and it is taboo for them to look at pregnant women. During the harvest period, it is taboo to kill animals, curse, or hit children. The people cannot collect or work with rice kernels that have fallen or been dropped because they believe that the rice's soul has fled from such rice.

With the end of the harvest, the villagers bring the spirit of the rice back to the village. First, they cut the panicles off the rice stalks they had stacked before the start of the harvest, and return them to the village while at the same time calling on the soul of the rice and the souls of people to also return to the village. These rice panicles are then inserted into the rest of the harvested rice panicles, which are held in large woven baskets in rice stores at the edge of the village. The bracelet that was also offered to the "spirit of rice" at the beginning of the harvest, together with the clothing items that formed part of the offering, is also placed with the rice panicles in the rice store, while at the same time asking that the "spirit of rice" remain with the rice in the store. After that, the whole village holds a ceremony to celebrate the end of the harvest. Each household dries its rice and pounds it. The people dip glutinous rice in water, stir in sesame seeds, and steam it. When it is cooked, they pound it to make rice cakes for 1 or 2 days. They eat one cake in the village and carry the rest to relatives in other villages. All the rice cakes are stored in the men's communal house. They offer the rice cakes to the *dyaang Apool* spirit, then divide them among all the people according to households. Now it is not taboo any more to talk about the harvest, and they are able to visit relatives.

Rituals to restore harmony

All sickness is a result of disharmony with the spirits and is caused when people break traditions or taboos. Harmonious social relationships are very important in Katu society, and breakdowns in relationships between individuals or villages cause disharmony, resulting in sickness. Harmony between people and with the spirits needs to be restored (Costello 2003, Sulavan and Costello 1994, Sulavan et al 1995). A dispute in words or actions between people can only be put right with a ritual to restore a right relationship with the spirits. People call on the shamaness to determine the cause of the sickness. It may have been caused by a wrong committed in trying to meet social obligations. In Katu society, a shamaness is important because she is able to communicate with the various spirits to ascertain which taboo or tradition has been broken, which spirit has been offended, and what fine or sacrifice is needed to appease that spirit. The Katu can have up to three shamanesses in one village. They are usually middle-aged women whom the *dyaang* spirits have possessed so that they can act as intermediaries between people and the spirits. A shamaness performs rituals and divination, and calls on the offended spirits to return the soul of the sick person.

The tradition of visiting relatives

The tradition of visiting relatives is a significant aspect of social interaction in Katu society involving obligations to certain relatives (Costello 2003, Sulavan and Costello 1994, Sulavan et al 1995). Not to carry out the required exchange of gifts is a wrong because the tradition has been broken, causing disharmony resulting in sickness, so a right relationship with the spirits needs to be restored. The shamaness is consulted and tells the people how to restore a right relationship with the *dyaang* spirits and with other people. It is important to maintain the tradition of visiting because, if there is a problem later between the two villages, harmony cannot be restored if the tradition has been broken.

During the season of rice cultivation, it is taboo to visit relatives in other villages to exchange gifts, so it is important for the Katu to be able to visit relatives at the end of the harvest. They catch fish, prepare rice and pigs, and hunt wild animals in order to have food to take to relatives. The visits are also a time to look for wives. Parents who will visit their married children prepare glutinous rice by steaming it in a basket, then wrapping it in packets in banana leaves, preparing 20 or 30 packets. Fish and frogs are also wrapped in packets. There are strict rules about the kind of food that can be given to each relative; for example, parents of girls must eat animals with four feet. Men give gifts to female relatives and women give gifts to male relatives. The people carry unhusked rice and corn, which are left outside the village they are visiting, to appease the local village spirits. People feel bad if they do not have enough food or alcohol to give to visitors.

Divination using rice

Rice also plays a significant role in divination (Costello 2003, Sulavan and Costello 1994, Sulavan et al 1995). When a person is sick, the shamaness tries to find out which taboo or tradition has been broken, and which spirit is displeased and has caused the sickness. Some of the associated rituals are performed with rice. In one such ritual, the household prepares husked rice and incense on a dish, with a sword, a bush knife, some money, and a smoking pipe on a separate tray. The incense is burned and the shamaness is asked to interpret and intercede. She picks up four or five rice seeds and holds them above her head, saying to the spirits, "You *dyaang* spirits come down and see the sick person. Which *brau* or *saq* local spirit caused the sickness?" Then she places rice on the palm of her hand and calls on the *dyaang* spirits to come down and see the rice. She lifts her hand and waits for the spirits to act. If the rice does not fall, she lifts her hand again and asks if different spirits caused the sickness. She keeps doing this until the rice falls, thereby identifying which spirits are displeased. Then she tells the relatives of the sick person which animal needs to be sacrificed to appease the spirits.

Another ritual involves the use of rice and a knife or sword. A shaman performs this ritual. First, he goes into the house and burns incense. He takes some rice and shakes it above his head, saying to the *dyaang* spirits, "Come down on me the leader and see which *saq* local spirit or *brau* spirit made this person sick. The *dyaang* spirits come down onto the shaman and then he holds the sword and divines to determine which spirits made the person sick. He calls out, "You *dyaang* spirits, grab the sword and make it stand up so it will not fall." He jabs the sword into the dish of rice and calls on *saq* spirits of trees to make the sword stand up on its own. He then waits and, if the sword stands on its own, those spirits are identified as having caused the sickness. If the sword falls, he calls on a different spirit. He continues, calling on various local *saq* and *brau* spirits until the sword stands to allow the identification of the cause of the illness.

Impact of changes on rice-related traditions and beliefs

Because the cohesion of Katu society is based on harmony with the spirits in the environment, any change to traditions and beliefs that alters this harmony disrupts the delicate intermeshing between people and the spirits (Costello 2003). The traditional beliefs of the Katu on which the harmony between the people and spirits is maintained have been based on how their lives have evolved in mountainous areas over several centuries. In upland areas where the Katu practice wet-rice and dry-rice cropping, they do not need to perform rituals to the spirits of the forest, but they still need to call on spirits to give them good crops, so they carry out fewer rituals. The relatively recent movement of some of the Katu to lowland areas of Laos has resulted in these groups not knowing how to react to different spirits that dwell in lowland areas. They generally feel strange in the new lowland abode; this is sometimes exacerbated by the gradual loss of their own language as they mix with other major language and ethnic groups. Sometimes, the vital tradition of visiting relatives to exchange gifts cannot be carried out because relatives have become separated, with some living in the lowlands and some still in the highlands. This worries the Katu because it is believed to reflect disharmony between people, as well as displeasing the spirits. These changes are regarded as a gradual erosion of social cohesion, leading to the breakdown of their harmonious society, which is a harmony maintained by pleasing the spirits by following taboos and traditions.

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Notes

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CHAPTER 9
Diversity within the traditional rice varieties of Laos

S. Appa Rao, J.M. Schiller, C. Bounphanousay, and M.T. Jackson

The development of improved rice varieties in most countries of Asia has generally resulted in their widespread adoption by farmers, with the replacement of traditional varieties, leading to an erosion of the rice germplasm base in these countries. In most Asian countries, this change took place during the 1970s and 1980s. In Laos, however, the period of the Green Revolution had little impact on the way rice was cultivated and, as late as 1990, more than 90% of lowland rice cultivation in the country was still based on the use of traditional varieties. In the rainfed upland environment, almost 100% of production was based on the use of traditional varieties (Schiller et al 2001). Change in rice production in Laos started about 1995, following the 1993 release of the first of a series of improved varieties developed within the country as part of the development of a national rice research program. Anticipating that Lao farmers would quickly adopt these improved varieties, in combination with the adoption of other technical recommendations capable of bringing about a substantial increase in yield, a program to assemble a representative collection of the traditional rice germplasm for long-term conservation began in mid-1995. In a collaborative program with the Lao Ministry of Agriculture and Forestry, the International Rice Research Institute (IRRI) jointly explored most rice-growing areas of the country from 1995 to early 2000. During this period, a total of 13,192 samples of cultivated rice were collected, together with 237 samples of six wild rice species of the genus *Oryza*. This chapter primarily describes the classification of the traditional rice germplasm that was collected and that is now being preserved at the Genetic Resources Center (GRC) of IRRI, as well as being used for the further improvement of varieties being developed by the national rice research program of Laos. More detailed information on the collections is available in records maintained by the GRC, as well as in detailed reports of the collecting missions (Appa Rao et al 1997b, 2002a,b,c).

Laos and the origin of Asian cultivated rice

The genus *Oryza*, to which cultivated rice belongs, has 20 wild and two cultivated species. Of the 20 wild species of *Oryza*, six are found in Laos (Appa Rao et al 1998, Kuroda et al, Chapter 15). Among these, the wild progenitor, *O. rufipogon,* of Asian rice, *O. sativa,* is found throughout the country and is particularly abundant in the central and southern agricultural regions. Spontaneous interspecific hybrids between the wild and cultivated forms of rice, showing continuous variation from wild to cultivated forms, have also been observed in Laos (Appa Rao et al 1997a, 1998, 2000d). Pottery shards bearing the imprints of the grains and husks of *O. sativa* and that date to at least 2000 B.C. have been recorded at archaeological sites in northeast Thailand, an area with geographic and historic continuity with modern-day Laos (Solheim 1972, White 1997). It is generally accepted that Laos lies within the general area that is accepted as the area of origin of Asian rice, *O. sativa* (Chang 1976, Oka 1988, Khush 1997).

Rice germplasm collected before 1995

Recognizing the diversity and importance of the traditional rice varieties in Laos, a number of rice germplasm collecting missions were undertaken in Laos from 1970 to 1990, being variously supported by USAID, Russia, Japan, and other agencies/ countries (Schiller et al 2001, Inthapanya et al 1997). From 1991 to 1994, a further collection of more than 1,000 samples was made in the upland environment in six provinces of the northern agricultural region of the country in a joint initiative between the Lao Ministry of Agriculture and Forestry (MAF) and a Swiss-supported national rice research program activity implemented through IRRI (Roder et al 1996). However, the passport information on the samples from for these collecting missions was generally incomplete. Further, because of the lack of appropriate storage facilities in the country during that time, the collections were unable to be maintained without annual rejuvenation and, unfortunately, these collections are no longer available.

Rice germplasm collected from 1995 to 2000

The systematic collecting undertaken from 1995 to 2000 was part of a project to collect and conserve the biodiversity of the rice gene pool in 22 countries in South and Southeast Asia, sub-Saharan Africa, and Central America (IRRI 1994). This was carried out with financial support from the Swiss Agency for Development and Cooperation (SDC).

Collection strategy

MAF and IRRI jointly undertook rice germplasm collecting throughout the country. In consultation with the Provincial Agriculture and Forestry Offices (PAFOs) for all provinces of the country, a 5-year collecting program was prepared and agreed upon. The level of genetic erosion occurring in a particular area (as reflected by the rate of adoption of improved varieties), the availability of local support, safety considerations, and accessibility of target areas formed the basis for selecting priority areas for collecting. From October 1995 to April 2000, all 136 districts in 17 provinces and the Saysomboun Special Economic Region (Fig. 1) were explored.

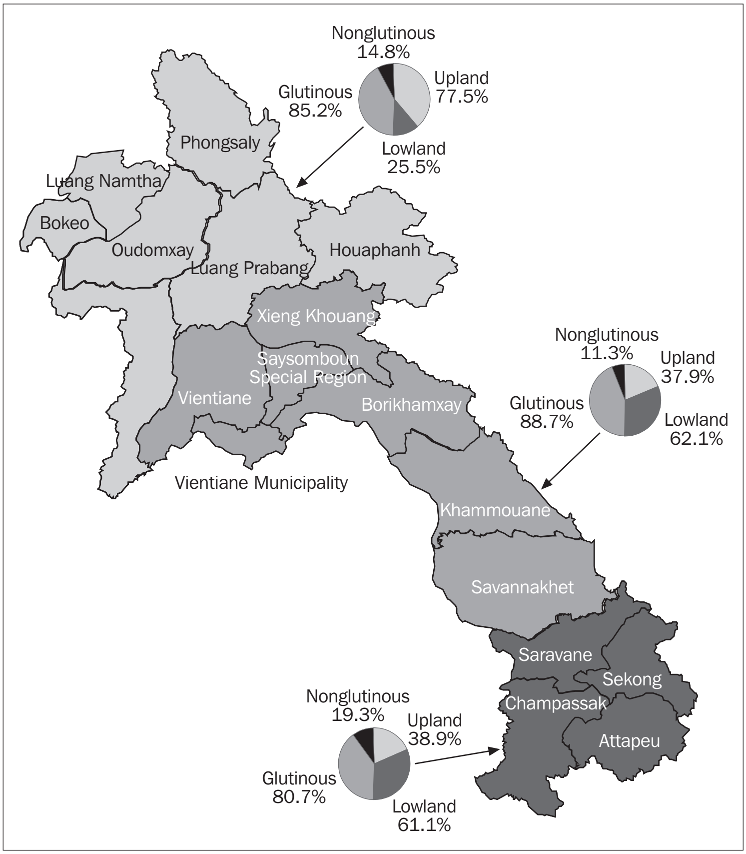

Fig. 1. Rice samples collected from the upland and lowland environments, with glutinous and nonglutinous endosperm, for the agricultural regions of Laos.

Collection procedure

The objective was to collect enough material to represent the maximum diversity with a minimum number of samples. To achieve this, the goal was to collect at least one sample of each variety from each district. While recognizing that farmers sometimes call different varieties by the same name, it was also acknowledged from the outset that different names are used in different areas for the same variety. Collecting started at crop maturity (about 1 week before harvest) and continued until threshing. Though the goal was to obtain most of the samples directly from farmers' fields before harvest (September-December), in areas inaccessible during the wet season, samples were obtained after harvest from the threshing floor or farmers' grain stores, from January to April. Generally, a greater proportion of upland varieties was collected after harvest because of difficulties of access during the growing season.

The collections were made by officials attached to the District Agriculture and Forestry Offices (DAFOs), supported by staff of the Lao national rice research program and an IRRI germplasm specialist. The district-level staff usually had a good knowledge of local farming practices and could communicate effectively with the farmers. The germplasm samples collected included landrace varieties, slightly improved varieties, intermediate weedy forms that occurred as spontaneous hybrids between wild and cultivated forms, and wild species of the genus *Oryza*. Collecting was done only from wet-season cropping areas, as, at the time of collecting, only improved varieties were being grown in the dry-season irrigated environment.

Sampling technique

The sampling technique depended heavily on the participation of farmers, and was a compromise between collecting individual plants from each field as separate samples and collecting a bulk sample of different types found in a single field. The method involved collecting each distinctive phenotype identified by the farmer, together with any other distinct type(s) identified by the collectors. For example, if five distinct types were identified in a field, all five types were collected as separate samples to facilitate conservation and subsequent characterization and use. When sampling from relatively uniform fields, only one random bulk sample was collected. However, when rare phenotypes were encountered, they were kept as separate samples. In general, an attempt was made to retain the landrace structure in the samples.

Although the goal was to collect one sample of each variety, for a number of reasons, several samples were sometimes collected for certain varieties. As collecting was being undertaken simultaneously in several districts, extension officers collected whatever varieties they found in their respective districts. Hence, duplicate samples (based on variety names) were sometimes collected, with their frequency of collection reflecting their relative abundance in an area. Though some duplicates appeared uniform in relation to grain characteristics, considerable variation was sometimes observed in some duplicate samples, particularly when these samples came from areas with differences in elevation. It is therefore acknowledged that, within the 3,169 different variety names assigned by farmers and recorded during collecting (see Chapter 10), some varietal names represent duplicate samples, whereas, at the same time, many samples that appear as duplicates may in fact be genuinely different varieties.

Apart from some localized areas for which accessibility was restricted, the collection of 13,192 samples of cultivated rice made from 1995 to 2000 is regarded as being representative of the rice genetic resource base of the whole of Laos. It is also regarded as one of the most comprehensive collections of the traditional rice germplasm made for conservation and use, for any single country, and by far the most comprehensive collection made for any country the approximate size of Laos.

Classification of the rice germplasm samples collected from 1995 to 2000

At the time of collecting samples from the farmers, information for up to 36 descriptors was obtained to provide the passport information for each sample, based on guidelines of the IRRI Genetic Resources Center. These descriptors were modified to suit the conditions of Laos by including endosperm type, aroma, and other traits

Table 1. Classification of germplasm samples based on region, ecosystem, and endosperm type.

Region	Total samples		Ecosystem				Endosperm type			
			Lowland		Upland		Glutinous		Nonglutinous	
	No.	%	No.	%	No.	%	No.	%	No.	%
Central	4,625	35.1	2,868	49.3	1,757	23.8	4,102	36.4	523	27.3
Northern	5,915	44.8	1,332	22.9	4,583	62.2	5,037	44.7	878	45.9
Southern	2,652	20.1	1,621	27.8	1,031	14.0	2,140	19.0	512	26.8
Total	13,192	100.0	5,821	100.0	7,371	100.0	11,279	100.0	1,913	100.0

unique to Laos. The passport information collected was largely based on the information provided by the farmers themselves. With the passport information collected, the germplasm samples were classified according to origin (province and district), ecosystem (lowland or upland), endosperm type (glutinous or nonglutinous), and maturity time (early, medium, or late).

The numbers of samples collected from the northern, central, and southern regions were 5,915 (44.8%), 4,625 (35.1%), and 2,652 (20.1%), respectively (Table 1). More samples (55.9%) were collected from the upland environment than from lowland sites (44.1%). Most of the samples (85.5%) had glutinous endosperm. The highest proportion of upland samples was collected from the northern agricultural region (77.5%), whereas about 38% of the samples came from the upland environment in the central and southern regions (Fig. 1). In all three regions, samples with glutinous (waxy) endosperm accounted for the majority of those collected (Fig. 1), with 85.5% of the total samples collected being in this category (Table 1).

The province from which the largest number of samples was collected was Luang Prabang in the northern agricultural region, with 1,243 samples (9.4% of the total), of which 875 (70.4%) were collected from the upland environment (Table 2). Other provinces from which large numbers of samples were collected in the upland environment were Oudomxay (675) and Sayabouly (632). Provinces for which the largest numbers of samples were collected in the lowland environment were Savannakhet (759) and Khammouane (671) in the central agricultural region and Champassak (677) in the southern region.

Diversity in the traditional rice varieties

Diversity of variety names

For the total of 13,192 samples of traditional varieties collected from 1995 to 2000, variety names were recorded for all but 6% (789). The inability to record variety names for these samples reflected the great ethnic diversity that exists in the areas where collections were made (Laos has 48 recognized ethnic groups, ADB 2001), and associated difficulties in translating some of the variety names of some ethnic groups

Table 2. Classification of germplasm samples based on region, province, ecosystem, endosperm type, and maturity.[a]

Region	Province name	Total	Lowland environment								Upland environment							
			Nonglutinous				Glutinous				Nonglutinous				Glutinous			
			E	M	L	Total	E	M	L	Total	E	M	L	Total	E	M	L	Total
Central	Borikhamxay (BK)	594	5	16	4	25	59	151	35	245	7	10	4	21	186	89	28	303
Central	Khammouane (KM)	867	9	30	15	54	147	329	141	617	1	2	3	6	101	62	27	190
Central	Savannakhet (SK)	989	5	36	8	49	130	401	178	709	10	6	2	18	97	65	51	213
Central	Vientiane Municipality (VM)	486	6	35	17	58	115	158	23	296	4	5	0	9	51	66	6	123
Central	Vientiane Province (VP)	787	1	15	15	31	71	183	104	358	14	18	2	34	181	165	18	364
Central	Saysomboun (XS)	342	5	18	5	28	25	62	22	109	11	36	12	59	36	94	16	146
Central	Xieng Khouang (XK)	560	6	25	18	49	47	83	110	240	22	27	33	82	47	107	35	189
Northern	Bokeo (BO)	686	16	10	13	39	34	68	62	164	17	20	39	76	98	161	148	407
Northern	Houaphanh (HP)	631	1	4	12	17	9	57	81	147		32	25	57	58	215	137	410
Northern	Luang Namtha (LN)	858	16	20	14	50	25	76	71	172	12	55	58	125	70	228	213	511
Northern	Luang Prabang (LP)	1,244	2	17	8	27	39	89	50	178	46	66	50	162	309	380	188	877
Northern	Oudomxay (OD)	848	7	5	5	17	11	27	39	77	20	18	42	80	177	201	296	674
Northern	Phongsaly (PL)	664	10	16	20	46	20	75	24	119	11	30	42	83	68	197	151	416
Northern	Sayabouly (SB)	984	6	13	8	27	66	108	78	252	14	23	35	72	127	311	195	633
Southern	Attapeu (AT)	640	20	62	38	120	56	149	72	277	8	26	44	78	67	55	43	165
Southern	Champassak (CS)	842	25	42	12	79	161	364	73	598	2	13	25	40	42	62	21	125
Southern	Saravane (SV)	774	2	24	8	34	90	215	84	389	9	22	12	43	100	146	62	308
Southern	Sekong (SG)	396	4	13	12	29	10	70	15	95	5	42	42	89	59	92	32	183
	Total	13,192				779				5,042				1,134				6,237

[a]E = early maturity, M = medium maturity, L = late maturity.
Source: Appa Rao et al (2002b).

Table 3. Distribution of distinct variety names in regions of Laos.

Region	Total samples collected	Number of samples with names	Number of names
Northern	5,915	5,613	1,120
Central	4,625	4,321	613
Southern	2,652	2,469	583
Total	13,192	12,403	2,316

into the Lao language (and subsequently into English). In addition, some farmers, particularly younger ones, did not know the variety names. Of the 12,403 samples for which variety names were recorded, ethnic names were recorded for 1,414 samples, which were later translated into Lao and English, whereas ethnic names for another 151 samples that were recorded were unable to be translated.

The largest number of names (1,120) was recorded in the northern agricultural region, and least (583) in the southern agricultural region (Table 3). A detailed analysis of the naming of the varieties is reported by Appa Rao et al (2002c) and in Chapter 10.

There was usually greater diversity of names in provinces with the larger areas of upland rice cultivation, reflecting the greater ethnic diversity in such areas, together with the associated diversity of rice preferences with different food quality attributes (see Chapter 10). The northern province of Luang Prabang, which has the largest area of upland rice of any single province in the country, had the highest number (462) of variety names. Although fewer individual varieties were collected from some provinces in the southern agricultural region, several of these provinces had high numbers of unique varieties (a variety was classified as unique to a province when it was recorded as having been collected only in that province). In the southern province of Attapeu, 62.2% of the samples collected and names were classified as being unique. This province, together with others with high levels of unique varieties, is remote and has a high level of ethnic diversity in the population. As might be expected, the number of unique variety names recorded in the lowland rice-growing provinces in the Mekong River Valley was generally lower than in other areas of the country. This reflected the fact that there is generally less ethnic diversity within the population in these areas, together with greater opportunities for variety exchange across provincial boundaries, and greater adoption of introduced varieties in the period before the collecting missions.

Diversity within a population

Traditional lowland varieties are relatively more uniform in terms of maturity, plant height, and grain and panicle characteristics than upland varieties. Upland farmers usually grow upland rice crops, which contain a mixture of several morphological

Table 4. Classification of germplasm samples based on growing environments and maturity.

Ecosystem	Total samples	Maturity[a]: no. (%)		
		Early	Medium	Late
Upland	7,371	2,087 (28.3)	3,147 (42.7)	2,137 (29.0)
Lowland[b]	5,821	1,261 (21.7)	3,066 (52.7)	1,494 (25.7)
Total	13,192	3,348 (25.4)	6,213 (47.1)	3,631 (27.5)

[a]Percentages represent comparisons between maturity groupings within each growing environment. [b]Represents the wet-season lowland environment (mainly rainfed) as the dry-season irrigated environment is planted only to improved varieties.

phenotypes, with variation in flowering, plant height, and panicle and grain characteristics (Photo 9.1). This difference between upland and lowland variety characteristics may be related to the differences in agroclimatic conditions, together with cultural differences and different seed selection practices in the different growing environments. Greater diversity in upland varieties is also probably partly due to the deliberate mixing of several phenotypes, with the hope that some types will perform better in the year-to-year uncertainty of growing conditions that are a feature of the upland environment. In one instance, where collecting was being undertaken in an upland field in the southern province of Champassak, 11 different phenotypes were found to be growing together, with differences in the shape and size of panicles, and in the pigmentation of the grain. In the northern province of Luang Namtha, eight different phenotypes were identified in a single upland field, with differences in the shape and size of panicles, and in the pigmentation of the grain.

Diversity for morphological characters

Landrace cultivars grown in both rainfed upland and lowland ecosystems differ for a range of characters, including crop duration; plant height; tillering; pigmentation on various plant parts; panicle shape and size; grain shape, size, and color; and cooking and eating qualities. The latter represent varietal preferences for different food preparations. A high level of variation was observed for brown rice color, from black to red, and to brown or white. Appa Rao et al in Chapter 12 give a separate description of the "black rice" collected from 1995 to 2000.

Diversity for races

Based on gross morphology of the plant, most upland varieties belong to the javanica group, as they produce thick culms, dark green, long, and wide leaf blades, few but large panicles, and large grain. Most lowland varieties produce narrow and long leaf blades, many thin culms, panicles that are small and numerous, with varying grain size that is typical to the indica race. Only two accessions in the collection belonged to the japonica group, both of which appear to be recent introductions. Intermediate forms between javanica and indica predominate. Most of the morphological characteristics that are generally considered typical for the tropical japonica are classified as the javanica varietal group. Isozyme analysis was done on 318 entries at IRRI-Los Baños using the methods described by Glaszmann (1987). Enzymatic analysis confirmed that more than 90% of the upland accessions belonged to the tropical japonica group (Roder et al 1995). Varieties belonging to this group often have a superior root system when compared with those of the other groups, and should be better adapted to areas, such as the upland growing environments, that experience periodic moisture stress.

Some characters appear to be associated with the particular ethnic groups found in different parts of the country. For example, farmers in Bolikhan District of Borikhamxay Province grow varieties that produce long peduncles, as the practice is to harvest the panicles with a small iron blade and tie them into bundles. Several ethnic groups in predominantly upland areas hand-strip the grain from a standing crop. These varieties have fewer but larger panicles with larger grains that thresh easily to facilitate easy stripping. The lowland Lao, who live near urban areas and along the border with Thailand, grow aromatic varieties because of the market demand and premium paid for high-quality aromatic grain. Some varieties are suited to specific food preparations; for example, the grain of some varieties of *Khao kam* (black rice) is often cooked with coconut milk to provide a sweetened dessert. The variety *Lep nok* (bird's claw), so named on account of the tip of the spikelet being hooked like a claw, is popular in the districts of Khong and Bachiang in Champassak Province, Phouvong District of Attapeu Province, and Khongsedon District of Saravane Province, all of which are in southern Laos, together with Viengxai District of Houaphanh Province in northern Laos. This variety is used to make the popular Lao confectionary crisp called *khao kiap*. The strong preference for such specialized uses of rice contributes to the overall diversity in grain quality attributes. In many situations, farmers grow specific varieties with specific quality attributes for particular food preparations, rather than select types that are specifically adapted to either the short growing season or the dry mountainous environments.

Diversity for ecosystems

Farmers' varieties grown under rainfed lowland and upland environments differ considerably for morphological, physiological, and grain quality attributes. The morphological differences are so great and distinct that it is often possible to differentiate and identify upland rice plants and/or rice grains from lowland plants or grains (Photo 9.2). The main characteristics used to differentiate between the two types are grain size, aroma, tiller number, and stem diameter. According to the farmers' main selection criteria, typical upland varieties are expected to have large but few panicles, strong thick stems, broad thick leaves, early flowering and maturity, and few but larger panicles with large grains. In contrast, lowland varieties often have many thin culms, narrow thin leaf blades, and many but smaller panicles with small to medium-sized grain.

Farmers normally do not grow upland varieties under lowland conditions and vice versa, unless compelled to do so on account of a lack of sufficient seed of appropriate varieties at sowing time. However, some varieties can be grown in both upland and lowland environments. Variety *Hai na (*upland-lowland) collected in Phoukhout District of Xieng Khouang Province, Xai and Beng districts of Oudomxay, and Fuang District of Vientiane Province is considered suitable for cropping in both environments. Another variety, *Hai na suan* (upland, lowland, garden), is popular in parts of Xieng Khouang Province and, although mainly grown under upland conditions, is also regarded as being suitable for the lowland environment. Usually, this variety is grown on elevated but level land, and is dibble-planted in the usual manner for upland rice. After 3 to 5 weeks, depending on the rainfall, excess seedlings are uprooted and planted in lowlands. Variety *Dok tiaw* (tiaw flower) grown in Saythany District of Vientiane Municipality is mainly grown in the lowland environment but can also be grown in upland conditions. Another variety, *Phae deng* (multi-tillering, red)*,* also found in Saythany District, is normally an upland variety but is also considered suitable for lowland conditions. These varieties are of considerable evolutionary significance as they may represent the transition of the adaptation of varieties from lowland to upland conditions, or vice versa. They may have also developed as a result of spontaneous hybridization between upland and lowland varieties, both of which are sometimes grown in close proximity.

Diversity for crop maturity time

Lao farmers allocate varieties to particular fields based mainly on crop duration and likely duration of available soil moisture. Care needs to be taken in the interpretation of maturity times between environments, for the definition of early, medium, and late varieties by upland farmers can differ from that of farmers in the lowland environment. The information recorded and the classification summarized in Tables 1 and 3 are based on the classification of individual samples provided by farmers who donated seed samples. It is generally accepted that varieties in the rainfed upland environment mature earlier than varieties in the wet-season lowland environment. Although a variety classified as early maturing might ripen in 90 to 120 days in the uplands, such a variety might in fact be harvested 3 or 4 weeks earlier than a variety classified as early maturing in the lowland environment. Despite the difference in harvest time, the actual time to maturity between the two environments might be similar on account of the earlier planting in the upland situation. Similarly, for late-maturing varieties, in the upland environment they would be harvested sometime in October, whereas, in the lowland environment, late-maturing varieties might not be harvested until late November or early December; however, sowing of late-maturing varieties in uplands would usually be considerably earlier than in lowlands. Generally, all the traditional varieties in each maturity category are photoperiod-sensitive, with the later-maturing varieties being more strongly photoperiod-sensitive than the earlier-maturing varieties.

For samples collected in the rainfed upland environment, 42.7% were classified as being of medium maturity, with approximately equal proportions classified as being early- and late-maturing (28.3% and 29.0%, respectively). For the lowland environment, 52.7% of the samples were classified as being of medium maturity, with a slightly higher proportion of late-maturing relative to early-maturing samples (25.7% and 21.7%, respectively).

Early-maturing varieties in the uplands are generally planted close to households, in low-lying areas or near the foothills of mountain slopes above the valleys, where water accumulates with the first rains. They provide a food source in the period immediately before harvest, when most upland households, in particular, have exhausted their food-grain reserves. In situations where households have significant and chronic rice deficits, early-maturing varieties are sometimes grown in fields that would normally be planted to a medium-maturing variety, the choice of the early-maturing variety being based on the need to obtain grain for consumption as early as possible in the growing season. Harvesting of early varieties often takes place in September, coinciding with the period of heaviest rainfall. After harvesting and threshing, the grain is dried on raised platforms in a shaded location.

Some farmers interviewed planted five different rice varieties. In lowland areas, farmers often grow varieties of different maturity to spread labor requirements, provide stability to offset environmental variation, and produce more. Some farmers interviewed planted five different rice varieties. Early- and medium-maturing varieties are usually grown in the upper parts of terraces where there is a greater likelihood of drought stress immediately after the end of the wet season. Long-duration varieties are mainly grown in low-lying areas on the beds of watercourses or inland valley swamps in areas with variable water levels. These varieties are planted last; they flower at the end of the rainy season (most are photoperiod-sensitive) and mature after more than 145 days. They grow very tall, produce very thick stems and long and broad leaves, are profusely tillering, are synchronous in flowering and maturity, and produce large panicles. The area under late varieties is limited on account of the prevailing low temperatures from December through February in the northern region, which limits crop growth. These varieties usually produce good-quality grain as they mature after November, when the rains stop.

Harvesting methods along with seed selection practices have probably contributed to variety evolution. Lao farmers practice panicle selection and grain stripping, and these stabilize the main seed types and also bring about systematic grouping among off-types. Early-ripening types are harvested as they ripen to secure some grain for consumption in those periods when households have a rice deficit; longer-duration types are left in the field to the gleaners. In this way, over a long period of time, panicle selection might have resulted in the differentiation of varieties into three distinct duration classes.

Diversity for endosperm type

The type of endosperm in the rice grain is related to cooking quality characteristics of rice. Glutinous grains have a higher viscosity than nonglutinous grains when heated, and so this type is popularly called sticky rice. Only after harvest, while drying, does glutinous rice grain become distinguishable from nonglutinous rice. In the overall collection, glutinous samples accounted for 85.5% of the total, reflecting farmer and consumer preference for this type of rice. Overall, 86.6% of lowland and 84.6% of upland samples collected were glutinous (Fig. 1). The relatively higher proportion of nonglutinous types sampled in the northern region is probably a reflection of the presence of significant numbers of farmers belonging to the Hmong and Yao ethnic groups in this region (UNDP 1998); both these ethnic groups consume nonglutinous rather than glutinous rice. Similarly, the greater number of nonglutinous varieties found in the upland environment (1,134 samples) relative to the lowland environment (779) also reflects the fact that the Hmong and Yao ethnic groups are to be found almost exclusively at higher altitudes in the upland environment.

For a few varieties, the endosperm is intermediate between glutinous and nonglutinous forms. Two such varieties are referred to as *Chao kheng* (nonglutinous, hard) and *Khao ma-yeng* (rice watched by a dog). Samples of *Chao kheng* were collected from Long and Nale districts of Luang Namtha Province, Xai District of Oudomxay Province, and Houayxay District of Bokeo Province, all in northern Laos, and also from Atsaphangthong District of Attapeu Province in southern Laos. *Khao ma-yeng,* on the other hand, was collected mainly from provinces in the central and upper southern regions—Vientiane Municipality and the provinces of Borikhamxay and Savannakhet; it was also collected from three districts of Luang Prabang Province. The eating quality of these intermediate types is considered to be so inferior that even a dog does not like to eat them but prefers to sit and look at them (hence the name *Khao ma-yeng* or rice watched by a dog). This type of rice is not usually grown by farmers but is found occasionally among glutinous varieties. Such types are eliminated during the time of seed selection. The occurrence of these intermediate types might be the result of spontaneous crossing between the glutinous and nonglutinous forms. The type *Chao niaw* (nonglutinous sticky rice), though considered as a nonglutinous variety, becomes sticky after cooking. Some varieties have the word *paeng* as part of their name to reflect their floury or powdery endosperm. A study of the amylose and amylopectin content of these varieties could help provide a better understanding of the evolution of sticky rice.

Varietal diversity at the household level

Lowlands

In the wet season, most lowland farmers grow a group of homogeneous stands of several varieties in small plots as a mosaic in the same field. The varieties grown differ for several characters that include grain quality attributes to suit various types of food preparations and maturity duration—early, medium, and late—besides others. Mixtures of two different varieties are sometimes grown to complement one another, but farmers usually try to keep their varieties separate. Lowland farmers, when growing traditional varieties, usually do not grow more than three (although small areas of speciality rice might also be grown in addition to the main varieties). With the adoption of the more recently available improved varieties, fewer varieties are generally being grown by individual households.

Uplands

Upland farmers clearly differentiate among early, medium, and later-maturing varieties and most households plant varieties from each group. This allows them to harvest rice for consumption as early as possible, distribute labor requirements for the harvest, and spread risk (Roder et al 1996). In addition, special varieties are sometimes grown for religious ceremonies, nonglutinous varieties for noodle making, and some varieties suited to making alcoholic beverages. Most upland farmers grow three to five varieties, with each variety showing differences in maturity.

Mixing of varieties

In both the upland and lowland environments, farmers sometimes grow a mixture of varieties in one field. This is more often the case in the upland environment, where a heterogeneous mixture of several varieties is sometimes grown. The purpose of such mixtures is to reduce the potential risks associated with single-variety cropping such as drought, pests, and diseases. The variety mixture usually results in greater yield stability. Although less frequent in the lowland environment, planting of varietal mixtures occasionally does take place. For example, in parts of Kham District in Xieng Khouang, a variety called *Mak pho* (banyan fruit), which has good resistance to lodging but has poor grain quality and is susceptible to gall midge, is mixed with another variety, *Khao bong,* which is susceptible to lodging but has good grain quality, is aromatic, has a high recovery after milling, and is resistant to gall midge. Farmers mix *Mak pho* with *Khao bong* at a ratio of about 35:65; the mix results in a crop that does not lodge and that gives a product with good eating quality. The two varieties are of the same height, mature at the same time, and have glutinous endosperm. However, the seed of the two varieties can be differentiated by the color of the glumes. In each of the three northern provinces of Luang Namtha, Oudomxay, and Houaphanh, some districts have varietal mixtures that are also sometimes grown in the lowlands, with the mixtures being believed to give higher yields and greater yield stability than single-variety crops.

In Pakse District of Champassak in southern Laos, farmers sometimes grow a single variety consisting of two morphologically distinct types. This variety, known as *Pua-mia* (husband-wife), appears to be composed of two isogenic lines that differ only in respect to glume color: one line has purple to brown glumes, while the other has green glumes that turn yellow upon maturity. The lines not only are similar morphologically but also flower and mature at the same time; farmers grow them together as if they constituted a single variety. The two types appear to be identical until the time of maturity, when a change in glume color identifies each line.

Varietal diversity at the community level

Lao farmers live in small community villages, with each village usually being inhabited by a particular ethnic group. However, in some areas, particularly resettlement areas in central and southern Laos, a village sometimes contains more than one ethnic group. Although individual farming households may grow only two or three varieties, at a community level there is often much greater diversity, depending on the region, ecosystem, and ethnic group. In the southern region, most communities grow a minimum of three varieties representing three maturity groups—early, medium, and late. However, some communities in Vientiane Province in the central region were found to be growing up to 10 varieties (Appa Rao et al 1997b). In Khamkeut District of Khammouane in the central region, 19 varieties with varying grain characters were collected from a single village. These varieties included rainfed lowland, rainfed upland, glutinous, and nonglutinous types of varying maturity time. In general, diversity at the community level is greater in the northern region than in the southern and central regions. In a single village in the district of Vieng Kham in Luang Prabang, 18 distinct varieties were recorded as being grown. Generally, variety diversity at the community level is greater in upland environments than in lowland areas. This, in turn, reflects the generally greater diversity of both ethnic groups and growing environments in the more mountainous northern areas of the country than in the main lowland rice-growing areas in the central and southern agricultural regions.

Seed selection procedures

The maintenance of the great diversity of traditional rice varieties found in Laos reflects the seed selection practices that have been developed. These practices are often quite different between the upland and lowland environments, with these differences in turn being reflected in the "within-crop" diversity that exists between these environments.

Upland environment

As upland farmers often grow mixtures of different varieties in the same field, as part of their seed selection process, they deliberately collect panicles representative of all types and keep the mixed population for seed purposes. While some households thresh the panicles and store the seed, others tie the panicles into bundles and store them in this form until planting time in the subsequent year. Another technique sometimes used is to hand-strip the grain from the more attractive panicles separately at the time of stripping panicles for grain purposes. Occasionally, farmers collect a small quantity of seed from the bulk-harvested grain for use as seed. However, specific attention is generally given by upland farmers to the selection of seed to be used for the following season's crop. Differences also exist in the seed selection procedures within the diverse ethnic groups found in the upland environment.

Lowland environment

Most lowland farmers select their most uniform and best fields for the purpose of obtaining seed for the succeeding crop; the area selected for this purpose is usually harvested and threshed separately from that which provides grain for consumption. Often, the part of the crop to be used for seed grain is also harvested after the harvest of the remainder of the crop. Before threshing the seed-grain component of the crop, off-type panicles are usually identified and removed, resulting in a crop with more uniform panicles. The seed grain is usually carefully packed and stored separately from the component of the crop used for consumption. Occasionally, to obtain seed grain, farmers may take bulk seed from the threshing floor and then sieve this to eliminate unfilled or partially filled seed and other impurities.

Germplasm erosion

Rice cultivation in both the rainfed lowland and rainfed upland environments of Laos has, until relatively recently, been based on the use of traditional varieties and minimum inputs, using family labor as the most important input. Even in the main lowland rice-growing areas of the Mekong River Valley in the central and southern agricultural regions, until as recently as the early 1990s, it was estimated that more than 90% of rice cultivation was based on the use of traditional varieties. In the upland environment, only traditional varieties were grown. The first improved Lao glutinous varieties were released in 1993 and they proved well suited to the main lowland areas, such that, by 2000, more than 80% of the wet-season rice area in most provinces in central and southern Laos was being cultivated with these varieties. The expanding dry-season irrigated rice environment at that time was being cropped only with improved varieties. The adoption of the improved varieties in the main lowland rice-growing areas of Laos has generally been associated with the discarding of most of the traditional varieties that had been selected by farmers and grown for generations. Many of the varieties collected from the wet-season rainfed lowland environment in the central and southern agricultural regions in the early years (1995 and 1996) of the germplasm collecting and conservation project were no longer being grown or available by the early 2000s. The samples in the germplasm collections being maintained *ex situ* now represent the only source of much of this material. In the northern agricultural region, the traditional varieties have continued to be grown in the rainfed lowland environment in many provinces only because the varieties released for the central and southern agricultural regions were not well suited to cultivation in the northern region. However, in the late 1990s, efforts began to develop improved higher-yielding varieties better suited to the specific growing conditions in the lowlands of the north. It can be expected that, as better-adapted improved varieties become available and are introduced to farmers in this region (and in some elevated lowland areas in more southern provinces), many of the traditional lowland varieties will disappear as fast as has happened in the lowland environment in the southern and central regions. The erosion of the traditional germplasm in most lowland areas of Laos, as a result of the adoption of improved higher-yielding varieties, might therefore be expected to be almost complete by about 2010. It is probable that only some specialist traditional rice such as black rice (Appa Rao et al, Chapter 12) and some well-known aromatic rice (Appa Rao et al, Chapter 11) will continue to be grown on a regular basis in some lowland farming areas.

In relation to the upland environment, there has not been the same level of focus on the development of improved higher-yielding varieties as for the lowland environment. Upland farmers have, until the early 2000s, continued to grow their traditional upland varieties. However, even in this environment, superior upland varieties have been identified from the evaluation of the collection of upland varieties assembled between 1995 and early 2000. In some areas where variety selections have been introduced to upland farmers in northern Laos, they are already being adopted and are expected to replace many of the varieties that have been grown for many years. It might be expected that, as a result of more active agricultural extension services introducing a few superior upland varieties throughout upland areas, there will be a gradual but significant reduction in the number of traditional rice varieties being grown throughout much of the rainfed upland environment in the north and elsewhere in the country. The erosion of the upland germplasm base might also be accelerated as a result of a gradual decline in the area of upland rice cultivated throughout Laos, in line with government policy to move from annual cropping (rice and other annual crops) to more sustainable agricultural practices in the uplands throughout the country.

Conservation of germplasm diversity

Conservation within Laos

Ex situ conservation of genetic resources in genebanks is the most secure and cost-effective strategy for the long-term preservation of rice germplasm. The country's first national cold storage facility to conserve germplasm was built in 1997 at the National Agricultural Research Center (NARC) at Thadokkham in Saythany District of Vientiane Municipality. The facility was designed for seed storage at 4 °C, at about 50% relative humidity. For long-term conservation, 20-g samples are kept in deep freezers maintained at –18 °C. This germplasm base is available for long-term breeding and evaluation purposes.

Duplicate conservation at the International Rice Genebank

Under an agreement signed between the Lao Ministry of Agriculture and Forestry and the International Rice Research Institute (IRRI), for long-term conservation, a duplicate set of all rice samples collected between 1995 and 2000 is being conserved at the International Rice Genebank (IRG) at IRRI headquarters in the Philippines.

Conclusions

The remarkable genetic diversity of the traditional rice cultivars in Laos jointly reflects the country's rich cultural and geographic diversity together with the country's relative isolation until recent times. The collecting that was undertaken from 1995 to 2000 was timely in that many of the traditional varieties collected then are no longer available in the farming areas where they were developed and grown, often for many generations. As with most other countries in the Asian region, farmers have been receptive to the adoption of improved higher-yielding varieties that have quickly replaced traditional lowland varieties. In the upland environment, a combination of the evaluation and subsequent distribution of superior upland varieties from among those collected in the latter part of the 1990s, together with a reduction in upland rice cultivation, can also be expected to result in a significant reduction in the diversity of varieties being grown in the uplands. Care needs to be given to ensure the proper maintenance and use of the traditional rice germplasm collections stored *ex situ* in both Laos and at the GRC at IRRI in the Philippines.

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Notes

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CHAPTER 10

Naming of traditional rice varieties by the farmers of Laos

S. Appa Rao, J.M. Schiller, C. Bounphanousay, A.P. Alcantara, and M.T. Jackson

The collection of traditional rice varieties from throughout Laos, together with a summary of the diversity observed and its conservation, has been reviewed in Chapter 9 of this monograph. While undertaking the collection of germplasm samples from 1995 to early 2000, information was collected from farmers on the special traits and significance of the different varieties, including the vernacular names and their meanings. Imperfect as literal translations might be, the names provide an insight into the diversity of the traditional rice varieties of Laos. Furthermore, the diversity of names can, when used with care, act as a proxy for genetic diversity.

When collecting started, variety names were recorded in the Lao language and an agreed transliteration into English was developed. The meanings of the variety names were obtained from all possible sources, but particularly from the farmers who donated the samples, together with Lao extension officers and Lao research staff members who understood both Lao and English. Variety names were translated literally, based on the explanations provided by farmers. For example, the red color of glumes is often described in terms of the liquid from chewed betel leaf, which is dark red. Aroma is sometimes indicated by the names of aromatic flowers like jasmine or the response to the aroma that is emitted by the grain of particular varieties during cooking. This chapter provides a summary of the information collected on the naming of traditional Lao rice varieties. More detailed information is available from records of the collections maintained by the Genetic Resources Center at the International Rice Research Institute (IRRI) and in detailed reports of the collecting missions (Appa Rao et al 2000).

Components of variety names

Most rice variety names in Laos have three elements: a basic name, a root name, and a descriptor. The basic name is *Khao*, which means rice. However, there are several very common root names: *Khao na* (rice, lowland), *Khao hai* (rice, upland), *Khao niaw* (rice, sticky/glutinous), *Khao chao* (rice, nonglutinous), and others. The third element, a descriptor name, allows farmers to further identify particular varieties within groups. For example, the variety name *Khao niaw do* refers to a glutinous early-maturing (*do*) variety, whereas *Khao niaw kang* indicates a glutinous rice variety of medium maturity (*kang*). Quite often, the word *Khao* is understood rather than being formally included in the name, so the name recorded was only the root name and the descriptor, such as *Khao phae deng* (profusely (*phae*) tillering, red (*deng*) variety).

Variety names with just one descriptor are the most common, but occasionally they may have two descriptors. Some examples of the dual-descriptor names are *Chao oon tam* (nonglutinous, soft, short), *Khaw pom kon dam* (white, globular grain, black apiculus), *Peek khaw gnay* (winged, white grain, big), and *Chao Lao-Soung dam* (nonglutinous, highland Lao, black grain).

Variants within varieties with similar root names

Naturally occurring variants of individual varieties are selected by farmers, tested for their performance, and maintained as new varieties. The number of variant forms varied considerably. For example, the variety *chao* (nonglutinous) has 159 variants (Table 1) as the farmer-consumers of nonglutinous rice use the prefix *chao* for most of the varieties they grow. In general, those traditional varieties that are grown extensively because of their adaptability and/or superior grain and/or eating quality have more variant forms. For example, variety *Khao kay noi* (small chicken rice) is a rainfed lowland glutinous variety valued for its excellent grain quality. It is grown extensively in the provinces of Houaphan and Xieng Khouang in the northern and northeastern regions. Among the collections of this variety, nine different forms were found with differences in glume color and other characteristics, with some of these varieties having additional descriptors in the varietal name to reflect these special traits (Table 2). Similarly, the glutinous variety *Khao sanpatong,* developed in, and introduced from, Thailand in about 1967, is extensively grown under rainfed lowland conditions throughout Laos. Within the collection, nine variants of this variety were identified, with differences in maturity time, aroma, and morphological characteristics (Table 2). Variation in the shape, size, and color of rice grains is often reflected within the root component *med* (grain) of the variety name. One of the most diverse varieties found throughout the country was *phae* (profusely tillering). Found in both upland and lowland environments, 38 different forms of *phae* were identified, with differences in maturity time and several morphological characteristics, such as presence or absence of hairs, color of glumes, and grain size.

Diversity of distinct variety names

For the total of 13,192 samples of traditional varieties collected from mid-1995 to early 2000 (Appa Rao et al 2002, Appa Rao et al, Chapter 9), variety names were recorded for all but 6% (789) of the samples (Table 3). As there are 48 recognized distinct ethnic groups in Laos (ADB 2001), most of whom speak markedly different languages, some of which are not all widely understood, some variety names could not be readily translated into the Lao language (and therefore into English). Some farmers, particularly the younger generation, are not aware of the variety names. Of

Table 1. Number of variant forms for some variety names.

Variety name	Meaning[a]	Variants	Variant groups with which the variety name is associated
Chao	Nonglutinous	159	Ethnic groups, maturity time, plants and animals
Dam	Black	26	Grain size, grain shape, endosperm type
Kam	Black	34	Grain size, maturity time, ecosystem, endosperm type
Khaw	White	40	Endosperm type, ecosystem, maturity time
Deng	Red	67	Size, shape, color, and quality of grain, aroma, maturity, pubescence, awns, yield, ecosystem
Leung	Yellow	29	Spikelet shape, awns, adaptation
Do	Early	105	Ecosystem, endosperm type, adaptation
Dok	Flowers	27	Different traits such as names of flowers, aroma, color
Kai	Chicken	10	Color, shape, and awns of spikelets, cold tolerance
Leb	Nail/toe	13	Bear, bird, dog, dragon, elephant, lady, rhinoceros
Mak	Fruit	114	Various fruits
Pa	Fish	33	Grain size, grain shape, flooding tolerance
Peek	Winged	16	Color, shape, and size of spikelets
Met	Grain	21	Size, shape, and color of grain
Mon	Globular (grain)	11	Maturity, endosperm type
Namman	Fat	11	Cow, crab, duck, sandalwood, sesame
Oon	Soft (grain)	11	Endosperm, grain size
Phae	Many (tillers)	38	Size, shape, color, and quality of grain, aroma, maturity, pubescence, awns, yield, ecosystem
Sanpatong	Sanpatong[b]	9	Maturity time, grain size, aroma

[a]Words in parentheses implied. [b]Sanpatong = name of variety originating from Sanpatong District, Thailand.

the 12,404 samples for which names were recorded, 1,414 were recorded as having ethnic names that were later translated into Lao and English, whereas the ethnic names for another 151 samples recorded could not be translated.

For the 12,404 samples collected for which variety names were recorded (or recorded and translated into Lao), 3,169 names were distinct. The prevalence of distinct variety names varied among the provinces in which collections were made (Table 3). The largest number of names (1,120) was recorded in the northern agricultural region and the least (583) in the southern agricultural region. The northern province of Luang Prabang, which has the largest area of upland rice of any single province, had the highest number (462) of variety names; the largest number of samples (1,244) was also collected in this province. Although fewer individual varieties were collected in some of the southern provinces, some of these had the highest number of unique

Table 2. Variant forms of the varieties *Khao kai noi* and Khao Sanpatong.

Lao name of variant	English name equivalent	Character	Source of sample	
			Province	Ecosystem
Variants of the variety *Khao kai noi* (small chicken rice)				
Khao kay noi	Chicken, small	Standard variety	Northern region	Lowland
Khao kay noi dam	Chicken, small, black	Black glumes	Houaphanh	Lowland
Khao kay noi deng	Chicken, small, red	Red glumes	Houaphanh	Lowland
Khao kay noi khaw	Chicken, small, white	White glumes	Houaphanh	Lowland
Khao kay noi leuang	Chicken, small, yellow	Yellow glumes	Houaphanh	Lowland
Khao kay noi lai	Chicken, small, striped	Striped glumes	Houaphanh	Lowland
Khao kay noi hai	Chicken, small, upland	Adapted to uplands	Houaphanh	Upland
Khao kay noi hom	Chicken, small, aromatic	Aromatic	Houaphanh	Lowland
Khao kay noi hang	Chicken, small, awned	Awned spikelets	Xieng Khouang	Lowland
Khao kay noi/nam yen	Chicken, small, cold water (tolerant)	Cold-tolerant	Houaphanh	Lowland
Variants of the variety *Khao sanpatong*				
Khao sanpatong	Sanpatong	Standard variety	Khammouane	Lowland
Khao sanpatong do	Sanpatong, early	Early maturity	Savannakhet	Lowland
Khao sanpatong do hom	Sanpatong, early, aromatic	Early maturity, aromatic	Vientiane Municipality	Lowland
Khao sanpatong gnay	Sanpatong, big	Large grains	Sekong	Lowland
Khao sanpatong hang dam	Sanpatong, black awned	Black-awned spikelets	Borikhamxay	Lowland
Khao sanpatong kang	Sanpatong, medium	Medium maturity	Sekong	Lowland
Khao sanpatong ngan	Sanpatong, late	Late maturity	Sekong	Lowland
Khao sanpatong noi	Sanpatong, small	Small grains	Vientiane Municipality	Lowland
Khao sanpatong pee	Sanpatong, late	Late maturity	Vientiane Municipality	Lowland

variety names (a variety was regarded as unique to a province when it was recorded as having been collected only in that province). In the southern province of Attapeu, approximately 62% of the samples collected (and named) were classified as unique (Table 3). Other provinces with high levels of unique varieties were Sekong in the south and Phongsaly in the north, for which 54.7% of the samples collected in both provinces were categorized as unique. These three provinces (Attapeu, Sekong, and Phongsaly) are remote and they have high levels of ethnic diversity in their population. As might be expected, the number of different names and the proportion of samples with unique names were lower in Vientiane Municipality and other provinces of the central agricultural region in the Mekong River Valley, whose population has less

Table 3. Distribution of variety names among regions and provinces of Laos.

Region/ province	No. of samples collected	No. of samples with names	Number of names	Number[a] of unique names	Unique[a] names as % total for province	No single-name occurrences	Single-name occurrences as % total for province
Northern region	5,915	5,613	1,120	–	–	968	–
Luang Prabang	1,244	1,162	462	191	41.3	158	21.1
Sayabouly	984	949	416	168	40.4	140	23.7
Luang Namtha	858	798	406	202	49.8	190	27.7
Oudomxay	848	814	343	116	33.8	99	17.4
Bokeo	686	665	299	103	34.4	87	19.8
Phongsaly	664	646	373	204	54.7	177	37.3
Houaphanh	631	579	300	136	45.3	117	29.0
Central region	4,625	4,321	613	–	–	513	–
Savannakhet	989	968	358	148	41.3	117	21.0
Khammouane	867	840	296	102	34.4	86	15.4
Vientiane Province	787	717	331	108	32.6	89	19.8
Borikhamxay	594	560	273	91	33.3	77	19.8
Xieng Khouang	560	535	223	74	33.2	64	17.6
Vientiane Municipality	486	380	197	48	24.4	43	16.1
Saysomboun Special Region	342	321	161	42	26.1	37	17.1
Southern region	2,652	2,469	583	–	–	482	–
Champassak	842	773	283	97	34.3	77	15.8
Saravane	774	741	335	144	43.0	110	26.3
Attapeu	640	596	336	209	62.2	180	42.3
Sekong	396	359	243	133	54.7	115	45.7
Total	13,192	12,403	3,169	2,316[b]	–	1,963	–

[a]Recorded for a single province; a unique name may have been recorded more than once within a province. [b]This is the total number of different names across all provinces (and not the sum of this column); 853 (26.9%) of the names were recorded in more than one province.

ethnic diversity and where opportunities have been greater for the exchange of modern varieties across provincial and national boundaries. The adoption of introduced improved varieties before the collecting missions reported in this chapter has also been greater.

There is greater diversity, and therefore diversity of names, of the varieties grown in the upland environment than in the lowlands. This probably reflects several factors, such as the greater ethnic diversity within the population in the uplands and their associated diversity of preferences for food quality attributes (endosperm type, grain quality, aroma of cooked grain, etc.) in the types of rice they grow. The diversity of upland varieties also probably reflects the greater diversity in the agroclimatic conditions under which these varieties are grown.

Diversity of variety root names

The most common root names reflected the fact that a variety was glutinous or non-glutinous, together with the color of the seed (Table 1). The most common root names recorded were *chao* (nonglutinous) (159 times), *do* (early) (105), *deng* (red) (67), *kam* (black) (34), and *pa* (fish) (33 times) in the collection of 12,404 samples for which names were recorded. Some root names are slightly different in the Lao language but have the same meaning; for example, black (usually referring to the color of the glumes) can be referred to by the root names as either *kam* or *dam.* The root name *peek* (winged or long glumes) was recorded in 16 variety names. Although variety names are mostly distinct, and varieties often have unique characters associated with the name, the same apparent variety is sometimes called by different names by different ethnic groups. Conversely, varieties with different morphological and physiological characters (Photo 10.1) are sometimes given the same name by different groups. For example, the variety *Khao kam* (black rice) differs for a large number of characters, but farmers use the same name as long as the pericarp is black or purple, and generally ignore all other characteristics. Similarly, they use the name *Khao peek* (winged rice) for any variety that has long glumes, ignoring all other characteristics. Hence, there may be more varieties with specific characteristics than the lists of names indicate.

The naming of varieties by Lao farmers

Lao farmers use a functional system to name a variety that is based on useful characters that make it readily identifiable, and sometimes to reflect its more innate characteristics (particularly those relating to cooking and eating quality). Table 4 summarizes the diversity in the common names that were recorded in the collection of 12,404 samples of traditional rice collected in 1995-2000.

Naming of varieties to reflect endosperm type, grain quality, and aromatic characteristics

Lao farmers give names to varieties based on endosperm type: *niaw* (glutinous or sticky) and *chao* (nonglutinous). Some traditional varieties are intermediate between glutinous and nonglutinous forms and their names reflect this characteristic: *Khao chao niaw* (rice, glutinous/nonglutinous). These varieties are regarded (by the Lao farmers who grow them) as nonglutinous, but they become sticky like glutinous rice after cooking. The eating quality of these intermediate types is generally regarded as inferior to that of the recognized glutinous and nonglutinous types. The amylose content of such varieties ranges from 5% to 15% and they are characterized by having grain that remains very hard after steaming (as required for glutinous rice), but which becomes soft after being cooked in the manner of nonglutinous rice. Examples of these intermediate types were found in Kham District of Luang Prabang in the northern

Table 4. The most common names used in the naming of rice varieties by Lao farmers.

Group	Names
Animals	Spider (*beung*), deer (*kouang*), chicken (*kay*), buffalo (*khouay*), rhinoceros (*haed*), monitor lizard (*lan*), dog wild (*ma nay*), brown bear (*mee-uay*), cow (*ngoua*), rat (*nuu*)
Animal blood	Blood of deer (*leuad fan*), blood of rhinoceros (*leuad haed*), blood of bird (*leuad nok*)
Animal nails	Toe of dog (*leb maa*), nail of black bear (*leb mee dam*), toe of Naga (*leb ngeuak*), claw of bird (*leb nok*), toe of elephant (*leb saang*),
Animal organs	Turtle shell (*ket tao*), bone of palat fish (*kang palat*), hair of cow (*khon ngoua*), back of turtle (*lang tao*), cow milk (*nom ngoua*), eyes of frog (*ta khiat*), liver of brown bear (*tab mee-uay*)
Animal tails	Tail of eel (*hang ean*), tail of chicken (*hang kay*), tail of dog (*hang maa*), tail of horse (*hang maa*), tail of otter (*hang nak*), tail of civet (*hang ngen*), tail of cow (*hang ngoua*)
Animal teeth	Teeth of buffalo (*kheow khouay*), teeth of dog (*kheow maa*), teeth of horse (*kheow maa*), teeth of pig (*kheo muu*)
Animal manure	Cow dung (*khii ngoua*), buffalo dung (*khii khouay*)
Birds	Crow (*ka*), parrot (*nok keo*), hill myna (*nok khek*), wild quail (*nok khoum*), owl (*nok khouw*), dove (*nok khoua*), pheasant (*nok kod* and *nok peud*), finch (*nok peed*), quail (*nok tha*)
Ethnic group	Kui, Hmong, Black Hmong, White Hmong, Hor, Katu, Khmu, Kor, Laobid, Laotheung, Lenten, Leu, Museur, Pako, Phay, Phutai, Taliang, Yaheun, Yang, Yao, Yuan
Fish	Goby fish (*pa bou*), giant snakehead fish (*pa do*), perch (*pa kheng*), bitter fish (*pa khom*), scorpion fish (*pa lad*), eel (*pa laay*), improved fish (*pa phan*), rasbora fish (*pa siev*), jullien's mud carp (*pa soi*)
Flowers	Aster flower (*dok chan*), Hien flower (*dok hien*), aromatic flower (*dok hom*), Keaw flower (*dok keaw*), Pandanus, galanga flower (*dok kha*), shorea flower (*dok khagnom*), golden flower (*dok kham*), golden shower tree flower (*dok khoun*), wild sugarcane flower (*dok louw*), yellow flower (*dok leuang*), jasmine flower (*dok mali*), aromatic flower (*dok om*), coconut flower (*dok phao*), gardenia flower (*dok phoun*), blooming flower (*dok tek*), flower (*dok teuy*), drooping flower (*dok teuy*), tiaw flower (*dok tiaw*), orchid flower (*dok pheung*)
Fruits, nuts, and vegetables	Kaffir lime fruit (*mak khie houd*), ley fruit (*mak ley*), cucumber (*mak teng*), fruit of bid tree (*mak bid*), almond (*mak bok*), sponge gourd (*mak bouab*), red fruit (*mak deng*), fruit of banyan tree (*mak hay*), liam fruit (*mak liam*), fruit of lod (*mak lod*), fruit of mulberry (*mak mone*), fruit of mouay (*mak mouay*), fruit of moy (*mak moy*), bottle gourd (*mak nam tao*), lemon (*mak nao*), sesame (*mak nga*), fruit of ngoua (*mak ngoua*), passionfruit (*mak nod*), fruit of phan (*mak phan*), fruit of marian plum (*mak phang*), fruit of coconut (*mak phao*), fruit of bodhi tree (*mak pho*), fruit of phod (*mak phod*), fruit of phoua (*mak phoua*), fruit of jute (*mak po*), fruit of sugar palm (*mak tan*), fruit of tek (*mak tek*), cowpea (*mak thoua*), durian (*mak thoua lien*), ash gourd (*mak ton*), fruit of toun (*mak toun*), fruit of jambolan tree (*mak wa*), fruit of rattan (*mak vay*), star gooseberry (*mak fay*), orange (*mak kieng*)
Country	America, China, Czechoslovakia, Japan, India, Cambodia, Laos, Myanmar, Philippines, Thailand, Vietnam
District (within Laos)	Thakhek, Luang Prabang, Khob, Ngeun, Hongsa, Houyxai, Houn, Viengthong, Khong, Beng, Ham, Kao, Khoua, La, Leuy, Long, Nga, Nong, Sing, Nambak, Ngoy, Pakse, Phonsavan, Pialad, Taoey, Thateng, Vangvieng, Xiengsen

Continued on next page

Table 4 continued.

Group	Names
Provinces (within Laos)	Sekong, Luang Namtha, Samneua, Phongsaly, Saravane, Savannakhet, Sayabouly, Xieng Khouang
Provinces (elsewhere)	Ubon (Thailand), Khon Kaen (Thailand)
Rivers and water	Hi (Nam Hi), Hoy (Nam Hoy), Kai (Nam Kai), Kha (Nam Kha), Khoun (Nam Khoun), Neun (Nam Neun), Nga (Nam Nga), Ou (Nam Ou), Paa (Nam Paa), Pee (Nam Pee), Soua (Nam Soua), Toon (Nam Toon), Xeng (Nam Xeng), Lay (Nam Lay)
Villages	Bong, Deua, Keaw, Kuen, Lem, Pheng, Phon, Pong, Poung, Sok, Tad, Tay, Tem, Bengkham, Hadsa, Nagnang, Nalong, Nangoy, Nadeng, Nagnao, Nangom, Nakan, Nakok, Nalee, Naleng, Napan, Napho, Napoung, Nasala, Nasan, Naso, Nateun, Natong, Thongkham
Names of people	Bouakham, Leng, Kham, Kong, King, Cho, Ke, Koum, Le, Leuam, Lod, Lon, Long, Loua, Louy, Mang, Noi, Oe, Ouy, Phouan, PO, Pouad, Rak, Se, Seng, Soy, Ton, Took, Tou, Vieng, Yee, Khambou, Khamdeng, Khamhok, Khamhoua, Khamlay, Khamlone, Khammalone, Khamphay, Khamphone, Khamsen, Bounlang, Kongchay, Xiengdee, Phan, Ay, Bounma, Choum, Deng, Dom, Gni, Keaw, Khouay, Kon, La, Mao, Som, Tia, Houng, Bay, Tem, Houm, Sy, Thongchanh, Pee

agricultural region, and in Outhoumphone District in Savannakhet in the lower part of the central agricultural region.

One of the most important criteria for selecting a variety is grain quality. Two well-known traditional lowland varieties with excellent grain quality and good aroma are known by the romantic names of *Khao nang nuan* (rice, soft lady) and *Khao hom nang nuan* (rice, sweet smelling, soft lady). At the time the collections were made in 1997, these varieties were being grown extensively in parts of Vientiane Province, particularly in Vangvieng District. The aromatic characteristics of a variety are often likened to well-known aromatic flowers such as the jasmine flower and the strongly aromatic wood, sandalwood (Table 5). Sometimes, the variety name reflects poor grain quality characteristics, as with *Khao hav* (rice, grain cracks) and *Khao pheng* (rice, floury endosperm). The nature of the grain after cooking is also sometimes reflected in the name. One lowland glutinous variety grown in Sayabouly District of Savannakhet with particularly hard grain is called "broken jaw rice" (*Kang loud hak*). The names of other varieties that reflect their good quality include *Leum pua* (forgets husband)—this variety is so aromatic and good to eat that it is likened to a wife who, on eating the rice, forgets that her husband has yet to eat. Another such variety is called *Pha nya leum kheng* (the king forgets his soup)—the king, on eating this rice and finding it so good, forgets to eat his soup. The word *ma* (dog) is often linked to the eating quality of varieties. For example, *Khao mayeng* (a poor-quality variety) means "rice watched by a dog," based on the belief that a dog will eat the grain of this variety only reluctantly, preferring to sit and stare at it. The names *Ma thoun* (dogs wake up) and *Ma keu* (dogs rush) indicate rice of such good quality that dogs will interrupt their sleep or come rushing when they smell the aroma of the grain of these varieties after cooking. A variety collected in Sekong Province is called *Khao leum ma leum meo* (rice,

Table 5. Varietal names reflecting aromatic and eating quality.

Character	Lao name[a]	Literal English meaning of variety name	Source of collection (province and ecosystem[b])	
Aromatic	*Aham*	Aromatic	Savannakhet	UP
	Ahom	Aromatic	Sekong	UP
	Hom	Aromatic	Khammouane	L
	Ba hom	Aromatic rice	Sekong	UP
	Chao hom	Nonglutinous aromatic	Houaphanh	UP
	Chao hom khao	Nonglutinous aromatic and white	Houaphanh	UP
	Chao mali	Nonglutinous jasmine	Khammouane	L
	Chao hom mali	Nonglutinous aromatic jasmine	Vientiane Municipality	L
	Hom mali niaw	Aromatic, jasmine, glutinous	Borikhamxay	L
	Hom mali kang	Aromatic, jasmine, medium (maturity)	Vientiane Municipality	L
	Dok mali	Jasmine flower	Vientiane Municipality	L
	Hom bay	Aromatic leaves	Borikhamxay	L
	Hom chan	Aromatic, sandalwood	Champassak	L
	Hom nuan chan	Aromatic, sandalwood, soft	Vientiane	L
	Naman chan	Sandalwood oil	Luang Prabang	UP
	Hom deng	Aromatic, red	Khammouane	L
	Hom dok dou	Aromatic *Pterocarpus* flower	Vientiane Municipality	L
	Hom keaw	Aromatic crystal	Vientiane Municipality	L
	Hom Nang nuan	Sweet smelling, soft, young lady	Borikhamxay	L
	Hom sam heuan	Aromatic, three houses	Borikhamxay	L
	Hom saa-ngiem	Aromatic, pleasant	Vientiane	L
	Hom saa-nga	Aromatic, highly	Borikhamxay	L
	Hom oudom	Aromatic, highly	Sayabouly	L
	Hom Phama	Aromatic Myanma	Sayabouly	L
	Hom Thai	Aromatic Thai	Savannakhet	L
	Hom seethii	Aromatic rich person	Borikhamxay	L
	Hom ngan	Aromatic, late	Sekong	L
	Intok hom	(From) Intra, aromatic	Champassak	L
	Tok hom	Aromatic from heaven	Champassak	L
	Thoua hom	Leguminous aromatic	Oudomxay	U
	Ma tuen	Dog wakes up	Khammouane	L
	Leum pua	(Woman) forgets husband	Houaphanh	UP
Good eating quality	*Leum ma leum meo*	Forgets the dog and the cat	Sekong	L
	Ma keu	Dog rushes (the rice)	Luang Prabang	UP
	Nam Pheung	(Taste) like honey	Borikhamxay	L
	Namtan	(Taste) like sugar	Vientiane	L
	Nuan	Soft	Sekong	UP

Continued on next page

Table 5 continued.

Character	Lao name[a]	Literal English meaning of variety name	Source of collection (province and ecosystem[b])	
	Nang nuan	Soft lady	Sekong	L
	Nuan chan	Soft aster (flower)	Luang Prabang	L
	Oon dam	Soft and black	Luang Namtha	L
	Phanga leum Keng	King forgets soup	Attapeu	L
	Oon dam	Soft black	Luang Namtha	L
	Oon thong	Soft field	Luang Namtha	L
	Ma ngaeng	Dog stares	Borikhamxay	L
	Khang vay	Broken jaw	Sayabouly	UP
	Khang loud hak	Broken jaw	Sekong	L
	Peng	Floury (endosperm)	Sekong	UP
	Peng hang	Floury (endosperm) and awned	Savannakhet	UP
Poor eating quality	*Hav noi*	Cracks, small	Sekong	UP
	Hav ngan	Cracks, late	Savannakhet	UP
	Hav leum pua	Cracks, forgets husband	Sekong	UP
Poor endosperm quality	*Hav leng*	Cracks, dry	Sayabouly	UP
	Hav do	Cracks, early	Khammouane	UP
	Hav dam	Cracks, black	Borikhamxay	L

[a]Most varietal names are prefixed by the word *Khao,* which means rice. [b]L = lowland, UP = upland ecosystem.

forgets dog, forgets cat) on account of it being so good that, when it is being eaten, it is so tasty that the needs of the dog and the cat are forgotten. The name *Khao sam heuan* (rice, three houses) indicates that the variety is so aromatic that, on cooking, it can be smelled over an area occupied by three houses, not just the house in which it is being cooked (Table 5).

Names reflecting grain characteristics

The names of varieties can often reflect their grain characteristics—size, shape, and color, and combinations of these (Table 6). “Black” rice is usually clearly identified by its name in both upland and lowland environments: *Khao kam* or *Khao dam*. However, other grain colors and grain characteristics often tend to be reflected more in the names of traditional varieties grown in upland areas than those grown in the lowland environment. With the exception of names identifying red pericarp in nonglutinous varieties, names reflecting variation in pericarp color other than red were found only in glutinous varieties. Red pericarp nonglutinous varieties were found in Luang Namtha Province. Fish (*pa*) are consumed regularly (fresh or fermented) by the Lao and are an important part of the diet. Thirty-three of the names recorded were fish-related (Table 3). *Pa siev* (tiny carp) indicates that the grains are long and slender. Similarly, the variety name *Ked tao* (turtle shell) is used to indicate the shape of the grain, but also thick and hard glumes (Table 6).

Table 6. Varietal names reflecting grain characteristics.[a]

Characteristic	Lao name[b]	English meaning	Province, endosperm type, and ecosystem		
Grain size	*Met gnay*	Big grain	Vientiane	G	UP
	Do met noi	Early (maturity), small grain	Champassak	NG	L
	Kang met gnay	Medium large grain	Vientiane	G	UP
	Kang noi	Medum small grain	Sekong	G	L
	Chao met noi	Nonglutinous, small grain	Champassak	NG	L
Grain color	*Dam pi*	Very black	Sayabouly	G	UP
	Dam lay	Black striped	Xieng Khouang	NG	UP
	Dam soung	Black, tall	Sayabouly	G	UP
	Dam peek	Black, winged	Luang Namtha	G	UP
	Khaw phoy	White, brittle	Luang Prabang	G	UP
	Khaw nok met dam	White glumes, black grain	Houaphanh	G	UP
	Khao pee	White, late (maturity)	Luang Prabang	G	UP
	Khao soung	White, tall	Champassak	G	L
	Leuang nga	Yellow ivory	Sekong	G	L
Grain shape	*Met gnao*	Long grain	Sayabouly	G	L
	Chao mon	Nonglutinous, globular	Borikhamxay	NG	UP
	Chao met pom	Nonglutinous, globular	Sayabouly	NG	L, UP
	Lang tao	Back of turtle	Luang Namtha	NG	UP
	Ket tao	Shell of turtle	Khammouane	G	UP
	Ket tao	Shell of turtle	Champassak	G	L
	Pa siev	Carp, tiny	Attapeu	NG	L
	Pa siev	Carp, tiny	Borikhamxay	G	UP
Grain color and size	*Dam met gnay*	Black, large grain	Luang Prabang	G	UP
	Dam noi	Black, small grain	Xieng Khouang	NG	UP
	Khao noi	White, small grain	Borikhamxay	G	UP
	Leung met noi	Yellow, small grain	Luang Prabang	G	UP
	Met gnao khaw	Long grain, white	Borikhamxay	G	UP
Grain color and shape	*Dam met gnao*	Black, long grain	Phongsaly	G	L
	Kam met pom	Black, globular (grain)	Vientiane	G	UP
	Khao pom	White, globular	Borikhamxay	G	UP
	Met gnao khaw	Grain, long, white	Borikhamxay	G	UP
	Khao pom kon dam	White, globular, black apiculus	Houaphanh	G	UP
	Lueng pom	Yellow, globular	Luang Namtha	G	UP

[a]G = glutinous, NG = nonglutinous, L = lowland, UP = upland. [b]Many of these names are preceded by the prefix *Khao*, meaning rice.

Naming of varieties to reflect their stress tolerance

Lao farmers have selected varieties that have resistance to some of the commonly occurring stresses such as drought or flooding. Drought is an important production constraint in both the rainfed lowland and rainfed upland environments (Schiller et al 2001). Drought tolerance of varieties is reflected in the use of a range of root names such as *Bo ngo nam* (does not care for water), *Do nam pa* (early maturing, water vanishes, it can escape drought), *Khok* (upper terrace, which is the most drought-prone lowland

Table 7. Varieties named to reflect particular characteristics of stress tolerance.

Stress tolerance	Lao variety name[a]	English meaning	Province and ecosystem	
Drought	*Beua nam*	Does not need water	Luang Namtha	L
	Heng	Dry	Sekong	UP
	Na leng	Dry paddy field	Sayabouly	L
	am heng	Without water	Phongsaly	L
	Peud nam	No need for water	Savannakhet	L
	Thon leng	Drought-tolerant	Luang Prabang	L
Flooding	*Long Kong*	Flows in the Mekong	Bokeo	L
	Louk pa	(Like a) fish fingerling	Vientiane	L
		(Like a) fish swimming	Vientiane, Sekong	L
Low temperature	*Nam yin*	Cold water (tolerant of low temperature)	Xieng Khouang	L
Lodging	*Aev*	Bends (but does not break)	Bokeo	UP
	Aev dang	Bends and whitish	Bokeo	L
	Aev deng	Bends and red	Luang Prabang	UP
	Aev gnay	Bends, big	Luang Prabang	UP
	Aev noi	Bends, small	Luang Prabang	UP
	Baang lom	Protects from wind	Oudomxay	L
	Pan lom	Protects from wind	Vientiane	L
	Tam Cheen	Short Chinese	Luang Prabang	L
	Bong	Bamboo (strong stemmed)	Houaphanh	L
	Kok lek	Iron stemmed	Luang Namtha	L
	Kok lek	Iron stemmed	Houaphanh	
Pest tolerance				
Birds	*Li nok*	Avoids birds	Bokeo	UP
Weeds	*Phae nga*	Competes with weeds	Sayabouly	L
Other pests	*Ea Pouak*	Resists termites	Champassak	L
Broad adaptability	*Bo hina*	Does not refuse any field	Sekong	L

[a]Many of the names have the prefix *khao* (meaning rice). [b]L = lowland, UP = upland.

area), *Ea phon* or *Phon* (ant hill), and many others (Table 7). Flooding commonly occurs along the Mekong River and its tributaries. Variety root names that indicate an adaptation to flooding in such areas include many such as *Loy pa* (floating fish) and *Louk pa* (fish fingerling) that reflect an ability of rapid stem elongation. Many of the traditional varieties grow very tall and lodging is a major constraint. Varieties that do not lodge are called by names such as *Kok lek* (iron stem), *Bong* (bamboo stem), *Aev* (flexible stem), and *Tia* or *Tam* (short plant), for example. Names can also indicate adaptation to poor soil conditions, such as *Bo hina* (any field). High-altitude areas in the northern region can encounter low temperature toward the grain-filling stage. A variety reported to be adapted to these conditions was collected in Xieng Khouang Province, known locally as *Khao nam-yen* (rice cold water). Resistance to biotic stresses such as birds is indicated by the name *Li nok* (hidden against birds; for this variety, the panicle is "protected" by the upper erect leaves of the plant and

Table 8. Names given to reflect the high yield potential of varieties.

Lao variety name	Literal English meaning of name	Province, endosperm type, and ecosystem[a]		
Khao baa li	Yield so great that it breaks the shoulders of the carrier	Vientiane	G	L
Khao lave tek	Yield so great that the rice store collapses	Luang Namtha	NG	L
Khao ye tek	Yield so great that the rice store collapses	Luang Namtha	G	L
Khao leua lave	Yield exceeds the capacity of the rice store	Borikhamxay	G	L
Khao leua na	Production exceeds the capacity of the field	Borikhamxay	G	L
Khao lod kwien	Yield so great it exceeds the capacity of the cart to carry the grain (rice drops from the cart)	Khammouane	G	L
Khao meun lan	12:1,000,000 (12 seeds planted give 1 million grains)	Luang Prabang	G	UP
Khao jet roy	700 (one seed planted gives 700 grains)	Borikhamxay	G	L
Khao phokha leum khuay	Yield is so great that the merchant forgets the buffalo	Vientiane Municipality	G	L
Khao loong ban	The yield is so great and the owner so overwhelmed that he/she forgets the path to his/her home	Luang Prabang	G	UP
Khao loong ban keut	The yield is so great that the owner forgets the road to the village of his/her birth	Sayabouly	G	L
Khao mae hang leum pua	The yield is so great that the divorced woman forgets her husband	Khammouane	G	L
Khao mae hang tob euk	The yield is so great that the divorced woman beats her chest	Borikhamxay	G	UP
Khao ngod nang	The yield is so great it is like a "superwoman"	Vientiane	G	UP
Sao leum ngang	The crop is so bountiful that the young girl forgets to continue her walk	Vientiane	G	L

[a]G = glutinous, NG = nonglutinous, L = lowland ecosystem, UP = upland ecosystem.

so is less obvious to birds). *Phae nya* (win over weeds) indicates good competition with weeds (Table 7).

Names reflecting yield potential

When a variety is regarded as having a high yield potential, this is often reflected in its name (Table 8). These names often reflect the difficulty in transporting the grain produced back to the village or problems in storing the large quantity of grain produced: *Baa lii* (broken shoulders, the yield is so heavy that it breaks the farmer's shoulders when the grain is being carried to the village) and *Lod kwien* (falls from the cart, the yield exceeds the capacity of the cart to carry it and so some falls from the cart) reflect the difficulty in transporting all the grain produced by these varieties, whereas the names *Lave tek* (broken store) and *Leua lave* (exceeds the store) reflect the storage difficulties associated with the high yields of these varieties. The high yield potential of some varieties is sometimes associated with women such as with the varietal names *Gnod nang* (super woman), *Mae hang* (divorced woman), and *Mae hang leum pua*

Table 9. Variety names that reflect the "foreign" origins of varieties.[a]

Lao varietal name	English equivalent	Endosperm type	Source of collection (ecosystem and province)	
Khao Philippine	Philippine rice	NG	Attapeu	L
Khao Amelika	American rice	NG	Attapeu	L
Khao India	Indian rice	G	Sayabouly	L
Khao Do Phama	Myanmar early rice	G	Champassak	L
Khao Hom Phama	Myanmar aromatic rice	G	Sayabouly	L
Khao Czek	Czechoslovakia rice	NG	Xieng Khouang	L
Khao Do Yuan	Vietnamese early rice	G	Khammouane	L
Khao Viet	Vietnamese rice	NG	Sekong	L
Khao Do Viet	Vietnamese early rice	G	Champassak	L
Khao Kang Viet	Vietnamese medium rice	G	Attapeu	L
Khao Thai	Thai rice	G	Luang Prabang	UP
Khao Kampouchia	Cambodian (Kymer) rice	NG	Attapeu	L
Khao Khamenh	Cambodian (Kymer) rice	NG	Attapeu	L
Khao Kamenh Do	Cambodian early rice	NG	Attapeu	L
Khao Cheen	Chinese rice	NG	Bokeo	L
Khao Tam Cheen	Chinese dwarf rice	G	Luang Prabang	L

[a]NG = nonglutinous, G = glutinous, L = lowland, UP = upland.

(divorced woman forgets husband); the latter two names relate to the yields of these varieties being so bountiful that, in the first case, the woman is so busy harvesting that her impatient husband leaves her, whereas, in the second case, the woman is so busy with her crop that she forgets her divorced husband. In the reverse sense, the variety *Mae maay* (widow) is so named because it often produces some unfilled grain and empty spikelets. The use of such varietal names also reflects the fact that many of the rice farmers in Laos are women.

Variety names reflecting the place of origin of varieties

Some names indicate a variety's country of origin (Table 9), such as *Khao Phama* (rice, Myanmar), *Khao Thai* (rice, Thailand), *Khao Viet* (rice, Vietnam), *Khao Kampuchea* (rice, Cambodia), *Khao Nippon* (rice, Japan), *Khao Czek* (rice, Czechoslovakia), *Khao India* (rice, India), *Khao America* (rice, America), *Khao Philippine* (rice, Philippines), and others. However, the country identity of such varieties sometimes refers to the country identity of the organization or agency that made a variety available rather than the variety actually originating from the country identified in the name. The variety names *American rice* and *Philippine rice* were designated by farmers for varieties introduced and distributed by the Philippine Brotherhood Movement and USAID, respectively, during the latter part of the 1960s and early 1970s. However, in many instances the varieties bearing country names relating to China, Vietnam, Cambodia, and Thailand were collected from Lao provinces adjacent to or near those countries, suggesting that these varieties were introduced from those countries (possibly by farmer-to-farmer exchange across country borders rather than being officially introduced) and given names to reflect the country of origin. Some variety names also reflect other historical factors relating to the source of the variety. For example, the variety called *Khao intok* (rice from heaven) collected in Champassak District of Champassak Province and Mahaxai District of Khammouane (in the southern and central agricultural regions, respectively) reflects the fact that its cultivation was based on seed collected after rice was dropped into the area by USAID-sponsored flights, during the late 1960s and early 1970s, in an effort to alleviate the severe rice deficits that existed in many upland areas as a result of disruption to the normal cropping cycles during a period of internal conflict within Laos.

In addition to names that reflect the "foreign" origins (or association) of a variety, many varieties have names that refer to their more local origins—province, district, village, river, and person. These are listed in Table 4. Those names with a geographic connotation generally indicate that the variety came from that particular location. Names identified with people can mean that a particular individual (after whom the variety was named) was responsible for developing the variety, or can sometimes indicate that the person after which the variety has been named was responsible for introducing it to a particular area as a "new" variety. Similarly, many varieties carry the names of particular ethnic groups within Laos (Table 4); the naming of such varieties in this way generally indicates that the variety has been sourced from a village of a particular ethnic group, and has then been grown elsewhere by another ethnic group, with the latter giving the variety a name to reflect the origins or source of the seed.

Conclusions

The richness and the diversity of the characteristics in the traditional rice varieties of Laos are clearly demonstrated in the names given to them by Lao farmers. Within this context, the importance of the quality of the rice grown and consumed by the people of Laos is manifest in the way many of the varieties have been named to reflect various quality characteristics of glutinous and nonglutinous grain, in both its cooked and uncooked forms, and in both the upland and lowland environments. The analogies of the superior qualities of some varieties with the qualities of women (as reflected in the names of some varieties with superior aromatic and eating quality) might be interpreted as representing a solid imagination as well as the elevated status of women in Lao society.

In most instances, the variety names given reflect desirable qualities such as yield potential, stress tolerance, good grain quality, aroma, and others. It might therefore be regarded as surprising that some of the varieties collected (and being maintained by rural households) have names that reflect relatively undesirable qualities such as hard grain, a tendency for cracking, floury endosperm, etc. It might naturally be assumed that, given the importance that the rice farmers and consumers of Laos place on desirable qualities, those varieties with undesirable qualities would normally be discarded in the process of farmer selection for desirable characteristics. That these varieties are retained probably indicates that they possess other desirable qualities (such as adaptation to climatic stresses, tolerance of pests and diseases, or perhaps they are retained for specialist consumption purposes) that are not revealed in the name.

The diversity of imaginative names given to the traditional rice varieties of Laos reflects the potential value of the indigenous knowledge relating to the history of these varieties, thereby highlighting the importance of proper documentation of this knowledge, at the same time that efforts are made to preserve and conserve the traditional rice germplasm. This knowledge will inevitably be lost as the traditional varieties are replaced by improved varieties and as the current generation of farmers is replaced. In the main rainfed rice-growing region of the Mekong River Valley, it has already been noted (Schiller et al 2001) that, within a period of about 7 years after about 1993, the area sown to traditional varieties had dropped from in excess of 90% to less than 20% (and less than 10% in some provinces).

The record of variety names, when used in association with other passport data for the traditional rice germplasm samples collected and preserved, has the potential to be of considerable value when looking for specialized traits for incorporation into a future variety improvement program, to provide varieties with special characteristics for the different growing environments throughout the country.

The diversity of names presented in this chapter does not reflect the full diversity within the country. Language problems with some of the 48 ethnic groups within the country made it difficult to translate some variety names into Lao and English.

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Notes

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CHAPTER 11

The aromatic rice of Laos

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A unique feature of many of the traditional glutinous and nonglutinous rice varieties from Laos is their aromatic character. For centuries, there has been conscious selection for this aromatic character within varieties grown and consumed by many of the 48 ethnic groups that constitute the population of Laos. The leading aromatic fine-quality rice of international markets, the basmati rice of the north and northwestern parts of the Indian subcontinent and the jasmine rice (*Khao dok mali*) of Thailand, is very well known. The internationally known aromatic rice is generally all nonglutinous. The aromatic rice varieties of Laos are little known outside the country, despite a diversity that is probably unsurpassed for any single country. The Lao aromatic varieties have both glutinous and nonglutinous endosperm and can be found in both upland and lowland environments.

From 1995 to 2000, a program of rice germplasm collecting was undertaken jointly between the Lao Ministry of Agriculture and Forestry (MAF) and the International Rice Research Institute (IRRI). From this program, 13,193 samples of cultivated rice were collected throughout the country (Appa Rao et al 2002a), and one of the characters recorded was the aromatic character in some of the traditional varieties. This chapter describes the diversity that was recorded for the Lao aromatic rice varieties collected during that program.

The chemical basis of aroma

Aromatic rice varieties differ in their degree of aroma and are broadly classified as strongly, moderately, and weakly scented types (Singh et al 2003). The pleasant aroma associated with aromatic varieties is not only associated with cooked rice but is also often emitted by these varieties in the field at the time of flowering (Weber et al 2000, Widjaja et al 1996). Aroma is caused by an extremely small amount of volatile compounds, which are contained as a complex mixture. The number of compounds that constitute aroma reported by different researchers varies considerably and no individual compound has been identified or can be attributed to be responsible for the aroma of cooked scented rice. Rather, a blend of a number of volatile compounds is believed to impart the characteristic aroma and flavor to the aromatic rice. Among these, 2-acetyl-1-pyrroline (2-AP) is considered by some researchers to be the most important (Buttery et al 1988, Weber et al 2000).

The genetic basis of aroma

Aroma is a complex character that is genetically determined but whose expression is also strongly influenced by environmental factors. Researchers differ in their assessment of the number of pairs of genes believed to control the inheritance of aroma in rice, with one to four pairs being reported (Dhulappanavar 1976, Tripathi and Rao 1979, Berner and Hoff 1986, Lin 1991, Pinson 1994, Brijal and Gupta 1998). Khush and De La Cruz (1998) believe that aroma is a quantitative character, as segregants with varying levels of aroma have been observed in crosses between aromatic and nonaromatic varieties. They further suspect one major gene to be responsible for aroma and several modifiers or quantitative trait loci (QTLs) also to be involved.

The expression of aroma

Although the genetic background of a variety is very important in determining its aromatic character, several other factors are well known to affect the expression of aroma, such as temperature during the latter stages of crop growth, soil type and related crop nutrition, agricultural factors, and grain storage and processing. The potential effects of many of these factors on the expression of aroma and other grain characteristics have been reviewed by several authors (Goodwin et al 1994, Khush and De la Cruz 1998, Singh RK et al 2000, Singh US et al 2003).

Temperature

Quality traits of aromatic rice are known to be influenced by temperature, particularly at the time of flowering, grain filling, and maturity. It is generally acknowledged that aroma formation (and retention) in grain is better at lower temperature during the grain-filling stage (Singh et al 2003). For example, Juliano (1972) reports that the retention of aroma in basmati rice is best when, during crop maturity, relatively cool day/night temperatures of 25/21 °C are experienced. Cooler temperatures in the period after flowering and during the grain-filling stage are one of the reasons why north and northeast Thailand are regarded as being suited to the growing of the well-known Thai jasmine rice (Sarkarung et al 2000).

Soil factors

Soil factors are known to affect aroma and other quality characteristics in ways not properly defined but that are believed to be related to the interaction of nutrients with aroma-related volatile compounds (Singh et al 2003). Lighter soils and upland conditions are generally perceived to favor aroma formation, with soils low in nitrogen producing better-quality grain (Singh RK et al 2000, Singh US et al 2003). The application of nitrogen fertilizer is also known to adversely affect cooking and eating quality (including aroma) of rice, with the grain quality of the well-known Thai jasmine rice variety *Khao dok mali 105* (KDML 105) varying inversely with the N content of the grain (Suwanarit et al 1996). On the other hand, potassium and sulfur fertilizers are known to favorably influence the cooking and eating quality of rice, including aroma (Singh et al 2003, Suwanarit et al 1997a,b). Diminishing soil moisture during the grain-filling stage is also believed to significantly affect the expression and accumulation of aroma, and is believed to be important in the expression of aroma by the jasmine rice of Thailand when grown under rainfed lowland conditions rather than in the irrigated environment (Sarkarung et al 2000).

Cropping factors

Time of harvest is also recognized as another factor that could influence aroma and other quality traits in rice. In the case of the photoperiod-sensitive Thai variety KDML 105, Suwanarit et al (2001) demonstrated that increasing maturity time (through earlier planting) significantly improved the quality characteristics of the grain, including aroma. However, a delay in harvesting after maturity is known to reduce aroma and influence the eating quality of aromatic rice (Rohilla et al 2000).

Storage and processing

In most countries, rice is stored and transported as paddy. Rice storage for a few months is usually regarded as having a positive influence on quality. However, storage for longer periods can result in a significant loss of aroma. Stored rice is known to cook relatively drier than freshly harvested rice, which becomes soft, moist, and sticky after cooking. During storage, there is an increase in grain hardness and gelatinization temperature, which enhances the swelling and elongation of rice grain during cooking (Singh et al 2003). The changes that take place in the grain during storage are not well understood.

The origins of aromatic rice in Laos

As with the diversity of traditional cultivated rice in Laos as a whole (Appa Rao et al 2002a), the diversity of the country's aromatic varieties reflects a combination of factors: (1) the ethnic diversity that exists in the country—48 distinct ethnic groups are recognized, all of which grow and consume rice as their staple food, and almost all of them have diverse and specialist uses for rice; (2) the diversity of the growing environments; (3) a past lack of infrastructure throughout the country that limited the movement of varieties (both introduced and traditional); and (4) the Green Revolution of the 1970s and 1980s, which had little impact on Laos and, until the mid-1990s, most rice cultivation throughout the country was still based on the use of traditional varieties with low levels of purchased inputs (UNDP 1998), and this remained the situation in the upland environment in the early 2000s.

Reference is made to the aromatic character of Lao rice as early as the middle of the 17th century, with French and Italian records published in 1663 and 1666 referring to the rice of Laos during that time in the following terms: "*The staple rice is*

Table 1. Descriptor names of ethnic groups indicating that a variety is aromatic.

Resemblance to root name *Hom*	Ethnic group	Descriptor name for aroma
Similar to the most common root name	Laven	*Hoom*
Similar to the most common root name	Yaheun	*Oom*
Similar to the most common root name	Phunoi	*Ahom*
Includes name of ethnic group in variety name	Kor	*Ahom kor*
Includes name of ethnic group in variety name	Kui	*Kui hom*
Has a prefix similar to common root name	Triv	*Thao hum*
Has a prefix similar to common root name	Taoey	*Pa hom*
Has a prefix similar to common root name	Taliang	*Soi hum*
No resemblance to common root name	Pako	*Keepua*
No resemblance to common root name	Katu	*Thamu*
No resemblance to common root name	Katang	*Mahuam*
No resemblance to common root name	Ngae	*Tasang*

Source: Appa Rao et al (1997).

incomparable there and it has a characteristic odor and wildness that is specific to all that grows in this eastern part of the kingdom" (de Marini 1998).

The naming of aromatic rice in Laos

Most rice variety names in Laos have three elements: the basic name, the root name, and a descriptor name (Appa Rao et al 2002b). The basic name *khao* indicates rice; the most common root name for aroma is *hom* (aromatic). All varieties with the root name *hom* are aromatic. The third component, the descriptor name, allows farmers to further identify particular rice varieties within different groups. For example, *Khao hom do* is an aromatic, early-maturing (*do*) variety. Likewise, the variety name *Khao niaw hom do* has two descriptor names: *niaw* means that the variety has glutinous endosperm and *do* again refers to its early maturity.

Among the different ethnic groups in Laos, there is often variation in the word *hom* to indicate that a variety is aromatic (Table 1). Slight variations in the root name *hom* are used by some ethnic groups in Laos to indicate that a variety is aromatic. The Laven use the word *hoom*, whereas the Yaheun use the word *oom.* The Phunoi use *ahom* to indicate an aromatic variety. The name of the ethnic group is also sometimes associated with slight variations of the word *hom* such as in *Ahom kor* by the Kor, *Kui hom* by the Kui, *Soi hum* by the Taliang, and *Thao hum by* the Triv. Other ethnic groups sometimes use names that have no resemblance to the common root name, such as *thamu* by the Katu, *keepua* by the Pako, and *tasang* by the Ngae.

Consumption of aromatic rice in Laos

Aromatic rice, whether glutinous or nonglutinous, is a normal component of the diet of almost all ethnic groups in Laos. Although the names of many traditional varieties may not reflect their aromatic character, the basis for their selection and adoption has usually always included attention to characteristics related to the consumption or quality. This attention to quality is not unique to Laos, but is common in many countries in Southeast Asia. It is also one of the main reasons why the higher-yielding varieties that were originally released by the International Rice Research Institute in the latter part of the 1960s and during the 1970s as part of the Green Revolution were not readily accepted in some countries of the region despite their recognized high yield potential. Rather, the yield potential and other traits of these modern varieties were usually later blended with the quality characteristics of the traditional varieties in national breeding programs to produce improved "national" varieties that had more general acceptability. In the case of Laos, the early introductions of "modern" varieties in the late 1960s and early 1970s by organizations such as the Philippines Brotherhood Movement and USAID resulted in very little farmer adoption. However, this was not only because these varieties lacked the "quality characteristics" of traditional varieties but also because the early improved high-yielding varieties were almost exclusively nonglutinous, whereas more than 90% of the rice being consumed in the country at that time was glutinous or "waxy" rice. Similarly, in the latter part of the 1970s and early 1980s, when several varieties were introduced from Vietnam in an effort to improve yields and help achieve national rice self-sufficiency, the only variety to be grown to any significant degree was the nonglutinous variety CR203 (which also has IRRI parentage). However, even for this variety with its recognized high yield potential relative to most of the traditional lowland varieties being grown in Laos at that time, its acceptance was not based on its acceptability for general consumption, but rather its suitability for noodle and alcohol production. The aromatic character that is a characteristic of most traditional Lao rice varieties is expected to remain the basis for acceptability of most improved varieties that might be developed within the Lao National Rice Research Program.

Representation of aromatic rice in the germplasm base for Laos

At the time of collecting samples of traditional varieties for conservation and use in 1995-2000, information on up to 36 descriptors, which also included aroma of cooked rice, was obtained from the farmers who provided samples. Aromatic varieties were identified based on the name of the variety and information provided by the farmers. Agricultural extension officers and Lao scientists who had knowledge of the traditional rice varieties supplemented this information. All the collected samples were classified according to ecosystem, endosperm, and maturity type, in addition to the district and province from where each sample was collected.

Geographic distribution of aromatic varieties

Out of the 13,193 samples collected during 1995-2000, variety names were available for 12,411 samples (Appa Rao et al 2002). Among these, 477 samples (3.84%) had names identifying them to be aromatic. These samples were collected in all 136 districts of the country where collecting was done. However, variation was considerable among regions, provinces, and districts in the number and proportion of aromatic samples collected (Table 2). Among the provinces, Houaphanh in the northern region had the highest number (51 samples), followed by the provinces of Vientiane (46) and Khammouane (44) in the central agricultural region. Among regions, the central agricultural region had the highest proportion (47%) of aromatic varieties collected, followed by the northern region (38%). The proportion of aromatic varieties was greatest among samples collected from the rainfed lowlands (66.6%), suggesting a greater preference for aromatic varieties by lowland farmers and consumers.

More glutinous samples were aromatic (79.7%) than nonglutinous samples (20.3%). This is consistent with findings reported by Champagne et al (2004), who found that grain flavor and aroma of rice varieties are often correlated highly and negatively with amylose content; glutinous (or waxy) varieties are more likely to display more grain flavor. This, in turn, is reflected in the fact that the Hmong ethnic group, the primary consumers of nonglutinous rice in Laos, appear to be less concerned with aroma as a sought-after characteristic in the varieties they grow.

Distinct variety names for aromatic varieties

Among the 477 aromatic samples collected, 98 distinct variety names designating aroma were used by Lao farmers (Table 3). Besides the use of designations specifically indicating aroma, Lao farmers use a range of other names to indicate that a variety has aromatic qualities. These names may include reference to aromatic flowers or plants, country of origin, endosperm type, maturity time, and other grain and plant characters, singly or in combination. Names used to indicate aroma relating to plants include aromatic jasmine (*Hom mali*), jasmine flower *(Dok son*), and Arabian jasmine flower (*Dok phut*). Some variety names relate to aromatic plants, such as sandalwood (*Hom chan*) and sandalwood oil (*Namman chan*). Grain size is also sometimes reflected in combination with the aromatic character—aromatic large grain (*Hom gnay*) and aromatic small grain (*Hom noy*). The soft texture and aroma of the grain after cooking are also sometimes referred to in a romantic way—*Hom nang nuan* (sweet-smelling soft lady, Photo 11.1) and *Hom nuan* (sweet and soft). Aroma is also linked to grain color—red aromatic (*Deng hom*), white aromatic (*Hom khaw*), and aromatic striped (*Hom lay*). Aromatic names can also be linked to agronomic traits—aromatic and excessively tillering (*Hom phae phalo*) and dwarf aromatic (*Hom tam*). The name may also indicate the country from where a variety was introduced—aromatic Myanmar *(Hom Phama*), aromatic Thailand (*Hom Thai*), and aromatic Cambodia (*Hom Kampuchea*). The intensity of aroma is reflected by names such as highly aromatic (*Hom oudom)* and mildly aromatic (*Hom noi*). It is interesting to note that some aromatic rice varieties exhume aroma not only from grains but also from culms and leaves. This is also sometimes reflected in the name—*Hom thong* (aromatic field) and *Hom bay (*aromatic leaf).

Table 2. Geographic distribution and classification of aromatic samples collected in Lao PDR from 1995 to 2000.[a]

Region and province	Samples (total)	Samples (aromatic)	Aromatic		Lowland					Upland				
			% Total	% Aromatic	G	N	E	M	L	G	N	E	M	L
Northern region	5,919	181	44.9	37.9	87	19	17	34	55	47	28	27	27	21
Bokeo (BO)	689	17	5.2	3.6	7	2	2	3	4	3	5	2	1	5
Houaphanh (HP)	631	51	4.8	10.7	36	1	0	6	31	7	7	1	8	5
Luang Namtha (LN)	857	19	6.5	4.0	8	5	4	4	5	5	1	2	3	1
Luang Prabang (LP)	1,243	29	9.4	6.1	7	6	2	7	4	8	8	10	5	1
Oudomxay (OD)	849	12	6.4	2.5	3	1	2	2	0	7	1	7	0	1
Phongsaly (PS)	667	20	5.1	4.2	5	2	1	4	2	11	2	2	6	5
Sayabouly (SB)	983	33	7.5	6.9	21	2	6	8	9	6	4	3	4	3
Central region	4,623	224	35.0	47.0	164	20	34	103	47	36	4	23	15	2
Xieng Khouang (XK)	561	30	4.3	6.3	28	0	0	10	18	1	1	0	1	1
Borikhamxay (BK)	595	36	4.5	7.5	24	2	7	18	1	9	1	9	1	0
Khammouane (KH)	866	44	6.6	9.2	41	2	10	26	7	1	0	0	1	0
Savannakhet (SV)	988	26	7.5	5.5	21	3	3	17	4	1	1	1	0	1
Vientiane M. (VM)	485	36	3.7	7.5	15	11	6	15	5	10	0	5	5	0
Vientiane P. (VP)	787	46	6.0	9.6	31	2	5	17	11	12	1	7	6	0
Saysomboun (SB)	341	6	2.6	1.3	4	0	3	0	1	2	0	1	1	0
Southern region	2,651	72	20.1	15.1	37	9	5	35	6	23	3	8	14	4
Attapeu (AT)	639	6	4.8	1.3	1	5	0	4	2	0	0	0	0	0
Champassak (CS)	842	28	6.4	5.9	20	4	3	20	1	3	1	0	4	0
Sekong (SK)	396	12	3.0	2.5	4	0	1	3	0	6	2	5	2	1
Saravane (SV)	774	26	5.9	5.5	12	0	1	8	3	14	0	3	8	3
Grand total	13,193	477	100.0	100.0	288	48	56	172	108	106	35	58	56	27

[a]G = glutinous, N = nonglutinous, E = early, M = medium, L = late.

Table 3. Distinct aromatic variety names in Laos and their classification.[a]

Variety name	Meaning of variety name	Coll. no.	LG no.	Ec	En	Mt	Pv
Hom mali (L/N)	Aromatic jasmine	LR-1375	108	L	N	L	AT
Chao hom (L)	Nonglutinous aromatic	LR-1384	117	L	N	M	AT
Dokson	Jasmine small	LR-2115	220	L	G	M	CS
Deng dok chan (L/G)	Red aster	LR-2139	244	L	G	M	CS
Intok hom	From heaven aromatic	LR-2307	276	L	G	M	CS
Hom chan (L/N)	Aromatic aster	LR-2611	365	L	N	M	CS
Tok hom	Aromatic from heaven	LR-2635	389	L	G	M	CS
Kang hom	Medium aromatic	LR-2813	467	L	G	M	CS
Chao mali	Nonglutinous jasmine	LR-21003	482	L	N	M	CS
Do ngieng	Early aromatic	LR-21030	509	L	G	E	CS
Dok ket	Pandanus flowers	LR-21031	510	L	G	M	CS
Chao hom (U)	Nonglutinous aromatic	LR-3213	537	U	N	E	SG
Ea hom (L)	Aromatic	LR-3216	540	L	G	M	SG
Ahom (U)	Aromatic	LR-3225	549	U	G	E	SG
Ahom (L)	Aromatic	LR-3226	550	L	G	M	SG
Ea hom (U)	Aromatic	LR-3354	619	U	G	E	SG
Hom thong (L/G)	Aromatic field	LR-4105	635	L	G	M	SV
Niaw mali	Glutinous jasmine	LR-4411	661	L	G	L	SV
Hom mali niaw	Aromatic jasmine glutinous	LR-4442	692	L	G	L	SV
Hom do (L)	Aromatic early	LR-5109	856	L	G	M	SK
Ken chan	Seed of aster	LR-5515	959	L	G	M	SK
Hom (L/G)	Aromatic	LR-5518	962	L	G	M	SK
Hom noi	Aromatic small	LR-5736	1053	L	G	M	SK
Hom ngan	Aromatic late	LR-5763	1,080	L	G	L	SK
Hom vieng	Aromatic vieng	LR-5807	1,089	L	G	M	SK
Hom phae (L)	Aromatic many tillers	LR-5816	1,098	L	G	M	SK
Om lay	Aromatic striped	LR-6126	1,235	L	G	M	KM
Om noi	Aromatic small	LR-6127	1,236	L	G	M	KM
Do hom (L)	Early aromatic	LR-6337	1,311	L	G	E	KM
Hom khav	Aromatic white	LR-6468	1,385	L	G	M	KM
Hom lay (L)	Aromatic striped	LR-6516	1,399	L	G	L	KM
Ma teun (L)	Dog wakes up	LR-6805	1,452	L	G	M	KM
Hav hom	Cracks aromatic	LR-6867	1,514	U	G	M	KM
Kay noi (L)	Chicken small	LR-7103	1,529	L	G	M	BK
Kay noi (U)	Chicken small	LR-7118	1,544	U	G	E	BK
Hom bay	Aromatic leaves	LR-7324	1,589	L	G	M	BK
Hom do (U)	Aromatic early	LR-7350	1,615	U	G	E	BK
Hom Nang nuan	Sweet-smelling soft lady	LR-7506	1,655	L	G	M	BK
Hom sed thi	Aromatic rich man	LR-7519	1,667	L	G	M	BK
*Dok phoud**	Arabian jasmine	LR-7611	1,700	L	G	M	BK
Hom (U/G)	Aromatic	LR-8121	1,740	U	G	E	LP
Phae hom (U)	Many tillers, aromatic	LR-8301	1,891	U	G	E	VP
Hom phae phalo	Aromatic, too many tillers	LR-8666	1,996	L	G	M	VP
Hom chan (L/G)	Aromatic aster	LR-8809	2,012	L	G	M	VP
Hom nuan chan	Aromatic soft aster	LR-8821	2,024	L	G	M	VP
Sanpatong do hom	Sanpatong early aromatic	LR-9302	2,055	L	G	L	VM
Hom Phama	Aromatic Myanmar	LR-9805	2,112	L	G	L	VM

Continued on next page

Table 3 continued.

Variety name	Meaning of variety name	Coll. no.	LG no.	Ec	En	Mt	Pv
Hom mali (L/N)	Aromatic jasmine	Hv-19	2,341	L	G	M	HP
Dok hom	Flower aromatic	Bkt-03	2,473	U	G	E	BK
Nam yen/kay noi	Cold water/chicken small	Lac-229	2,692	L	G	L	HP
Kay noi deng	Chicken small red	H-14	2,727	L	G	L	HP
Cham hom	Nonglutinous aromatic	H-20	2,733	L	N	L	HP
Kay noi leuang	Chicken small yellow	Hs-13	2,746	L	G	L	HP
Kay noi dam	Chicken small black	Hs-22	2,755	L	G	L	HP
Chao hom khav	Nonglutinous aromatic white	Lac-278	2,808	U	N	L	HP
Khai hom	Hairy aromatic	Lac-260	2,851	L	G	M	HP
Hom keaw	Aromatic bottle	Kmm-14	2,918	L	G	M	KM
Khav hom	White aromatic	Ll-53	3,322	L	G	M	LP
Nuan chan	Soft aster	Ln-62	3,419	L	G	L	LP
Hom dang	Aromatic variable	Lac-153	3,442	U	G	E	LP
Namman chanh	Sandalwood oil	Lp-02	3,480	U	G	E	LP
Hom (L/N)	Aromatic	Lp-24	3,502	L	N	E	LP
Hom oon	Aromatic soft	Lac-945	3,808	U	G	M	LN
*Mak khen**	Fruit of khen	Nl-13	3,823	U	G	L	LN
Thoua hom	Cowpea aromatic	*On-23*	*4,089*	*U*	*G*	*E*	*OD*
Hom kang (U)	Aromatic medium	Lac-628	4,191	U	G	M	PL
Mak khen dam*	Fruit of khen black	Pb-27	4,227	U	G	L	PL
Mak khen khav*	Fruit of khen white	Pb-28	4,228	U	G	L	PL
Ahom ko	Aromatic ko	Lac-583	4,282	U	G	L	PL
Hom nga	Aromatic sesame	Pp-18	4,396	U	G	M	PL
Deng om	Red aromatic	Sp-21	4,503	U	G	E	SB
Hom oudom	Aromatic highly	Lac-1021	4,534	L	G	E	SB
Om (U)	Aromatic	Lac-1070	4,591	U	G	E	SB
Ba hom	Rice aromatic	Lac-1607	4,707	U	G	L	SG
Ea ham	Ea ham (ethnic name)	Lac-1557	5,250	U	G	E	SV
Kou hom	Kou aromatic	Lac-1504	5,350	U	G	M	SV
Aham	Aromatic	Svs-08	5,422	U	G	M	SV
Hom dok dou	Aromatic flower dou	L-134	5,532	L	G	M	VM
Hom mali deng	Aromatic jasmine red	Vmk-03	5,568	L	N	M	VM
Hom mali kang	Aromatic jasmine medium	Vmk-10	5,575	L	N	M	VM
Hom phae (U)	Aromatic many tillers	L-121	5,607	U	G	E	VM
Ma teun (U)	Dog wakes up	Ns-42	6,001	U	G	M	LN
Kay noi hay	Chicken small, upland	Abc-377	6,742	U	G	M	HP
Kay noi hang	Chicken small, awned	Abc-440	6,798	L	G	M	XK
Do hom (U)	Early aromatic	Abc-643	6,989	U	G	E	OD
Hom thong (L/N)	Aromatic field	Abk-1233	7,514	L	N	L	VM
Hom saa ngiem	Aromatic pleasant	Abv-1241	7,521	L	G	L	VP
Hom huan	Aromatic huan	Abv-1243	7,523	L	G	E	VP
Hom thong khav	Aromatic field white	Abv-1268	7,548	L	G	L	VP
Hom gnay	Aromatic big	Abv-1328	7,602	L	G	M	BK
Hom ka	Aromatic crow	Abv-1401	7,671	L	G	M	KM
Deng dok chan (L/N)	Red aster	Csb-18	8,958	L	N	M	CS
Deng hom (L)	Red aromatic	Kmg-14	9,175	L	G	M	KM
Do om	Early aromatic	Sk-27	9,616	L	G	L	SB

Continued on next page

Table 3 continued.

Variety name	Meaning of variety name	Coll. no.	LG no.	Ec	En	Mt	Pv
Om do	Aromatic early	Sn-23	9,661	L	G	M	SB
Hom Thai	Aromatic Thai	Svl-22	9,970	L	G	M	SV
Kay noi khav	Chicken small white	Xt-09	10,134	L	G	L	XK
Hom lay (U)	Aromatic striped	Xsh-34	10,162	U	G	E	XS
*Do dok phoud**	Early Arabian jasmine	Sp - 43	10,211	L	G	E	SK
Ma kheu	Dogs rush	Abs-201	10,417	U	G	E	BO
Dok keaw (L)	Keaw flower aromatic	Abs-718	10,910	L	G	E	XS
Om (L)	Aromatic	Abp-1089	11,251	L	G	L	SB
Kay noi hom	Chicken small aromatic	Abs-05	11,742	U	G	E	BK
Dok om	Flower aromatic	Bop-81	12,010	L	G	M	BO
Hom deng (U/N)	Aromatic red	Lnl-64	12,269	U	N	M	LN
Hom kang (L)	Aromatic medium	–	12,359	L	G	M	LN
Do mali gnay	Early jasmine big	svp-111	12,822	L	G	E	SV
Chao hom mali	Nonglutinous jasmine	vmt-113	12,842	L	N	M	VM
Deng hom (U)	Red aromatic	vpm-107	12,868	U	G	E	VP
Phae hom (L)	Many tillers aromatic	vpm-112	12,873	L	G	M	VP
Dok keaw (U)	Flower of keaw	vpn-125	12,907	U	G	M	VP
Hom sam heuan	Aromatic three houses	boo-147	12,997	L	G	E	BO
Chao lay hom	Nonglutinous striped aromatic	boo-150	13,000	U	N	L	BO
Hom saa nga	Aromatic highly	bkv-109	13,224	L	G	M	BK
Mali do	Jasmine early	bkv-134	13,249	L	N	E	BK
Mali	Jasmine	bkv-135	13,250	L	N	L	BK

[a]Coll. no. = collector number, LG no. = Lao genebank accession number, Ec = ecosystem, L = lowland, U = upland, End = endosperm, G = glutinous, N = nonglutinous endosperm, Mt = maturity, E = early, M = medium, L = late, Pv = province from where the variety was collected (refer to Table 2).

Distinct aromatic variety names

Among the 477 aromatic samples, Lao farmers give 98 distinct variety names for aroma (Table 3). Among them, in 87 cases, all the samples with a particular variety name have similar characters, such as adaptation to the ecosystem or endosperm type. However, in 11 cases, they differ for either the ecosystem or endosperm or both. Since these two characters are very important, such varieties should be considered as different; if so, there are 120 distinct variety names.

The highest number of 21 aromatic varieties was found in Borikhamxay and Vientiane provinces, followed by 19 in Khammouane and 18 in Sayabouly provinces and Vientiane Municipality (Table 4). This high frequency of aromatic varieties in these provinces may be because of easy access to markets in the neighboring country and the high premium price commanded by them. During crop maturity of aromatic varieties, combines are commonly found in these areas. In the northern region, the maximum number of varieties found was 18 in Sayabouly and 13 in Phongsaly. In the southern region, the maximum number of aromatic varieties found was 16 in Saravane and 15 in Champassak. Relatively more aromatic varieties were found in the lowlands than in the uplands. This may be because lowland farmers grow aromatic varieties for

Table 4. Diversity of characteristics within the collection of named aromatic rice varieties.

Trait	Minimum	Maximum	Mean
Seedling vigor[a]	2	9	3.5
Days to flowering	79	145	107.5
Culm length (cm)	50	210	113.9
Panicle length (cm)	3	9	4.7
Panicles per hill	15	31	24.0
Plant aspect score[a]	3	8	5.2
100-grain wt (g)	1.8	7	6.2

[a]Visual score of 1–9.

marketing, whereas most upland farmers produce for domestic consumption. However, Phongsaly grows the highest number of 8 upland varieties probably because of the strong preference for aromatic varieties. In the southern region, though the farmers have a commercial outlook, improved varieties with higher yield potential are grown. From the Saysomboun Special Region, only one aromatic variety was collected probably because the collection is not complete in this area. Other factors responsible may be inaccessibility to large markets, the lack of an urban population that can buy, and the recent migration of most of the people from other areas. The rainfed lowlands have 55 varieties, 46 glutinous and 9 nonglutinous. The uplands have 27 varieties, 24 glutinous and 3 nonglutinous. As expected, glutinous varieties outnumber nonglutinous ones because of the strong preference for such types. The number of variety names is only a proxy for varietal diversity. Though the names of varieties are mostly distinct and unique characters are associated with the name, we have also found varieties that appear identical but are named differently by different ethnic groups. Conversely, varieties that are clearly distinct morphologically and physiologically are called by the same name by some other ethnic groups. It is also recognized that there is a need for further confirmation of the aromatic varieties as they were selected based on the names given by the farmers.

Relation between number of distinct varieties and number of samples

In general, there is a very close relation between the percentage of samples and varieties collected (Table 2). The total samples collected and the number of aromatic samples and varieties differed considerably. For instance, out of the 36 samples, 21 distinct variety names were found in Borikhamxay and 12 varieties out of 17 in Bokeo, whereas in Houaphanh only 14 varieties out of 51 were found and 3 out of 6 samples collected from Attapeu. There seems to be no relation between the total samples and aromatic samples and varieties. Out of the 1,243 samples from Luang Prabang, the largest number collected, only 29 were aromatic samples, consisting of only 13 varieties, whereas, in Borikhamxay, out of the 595 total samples, 36 samples were aromatic, consisting of 21 varieties.

Characterization of the diversity within Lao aromatic rice varieties

During the 1999 wet season, aromatic varieties were characterized at the Agricultural Research Center (ARC) in Vientiane Municipality. For characterization, both lowland and upland varieties were grown under good management conditions. Data were recorded according to the standard evaluation system for rice (IRRI 1996) or descriptors for rice (IRRI and IPGRI 1980). It is acknowledged that some of the characteristics of the varieties recorded under these conditions could have differed from when the same varieties were grown in the environment where they were collected (for example, in addition to the evaluation being made under a favorable moisture regime, the prevailing temperature may have been higher, particularly at the end of the growing season, relative to that which prevailed in the "home" environment, particularly for upland varieties grown at higher elevations and in more northern areas). Even for lowland varieties, it has been shown that varieties normally grown in lowland areas of the Mekong River Valley can take up to 3 or 4 more weeks to mature when grown in more northern areas, the difference being largely a reflection of the influence of lower temperatures, particularly at the end of the growing season.

Considerable variation was observed among the 370 samples evaluated from different provinces: days to flowering varied from 83 to 135, culm length from 62 to 147 cm, panicle number from 3 to 7, and 100-grain weight from 2.3 to 4.2 g. Variation was similar in many other varieties. This observed variation within a variety might be due to changes brought about by the environmental conditions under which the variety was grown. It would be interesting to determine whether there are differences in aromatic characteristics among different samples of this variety and other samples. In some varieties, the more limited variation may be due to adaptation to specific environmental conditions. Grain size, which is a highly heritable character also, showed considerable variation among different samples.

Considerable diversity was observed for all the characters studied (Table 4), for example, days to flowering varied from 79 to 145, with a mean of 108. However, most of the accessions flowered within 120 days. In general, upland varieties flowered earlier than lowland varieties probably because of adaptation to available soil moisture conditions. Culm length ranged from 50 to 210 cm, with a mean of 114 cm. Most accessions grew very tall, and only nine accessions were shorter than 70 cm. Very late and strongly photoperiod-sensitive varieties grew taller than the early-maturing varieties. The number of productive tillers varied from 3 to 9 per hill. In general, upland varieties produced fewer tillers as it is a normal practice to dibble up to 15 seeds per hill. Flowering was synchronous and the number of productive tillers was more in the photoperiod-sensitive varieties. Panicle length varied from 15 to 31 cm, with a mean of 24 cm. Grain size, as inferred by the weight of 100 grains at around 11% moisture content, varied from 1.8 to 7.0 g. Considerable variation was observed for spikelet characters such as shape, length, width, and thickness; color of glumes; and pericarp color. However, the expression of upland varieties is not realistic and possibly may be different when they grow under upland conditions. Many of the glutinous aromatic varieties are globular in shape, which is in contrast to other aromatic varieties reported that have slender long grain with enormous elongation after cooking (Khush and de la Cruz 1998).

Aromatic varieties with nonaromatic names

As the Lao aromatic varieties reported in this chapter were identified, based on variety name, we recognize that probably a significant number of aromatic varieties in the 13,139 samples (for which names were recorded) collected throughout Laos in 1995-2000 have names that do not reflect their aromatic character. For example, variety *Khao kai noi* (small chicken rice) has a name that reflects its small grain size and globular shape rather than the aromatic character for which it is particularly well known. The 3.84% of the collection identified as aromatic is therefore probably a significant underestimate of the number of aromatic samples in the collection.

Future use of aromatic rice of Laos

Using results from the characterization of the aromatic varieties undertaken at the Agricultural Research Center in Vientiane Municipality in 1999, the Lao rice improvement program has already selected several accessions for use in the varietal improvement program. These include accessions that are particularly vigorous and have early flowering, short stature, a high tillering capacity, and a desirable phenotypic acceptability, long panicles, and heavy grains. These accessions will undergo further assessment for either direct introduction to farming areas and/or use in the ongoing breeding program.

By 2002, Laos was close to achieving rice self-sufficiency. In the near future, it may have a rice surplus, which could mean potential for export (Schiller et al 2001). However, it is recognized that it may be difficult for Laos to compete on the export market with other significant rice-exporting countries in the region, particularly Thailand and Vietnam. In particular, it is unlikely that Laos would be able to produce premium nonglutinous rice for the general export market and be able to compete with the well-known jasmine rice of Thailand and the basmati rice of the Indian subcontinent. It may be more appropriate for the country to develop export markets for “boutique” rice (Schiller et al 2000). In pursuing such an objective, the breeding program would need to largely focus on the development of aromatic nonglutinous rice rather than the more common aromatic glutinous rice collected from 1995 to 2000 (Appa Rao et al 2002a,b). The information contained in the variety names, including the aromatic varieties, would assist in the more effective use of traditional varieties in the Lao breeding program. It is generally acknowledged that the potential export market for glutinous rice is limited, largely on account of a lack of awareness in potential importing countries of the various ways in which glutinous rice can be prepared for consumption.

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CHAPTER 12

The colored pericarp (black) rice of Laos

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Rice varieties with colored pericarp (other than white and red) are usually called "black rice" by the farmers of Laos. Black rice varieties have been reported from many countries of Asia, including China (Zhang et al 1995, Hoahua et al 1996, Gu and Xu 1992), India (Sastry 1978), Japan (Natsumi and Noriko 1994), and Vietnam (Quan 1999). Chaudhary and Tran (2001) also report on black rice from Sri Lanka, Indonesia, the Philippines, Bangladesh, Thailand, and Myanmar. Although the black rice of Laos does not constitute a significant proportion of the total rice production, it is widely grown throughout the country and is grown by most ethnic groups. For some ethnic groups, the way black rice is grown is strongly influenced by their traditions and beliefs. The consumption of black rice varieties is usually in the form of specialty foods (and alcoholic drinks) rather than as a staple food in the same way white rice is consumed.

Among the 13,192 samples of cultivated rice germplasm collected within Laos from 1995 to 2000 (Appa Rao et al 2002a), based on the information provided by the farmers at the time of collection, 459 accessions (3.5% of the collection) were classified as having colored pericarp (Appa Rao et al 2003). Although many of these varieties with a colored pericarp are called black rice (*Khao kam* or *Khao dam*) by Lao farmers, the color of the pericarp of most of these varieties varies from dark purple to light brown, rather than being black.

There has been little documentation of black rice in Southeast Asia generally, and for Laos there is almost no documentation of the presence and diversity of the black rice in the country. This chapter describes the diversity of the black rice collected in Laos from 1995 to 2000 (Appa Rao et al 2000), together with its characterization postcollection and some aspects of its production and use.

The planting of black rice in Laos

Black rice is grown in Laos under rainfed conditions in both upland and lowland environments. However, the reasons for growing black rice often differ between these two environments, reflecting differences in the ethnic composition of the populations between these environments. For ethnic groups in the Mon-Khmer language grouping that are found mainly in the upland environment of the northern agricultural region, black rice is grown almost exclusively for use in spirit-related rituals. The black rice used in the various spirit-related ceremonies is usually true black rice (with a dark purple pericarp), rather than other forms of rice with a colored pericarp, such as "red" rice. There are also some rituals for which the use of black rice is specifically not acceptable, such as in commemorative ceremonies on behalf of the dead (for which sometimes a "false" black rice is used, produced by the blackening of white rice with charcoal dust). In most upland areas of Laos, small amounts of black rice are used for alcohol production, and often this alcohol is also used for spirit-related rituals.

In the lowland environment, black rice is more often grown to produce alcohol rather than for use in rituals and, relative to the upland environment, a much smaller proportion of lowland households grows black rice. In the lowland environment, there is also more direct consumption of various black rice-based products than is the case with communities in the upland environment. However, even in the lowland environment, where a high proportion of the population is Buddhist, there are taboos relating to the use of black rice in some Buddhist-related ceremonies. For example, black rice is never used in offerings to Buddhist monks or in making offerings in Buddhist temples. Such taboos do not extend to some of the other "colored" rice such as red rice. In both the upland and lowland environments, the older members of the different ethnic communities usually believe that alcohol made from black rice is far superior to alcohol made from white rice.

In both upland and lowland farming areas, only small areas of black rice are grown by individual households, and not all households in a community or village grow black rice. For some ethnic groups in the upland environment, it is often only the relatively more affluent families that celebrate various spirit-based rituals that grow black rice. Although small in area relative to the white-rice crop, in areas where black rice is predominantly used in spirit-related rituals, black-rice crops are regarded as being very important for the community, which collectively ensures that such crops are protected and thrive. For some ethnic groups for which black rice is used in animistic rituals, the village shamans who lead these rituals are often prohibited from both growing and consuming black rice and black-rice products.

The black rice of Laos, in both upland and lowland environments, almost exclusively has glutinous or waxy endosperm; Chaudhary and Tran (2001) report that most black rice found in other parts of Asia also has waxy endosperm. The usual quality characteristics that are the basis of the selection and consumption of white rice varieties (aroma and taste) are not always reflected in the black rice varieties of Laos, many of which are generally regarded as being inferior to white rice. In the uplands, the black rice varieties are usually all of relatively early maturity. Unlike the traditional white rice varieties, for which several varieties are often grown by individual households, usually no more than a single variety of black rice is grown.

Although included within the "colored pericarp rice," "red" rice is usually not associated with spiritual taboos that exist for black rice in some ethnic communities. Red rice, unlike black rice, can be used when making food offerings to Buddhist monks and in Buddhist temples. Red rice, on milling, usually has a "colored" pericarp and

Table 1. Distribution of black rice samples collected from different growing environments and regions in Laos.[a]

Region	Wet season[b]				Dry-season irrigated	Total samples	
	Upland		Lowland				
	No.	(%)	No.	(%)		No.	(%)
North	189	(41.2)	19	(4.1)	0	208	(45.3)
Central	110	(24.0)	66	(14.4)	0	176	(38.4)
South	35	(7.6)	40	(8.7)	0	75	(16.3)
Total	334	(72.8)	125	(27.2)	0	459	(100.0)

[a]All the black rice samples collected have glutinous endosperm. [b]Numbers in parentheses represent percentages (of total number of black rice samples).

is regarded as having superior eating quality to black rice. Also, the red rice found in Laos has both glutinous and nonglutinous endosperm. Sometimes the term "red rice" is also used to refer to the wild or intermediate (between wild and cultivated rice) forms of rice that can occur as weeds in cultivated rice fields.

Identification and classification of the black rice varieties of Laos

Using the passport data obtained at the time of collecting, and based on the information provided by farmers (up to 36 descriptors were used), the black rice collected from 1995 to early 2000 (Appa Rao et al 2000) was classified according to geographic distribution among the different provinces of Laos, production systems, maturity time, and endosperm type. Subsequent to being collected, it was also characterized for morphological and agronomic characteristics.

Representation of black varieties in the collection and among growing environments

Out of the 13,192 samples of traditional rice collected from 1995 to 2000, variety names are available for 12,411 samples (Appa Rao et al 2002b). Among these, 459 samples had names identifying them as black. Most (72.8%) black rice samples were collected from the upland environment, with the northern agricultural region accounting for 45.3% of the total (Table 1). No samples of black rice were collected in the dry-season irrigated environment, where 100% of the rice area is usually cultivated with improved white-rice varieties. The predominance of black-rice samples collected from the upland environment partly reflects the fact that, in the early 2000s, almost 100% of the upland rice area was still being sown to traditional rice varieties. However, at about the same time, for the wet-season rainfed lowland environment in the main rice-growing areas in the Mekong River Valley of central and southern Laos, improved varieties were being grown on 70% to 80% of the rice area. The largest number of black rice samples collected in the lowland environment came from the

Table 2. Distribution of black rice samples collected among ecosystems and provinces of Laos.[a]

Province/region	Total samples	Lowland ecosystem		Upland ecosystem	
		Samples	%	Samples	%
Central region	142	63	13.7	79	17.2
Borikhamxay (BK)	23	5	1.1	18	3.9
Khammouane (KH)	25	21	4.6	4	0.9
Savannakhet (SV)	21	15	3.3	6	1.3
Vientiane Province (VP)	25	4	0.9	21	4.6
Vientiane Municipality (VM)	10	5	1.1	5	1.1
Saysoumboun (SB) Special Region	14	2	0.4	12	2.6
Xieng Khouang (XK)	24	11	2.4	13	2.8
Northern region	245	24	5.2	221	48.2
Bokeo (BO)	37	5	1.1	32	7.0
Houaphanh (HP)	23	5	1.1	18	3.9
Luang Namtha (LN)	37	4	0.9	33	7.2
Luang Prabang (LP)	44	2	0.4	42	9.2
Oudomxay (OD)	27	0	0	27	5.9
Phongsaly (PL)	31	4	0.9	27	5.9
Sayabouly (SB)	46	4	0.9	42	9.2
Southern region	72	38	8.3	34	7.4
Attapeu (AT)	18	11	2.4	7	1.5
Champassak (CS)	17	12	2.6	5	1.1
Saravane (SV)	25	12	2.6	13	2.8
Sekong (SK)	12	3	0.7	9	2.0
Total	459	125	27.2	334	72.8

[a]All samples had glutinous endosperm and all were collected from wet-season cropped areas in the lowland (predominantly rainfed) and upland (rainfed) environments.

central agricultural region (66 samples, representing 14.4% of the collection). The smallest number of black rice samples from the lowland environment came from the northern agricultural region (19 samples, representing 4.1% of the collection).

Geographic distribution of black rice

Black rice samples were collected from all provinces and from all 136 districts of Laos (Bounphanousay et al 2004, Appa Rao et al 2004) (Table 2). Among the provinces, Sayabouly had the highest number of samples in the collection (46), followed by Luang Prabang (44), Bokeo (37), and Phongsaly (37). All of these provinces are in the northern agricultural region, and for all four black rice prevailed in the upland environment rather than in the lowland environment. The provinces with the largest numbers of black rice samples collected from lowlands were Khammouane (21) and Savannakhet (15) in the central agricultural region and Champassak (12), Saravane (12), and Attapeu (11) in the southern agricultural region. The smallest numbers of samples were collected from Vientiane Municipality (10), Sekong (12), and the Saysoumboun Special Region (SR) (14). One reason for the relatively small number of black rice samples collected from the Saysoumboun SR was that one of the dominant ethnic groups in this area, the Hmong, has a preference for the consumption of nonglutinous rice and has little interest in glutinous black rice. Although Vientiane Municipality is a significant market for black rice, there is a preference for growing improved white rice varieties in this and nearby areas (where there are significant areas of irrigated production) on account of the high yield potential of the improved white rice varieties. Most traditional black rice varieties are relatively low yielding. The black rice sold in markets of the capital, Vientiane, is mostly imported from other provinces.

Naming of black rice varieties

As reported by Appa Rao et al (2002b) and in Chapter 10, most names of traditional rice varieties in Laos have three elements: the basic name, the root name, and a descriptor. The basic name *khao* indicates rice; the most common root name for black rice is *kam* or *dam* (black). Most of the varieties with the root name *kam* or *dam* have this unique characteristic. The descriptor allows further identification of a particular variety within the different groups. For example, *Khao kam do* is a black (*kam*), early (*do*) maturing variety. The population of Laos constitutes 48 recognized ethnic subgroups (ADB 2001). Some of these ethnic groups sometimes use names other than *kam* or *dam* to indicate that a variety has purple (black) pericarp.

Within the 459 samples of rice that were collected and that had names indicating they had colored pericarp, the most common name was *Khao kam* (346 samples). However, not all samples with the root names *kam* or *dam* possess purple pericarp; in some instances, only the glumes were colored. In addition to the use of names that indicate directly that a variety is "black rice," Lao farmers also use a range of other names to indicate that a variety has a colored pericarp. These names include reference to black birds (the crow), insects, animal dung, and other colorful names (Appa Rao et al 2000b) (Table 3).

Lao farmers used 72 distinct variety names for the 459 samples of rice that were collected and classified as black rice (Appa Rao et al 2004, Inthapanya et al 2003) (Table 3). All but four of these varieties were grown exclusively in either the upland or lowland environments; four varieties were being grown in both environments. Varieties with the same distinct name were sometimes collected from more than one district and/or province (as reflected in the data tabulated for individual provinces in Table 4), reflecting the relative numbers of black rice samples collected between the upland and lowland environments, and between agricultural regions and provinces. The largest number of distinct variety names was recorded in the upland environment, with the largest number in the northern agricultural region, in Luang Namtha, Luang Prabang, Phongsaly, Houaphanh, and Sayabouly.

Diversity within black varieties

Pericarp color of black rice varieties in Laos is generally not black, but varies from dark purple to various shades of purple, and to brown (Photo 12. 1). For most varieties, the purple pericarp color is sometimes associated with purple pigmentation on vari-

Table 3. Distinct black rice variety names and their classification and characteristics.[a]

Sample no.	Variety name of black rice	English meaning of name	LG no.	GC	PC	Ec	En	Mt	Pv
1	*Ba haheuy*	Purple pericarp	8334	20	80	U	G	L	AT
2	*Baksa* (Kam)	Purple pericarp	4823	20	80	U	G	M	SG
3	*Ble dou*	Black pericarp	7472	52	88	U	G	L	OD
4	*Ble sa*	Purple pericarp	12339	20	88	U	G	L	BO
5	*Dam beung*	Black spider	1827	20	88	U	G	M	VP
6	*Dam* (U)	Black	3567	91	80	U	G	L	LP
7	*Dam* (L)	Black	13083	20	80	L	G	M	XS
8	*Dam dang*	Black, variable	2166	20	88	L	G	M	AT
9	*Dam do*	Black, early (maturity)	12312	90	80	U	G	M	LP
10	*Dam ka*	Black, crow	2757	20	88	L	G	M	HP
11	*Dam kieng*	Black, glabrous	13025	91	8	U	G	L	SB
12	*Dam med gnao*	Black, long grain	4346	20	88	L	G	M	PL
13	*Dam mo*	Black	13014	20	88	U	G	L	SB
14	*Dam noi*	Black, small	12936	20	88	U	G	L	XK
15	*Dam nuk*	Black glumes	3924	91	88	U	G	M	OD
16	*Dam pee*	Black, late (maturity)	12311	20	80	U	G	M	LP
17	*Dam peek* (L)	Black winged (L)	131	20	80	L	G	L	AT
18	*Dam peek* (U)	Black winged (U)	7332	20	80	U	G	L	LN
19	*Dam py*	Very black	13023	20	88	U	G	L	SB
20	*Deb kom*	Purple pericarp	5442	91	88	U	G	M	SV
21	*Deb ram*	Purple pericarp	5494	91	80	U	G	E	SV
22	*Do dam*	Early (maturity), black	12832	91	88	U	G	E	VM
23	*Ea dam*	Black	12780	91	80	L	G	M	SK
24	*Ea kam* (L)	Black pericarp	474	20	88	L	G	M	CS
25	*Ea kam* (U)	Black pericarp	8945	20	88	U	G	E	CS
26	*Gnon na* (kam)	Purple pericarp	11643	91	88	U	G	L	BO
27	*Hiang*	Purple pericarp	11479	20	88	U	G	L	LN
28	*Hodo/kam peek*	Purple pericarp, winged	2360	20	88	U	G	E	BO
29	*Hodoko/Kam*	Purple pericarp	4295	91	88	U	G	M	PL
30	*Kaateu*	Purple pericarp	8780	20	88	U	G	M	AT
31	*Kam* (L)	Purple pericarp	112	20	88	L	G	M	AT
32	*Kam* (U)	Purple pericarp	529	91	80	U	G	M	SG
33	*Kam bo mee khon*	Purple, glabrous	6648	90	88	U	G	L	HP
34	*Kam do*	Purple pericarp, early	3646	20	88	U	G	E	LP
35	*Kam gnay*	Purple pericarp, big	12217	20	88	U	G	L	LN
36	*Kam hang*	Purple pericarp, awned	6651	20	88	U	G	L	HP
37	*Kam hai*	Purple pericarp, upland	3763	100	88	U	G	L	LN
38	*Kam kab khaw*	Purple pericarp, glumes white	1386	20	88	L	G	M	KM
39	*Kam kang*	Purple pericarp, medium	5681	91	80	U	G	M	VP

Continued on next page

Table 3 continued.

Sample no.	Variety name of black rice	English meaning of name	LG no.	GC	PC	Ec	En	Mt	Pv
40	*Kam khaw*	Purple pericarp, white	10522	20	80	U	G	E	LP
41	*Kam khie*	Purple (dung) pericarp	6700	42	50	U	G	L	HP
42	*Kam khie ngoua*	Purple (cow dung) pericarp	130	20	88	L	G	M	AT
43	*Kam khon*	Purple pericarp, hairy	10355		88	U	G	E	BK
44	*Kam kieng*	Purple pericarp, glabrous	9055	20	88	U	G	L	HP
45	*Kam lay*	Purple pericarp, striped	8648			U	G	M	HP
46	*Kam leuang hang*	Purple pericarp, yellow awned	9757	20	88	U	G	M	SB
47	*Kam med gnao*	Purple pericarp, long grain	1853	91	80	U	G	M	VP
48	*Kam med pom*	Purple pericarp bold grain	1851	91	88	U	G	M	VP
49	*Kam mee khon*	Purple pericarp, hairy	6647	20	88	U	G	L	HP
50	*Kam na*	Black pericarp, lowland	13192			L	G	L	KM
51	*Kam noi*	Purple pericarp, small	12237	91	88	U	G	M	LN
52	*Kam peek*	Purple pericarp, winged	7156	20	80	U	G	E	PL
53	*Kam peng*	Purple pericarp, floury	6740	42	88	L	G	L	HP
54	*Kam peuak dam*	Purple pericarp, glumes black	9477	91	88	U	G	E	PL
55	*Kam peuak dam*	Purple pericarp, glumes black	11994	100	80	L	G	M	BO
56	Kam peuak deng	Purple pericarp, glumes red	11995	54	80	L	G	M	BO
57	*Kam peuak khaw*	Purple pericarp, glumes white	9478	20	88	U	G	L	PL
58	*Kam peuak khaw*	Purple pericarp, glumes white	11996	20	88	L	G	M	BO
59	*Kam pon*	Purple (mixed) pericarp	12709			U	G	M	SB
60	*Ko sareuay*	Purple pericarp	5467	100	88	U	G	M	SV
61	*Koda*	Purple pericarp	4323	91	80	U	G	M	PL
62	*Kok kam*	Plant black	9737	91	88	U	G	M	SB
63	*Kou cha*	Purple pericarp	5423	52	88	U	G	M	SV
64	*Mak eu*	Pumpkin fruit	5461	91	88	U	G	E	SV
65	*Nia*	Purple pericarp	12417	90	88	U	G	E	PL
66	*Niaw dam*	Glutinous, black	6874	91	80	U	G	M	XK
67	*Pa siev dam*	Tiny carp, black	11812	20	88	U	G	E	SB
68	*Pee dam*	Late black	12904	91	80	U	G	L	VP
69	*Peek dam*	Winged black	7401	91	80	U	G	L	LN
70	*Po*	Purple pericarp	8286	91	80	U	G	L	CS
71	*Se phong kanto*	Purple pericarp	4425	20	88	U	G	L	PL
72	*Tou valien*	Purple pericarp, awned	5419	20	88	U	G	M	SV

[a]LG no. = Lao Germplasm Bank no., GC = glume color, PC = pericarp color, EC = ecosystem, L = lowland, U = upland, En = endosperm type, G = glutinous, Mt = maturity, E = early, M = medium, L = late, Pv = province (refer to Table 2).

Table 4. Distribution of black rice (Khao kam) variety names in different ecosystems and provinces in Laos.

Region/province	No. of samples		Distinct black rice variety names		
	Total collected (no.)	Black rice samples (no.)	Total names	Number of names	
				Lowlands	Uplands
Northern region	5,915	142	67	12	55
Bokeo	686	23	9	4	5
Houaphanh	631	25	11	3	8
Luang Namtha	858	21	10	1	9
Luang Prabang	1,244	25	10	1	9
Oudomxay	848	10	5	0	5
Phongsaly	664	14	11	2	9
Sayabouly	984	24	11	1	10
Central region	4,623	245	33	14	19
Xieng Khouang	561	37	6	2	4
Borikhamxay	595	23	4	1	3
Khammouane	866	37	5	4	1
Savannakhet	988	44	3	2	1
Vientiane Mun.	485	27	4	2	2
Vientiane Prov.	787	31	8	1	7
Saysoumboun Special Region	341	46	3	2	1
Southern region	2,652	72	24	8	16
Attapeu	640	18	7	4	3
Champassak	842	17	5	2	3
Sekong	396	25	3	1	2
Saravane	774	12	9	1	8
Total	13,190	459	124	34	90

ous plant parts, such as the glumes, leaf blade, leaf sheath, midrib, peduncle, panicle (Photo 12.2), and spikelets (Photo 12.3). However, not all varieties with purple coloring in various plant parts have grain with colored pericarp. Similarly, for varieties in which the pericarp is colored, other plant parts, such as glumes and leaves, may not be purple. Black rice is found in both indica and japonica groups (Choudhary and Tran 2001). Roder et al (1996) reported that enzymatic analysis of part of a collection of traditional upland varieties obtained in northern Laos in 1991-93 indicated that more than 90% of the entries belonged to the japonica group. Although black rice was not specifically identified as part of this collection, it is unlikely that the black upland varieties of Laos would differ from the majority of the other upland varieties.

Characterization of black varieties

Out of the 459 accessions classified as having a purple pericarp, 241 were grown in the 1999 wet season at the Agricultural Research Center (ARC) in Vientiane Municipality for characterization and classification of their morphological and agronomic characteristics. For this characterization, both lowland and upland varieties were grown under good management conditions, including irrigation.

Data were recorded according to the standard evaluation system for rice (IRRI 1996). For a sample of 241 varieties, days to flowering ranged from 86 to 145, with a mean of 110; however, most accessions flowered within 120 days and, in general, upland varieties flowered earlier than lowland varieties. This earlier flowering (and subsequent earlier maturity) probably reflected specific selection and adaptation to the uplands, where the soils can rapidly dry out with the end of the wet-season rains, and where most varieties have to be harvested before the majority of lowland varieties. Culm length ranged from 61 to 155 cm, with a mean of 95 cm. Most accessions were very tall, with only nine being shorter than 70 cm. The later-maturing, strongly photoperiod-sensitive varieties were generally taller than the early-maturing varieties. The number of productive tillers varied from 2 to 11, with a mean of 5.5 per hill. In general, upland varieties usually produce fewer tillers than most lowland varieties. When dibble sowing rice in the upland environment, more seed is usually sown per hill than plants transplanted per hill in the lowland environment. Flowering within varieties was synchronous, with the number of productive tillers being greater in the more photoperiod-sensitive, later-maturing varieties. Panicle length varied from 15 to 33 cm, with a mean of 24 cm. Considerable variation was observed for spikelet characteristics such as shape, length, width, and thickness, and color of glumes (Photo 12.3) and pericarp. Steamed black rice was dark purple in color and was shining brightly, giving an appearance of "black pearl" (Photo 12.4). Grain size, a highly heritable character, also showed considerable variation among different samples. For a sample of 198 varieties, 100-grain weight was 2.3 to 4.4 g, with a mean of 3.1. Many of the glutinous black varieties have grains that are globular in shape. In a 2002 wet-season assessment of yield for 45 Lao black rice varieties, yield ranged from 1.4 to 3 t ha^{-1} (Inthapanya et al 2003).

Nutritional value of black rice

Black rice generally draws the attention of rice consumers because of its unusual color. However, in Laos, there is a general perception that black rice is inferior in quality to white rice. This contrasts with the situation in parts of southwest and central China, where black rice varieties have been developed that are reported to be of good quality and high yielding, and have multiple resistance (Chaudhary and Tran 2001). Some of these Chinese black rice varieties are reported to have higher protein, higher fat, and higher crude fiber contents than the common or white rice varieties as well as being rich in lysine, vitamin B_1, calcium, iron, zinc, and phosphorus (Chaudhary and Tran 2001, Gu and Xu 1992). However, it is acknowledged that the higher values for some of these characteristics may not necessarily always be genetically based but may also reflect processing (such as milling) methods. In Laos, black rice is often manually pounded to remove the glumes and consumed after minimum polishing or without polishing (Photo 12.1). As the aleurone layer where the vitamins and minerals, besides protein and fat, are located is not completely removed in black rice, the resulting product is often of higher nutritional value than polished white rice. It has also been reported (Quan 1999) that beverages made from black rice produced after fermentation can sometimes be of high quality. In Laos, black rice is also sometimes used for commercial production of fermented alcoholic beverages, and its older consumers regard it as a superior product to that produced from white rice.

Inheritance of colored pericarp

The intensity of pericarp color in rice depends on the presence of various kinds of pigments and their proportions in the pericarp. Among the several pigments present in the pericarp, glycoside cyanidin is the major one (Haohua et al 1996). These pigments have been found to be quite stable under normal temperature, light, and processing conditions (Haohua et al 1996). Reports on the mode of inheritance of pericarp color in black rice are few. Sastry (1978) reported that crosses between white and red pericarp parents produced F_1 plants with a red pericarp, revealing that red pericarp color was dominant over white. In the F_2 generation, the plants segregated in a ratio of 3 red to 1 white, suggesting that a single dominant gene controls red pericarp color in rice. On the other hand, crosses involving several parents with varying amounts of pigments (varying intensity of purple color) have showed that the intensity of color in the plants varies, depending on the number of genes present in the F_1 plants, the alleles for high pigment content being dominant to those for low pigment content, indicating additive-dominance (Zhang et al 1995). These authors report that two pairs of genes were found to control pigment content in the pericarp, with high pigment content (colored pericarp) being dominant to low pigment content (light-colored pericarp). The deep purple pericarp was expressed as dominant over purple, with the light purple pericarp being dominant to nonpigmented (white), indicating that two pairs of dominant genes control black pericarp pigmentation. As either one or two dominant genes control intensity of pericarp color in rice, it is easy to transfer colored pericarp character into high-yielding modern varieties.

Future use of the black glutinous varieties of Laos

As a result of the rice germplasm collecting and conservation program undertaken in Laos from 1995 to 2000, the country has one of the most extensive collections of traditional black rice germplasm of any single country where germplasm collecting and conservation have been done. Preliminary evaluation of some of this black rice germplasm base also indicates that there is significant diversity in many characteristics within the collection. Accessions have been identified that are extra vigorous, early flowering, and short-statured; some also have high tillering capacity, long panicles, and heavy grains, in addition to having a generally desirable phenotypic acceptability. However, this initial assessment is preliminary and was made under lowland conditions (whereas most of the varieties in the collection were collected in the rainfed upland environment). Considerable work remains to be done in properly evaluating and characterizing the Lao black rice germplasm collection in the environment in which it has traditionally been grown.

Despite projections of a future significant increase in rice needs (and therefore production demand) to meet the increasing population in 2020 (when projections of 7.7 million suggest that rice consumption requirements will need an annual production of at least 2.6 million tons of rice paddy), this increased demand will be mainly for white rice, perhaps with an increased proportion of nonglutinous rice relative to the early 2000s. The consumption of black rice within Laos will likely continue to be for the specialty foods for which it is currently grown and used. Perhaps, with greater urbanization of the population, consumption in traditional areas of production might decline. The export market for black rice is very specialized and also limited in size for the boutique rice in whose category black rice falls. It will be important for Laos to maintain the genetic resource base of black rice that it has. However, there may be little potential return from a significant allocation of limited research resources for the development of specialized black rice varieties through breeding. Rather, the full characterization of the collection, and subsequent evaluation in appropriate environments, to allow the identification of varieties that best fit specific growing conditions and environments in Laos should bring the greatest benefits.

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Notes

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CHAPTER 13

Development of traditional rice varieties and on-farm management of varietal diversity in Laos

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Present-day cultivated cereal crops have evolved from their wild relatives through natural selection of spontaneously occurring mutations, migration, and recombination of genetic variation (Harlan et al 1973). Cultivated crop varieties, often called landraces, primitive varieties, and farmers' varieties or traditional varieties, differ from their wild relatives mainly in relation to the nonshattering nature of physiologically mature grain, which has facilitated the harvesting of ripe grain for human consumption and animal feed. Farmers have, in turn, undertaken further selection within the naturally occurring variability to develop varieties that are suited to the prevailing agroclimatic conditions, provide stable yield and give varying taste, and possess a range of other associated characteristics desired by both the growers and consumers of these crops (Ford-Lloyd and Jackson 1986, Brush and Meng 1998, Harlan 2002). Though there is an awareness of the numerous traditional varieties of crop plants that have evolved over centuries through natural and human selection, records are relatively few of examples of the history of the development of varieties by farmers in any crop.

During the course of rice germplasm collecting missions undertaken from 1995 to 2000 in the Lao People's Democratic Republic (Laos) jointly by the Lao Ministry of Agriculture and Forestry (MAF) and the International Rice Research Institute (IRRI), many farmers were encountered who were able to describe the history of development of some of the varieties for which seed samples had been collected for conservation and use (Appa Rao et al 1997). This information was documented as far as was practicable, within the context of the program of germplasm collecting. The history of the varieties developed and the methods followed to develop them or select for special traits are fascinating in their own right and provide examples of the uniqueness of the indigenous farmers' knowledge that exists in many parts of Laos. It is expected that this knowledge might be lost if not documented, as agricultural practices are quickly changing with development throughout the country. Although the origin of the varieties described has been relatively recent, the records provide an insight into the way new varieties are identified and developed. The records also help document examples of the rationale used by Lao farmers when selecting the unique names for varieties that are described separately in Chapter 10.

In addition to collecting information from areas where the varieties were being grown at the time of germplasm collecting, all of the varieties described in this chapter were also grown and studied in the 1999 wet season at the National Agricultural Research Center near the capital, Vientiane. The purpose of growing the varieties under experimental conditions was to properly characterize and validate many of their attributes. In addition to documenting the history of a number of Lao traditional rice varieties, this chapter also describes how Lao farmers generally manage diversity and maintain these and other varieties in both lowland and upland situations.

The farmers' research environment

During the cropping season, Lao farmers build a small rest-house near the fields they cultivate. They use this rest-house as a base during the cropping season, tending their crops until the produce is harvested, threshed, transported, and stored in granaries in or near their villages. This intimate involvement with all growth stages of the crop provides farmers with an opportunity to observe varieties very closely as they grow. Farmers develop an intimate knowledge of each variety and its unique characteristics, based on which individual varieties are identified. Any plants that express differences in traits relative to those regarded as normal for any variety are usually quickly noted and special care is often taken of such plants, with their growth being closely monitored to maturity. Farmers often select such distinct morphological variants and then harvest, dry, thresh, and store them separately. The variants are then often planted separately in the following season, with careful observations being made in small plots for their morphological and other agronomic characteristics, to evaluate their potential for further multiplication and subsequent identification as a new variety to which is assigned a new variety name that often reflects some aspect of the history of the variety (Appa Rao et al 2002a,b). In this process of evaluation and assessment of variants, farmers apply their own criteria. Sometimes farmers deliberately look for variants that are needed to meet specific requirements or alleviate particular production constraints or because a variant possesses unique morphological traits that are a curiosity.

The origins of selected traditional Lao varieties

Khao ko diaw (single-hill rice)

Variety *Khao ko diaw* (single-hill rice) is a lowland glutinous variety that was reportedly developed through pure-line selection by a farmer (Mr. Sulan) in Pakuvai village in Xaibothong District of Khammouane Province in the Mekong River Valley. As reported by his family members, Mr. Sulan found a single rice hill growing in a shallow pond near his field in 1986. Mature seeds of that single hill were selected and tested in subsequent years. Satisfied with the grain yield and grain quality, the family then multiplied the seed and starting growing it as one of their regular varieties. Neighbors in the same village were also impressed with the variety and started growing it. It was later adopted by farmers in other villages in the same area. At the time of first noticing the variant, Mr. Sulan was impressed with the morphological characters in the single hill he selected for testing; he subsequently named it as *Khao ko diaw* (single-hill rice) and started growing it. This variety is characterized by profuse tillering and synchronous flowering and maturity, and it possesses many large, attractive drooping panicles and large grain free of any disease and insect damage.

When grown under experimental conditions in Vientiane Municipality, the variety was characterized by producing many tillers (up to 15), possessing long drooping panicles on maturity. The grains are large, well filled, and heavy. It has a maturity time of about 150 days. Like almost all traditional varieties, it is photoperiod-sensitive. It is adapted to being grown under conditions of minimum inputs. Many farmers grow this variety in an isolated area in and around Xaibothong District of Khammouane.

Khao ko diaw could have originated because of segregation from a spontaneous intervarietal hybrid. As rainfed lowland farmers in the Xaibothong area grow several varieties together in small adjacent plots, a spontaneous intervarietal hybrid between two cultivated varieties might have occurred and a more vigorous recombinant might have arisen with the preferred combination of characters. A second possibility is that of a spontaneous interspecific hybrid between cultivated and wild rice. In the same general area, *Oryza rufipogon* and *O. nivara* grow abundantly and flower at the same time as some of the cultivated forms (Appa Rao et al 1997). A spontaneous interspecific hybrid between cultivated and wild rice might have occurred and subsequently segregated. The interspecific hybrid must have been more vigorous to be able to compete with other weeds, and wild and intermediate forms of rice, gradually becoming a nonshattering type and losing its awns because of recombination and natural selection. It must have survived some environmental stress, whereas other segregating plants were lost as they could not survive and establish. This unique recombinant might have reached the pond where it was found through flowing water. A third possibility is that seeds of a cultivated form might have been transported from elsewhere through floodwater, animals, or birds. It might have established in the pond where it attracted the farmer’s attention (and he subsequently selected it), as it differs morphologically from other locally grown varieties in the same area.

Khao phae dam (tillering black rice)

Variety *Khao phae dam* (tillering black rice) was developed by Ms. Lasoy (Photo 13.1) of Muang La District in Oudomxay in northern Laos; the variety was developed from another upland variety, *Khao phae deng* (tillering red rice), which is a medium-maturing glutinous variety. When she grew *Phae deng* in 1997 on an area of about 1,500 m^2, she found five panicles, which were lax and longer than the rest, and spikelets that were larger with black (purple) glumes and for which the brown rice was longer, white, shiny, and attractive. The original variety, *Phae deng*, produces grain with red glumes. According to Ms. Lasoy, as there were no other varieties with such black glumes and attractive grain characteristics, she grew it in 1998 to further test it, and then multiplied its seeds. Impressed by its novelty, she started cultivating it on a regular basis. In turn, her neighbors obtained seed of the variety and started growing it as a new variety, which was not found in other nearby villages.

Khao hom do (aromatic early-maturing rice)

In 1984, a farmer (Mr. Bee, Photo 13.2) in the village of Sine-Sai in Bounthai District of Phongsaly in northern Laos obtained seeds of the lowland glutinous variety *Khao hom kang* (aromatic medium-maturity rice) from a neighboring village. When he grew this variety in his own village, he found some plants that flowered and matured a month earlier than the original variety (which matures in about 4 months). He harvested all the early-maturing panicles, bulked them, and grew the seed the following year. After testing in subsequent years, he found the selection to be superior to the original variety in relation to several characters, but particularly for early maturity, a character that he had been looking for. As claimed by Mr. Bee, *Khao hom do* matures in 90 days (30 days earlier than *Khao hom kang)*, produces dark green leaves and larger and longer panicles, and is higher yielding than the original variety. The grain is more aromatic, with good eating quality. Because of its early maturity, aroma, and other desirable characters, the new variety quickly spread among farmers in the village and then to neighboring villages, becoming very popular in the district within a relatively short time.

The early-maturing plants that formed the basis for the new variety, *Khao hom do,* might have arisen as a spontaneous mutation, or the seeds Mr. Bee grew initially might have been a physical mixture of early- and medium-maturing varieties, both of which were aromatic, allowing him to select and later multiply the shorter earlier-maturing plants.

Khao keut (created or born rice)

Variety *Khao keut* (created or born rice) was developed in 1993 by Mr. Khamphet, a farmer from Hin village in Kham District of Xieng Khouang in northeastern Laos. It was developed from a traditional variety called *Khao bong* (bamboo rice), whose culms are thick, strong, and long, resembling those of bamboo. When Mr. Khamphet grew the locally popular variety *Khao bong*, he found five plants that differed from those of the original variety. The variant plants were taller and produced large, long, and loose panicles. These off-type panicles were selected by Mr. Khamphet, with the seeds being kept separately for further testing in the following year, when it was found that they produced plants that were superior to the original variety. On cooking, it was also found that the grain of the new plants was soft and had very good eating quality. Mr. Khamphet and other farmers in the village then started growing the new variety on a regular basis, naming it *Khao keut* (created or born rice). Both the original variety, *Khao bong*, and the newly developed variety, *Khao keut,* are rainfed lowland glutinous varieties that are transplanted twice during the cropping cycle (a practice in some lowland areas of northern Laos) and mature in about 5 months. The off-type panicles that formed the basis of the selection for the new variety, *Khao keut,* might have arisen as a spontaneous mutation or segregation from a spontaneous intervarietal cross, with the segregating plants being subsequently easily noticed as a result of being conspicuous by their height and loose panicles.

Khao pong deng (regenerated red rice)

Variety *Khao pong deng* was developed in Ban Song village in Khun District of Xieng Khouang in northeastern Laos. Floods are very common in this area and can sometimes completely submerge and destroy the rice crop. During one such season of prolonged flooding, when almost the entire rice crop in the area was destroyed, a single plant was found in an otherwise destroyed rice field, and it survived to produce some grain. The farmer who found the plant, believing it to be a significant omen, gave the rice seeds that were produced to a local monk, who then multiplied the seed, testing the plants under field conditions, and subsequently distributed the seed to local farmers. The variety was named *Khao pong deng* (regenerated red rice) to reflect the belief that it was the regeneration of the rice destroyed by the flood.

A second version of the story relates to the origins of the variety. This version says that a local farmer found a single rice plant that had survived the flood and was growing in a local forest. Believing that plant had been created by "the spirits," the farmer gave it to the village monk, who grew it, multiplied the seed, and distributed the seed to local farmers. Variety *Khao pong deng* grows very tall, tolerates submergence for a considerable time, is late maturing, and has glutinous endosperm. Probably the single plant that was the basis of the variety was a spontaneous mutant that has the ability to regenerate, but the trait was expressed only when the flood stress was imposed, enabling it to express its unique capacity for regeneration.

Khao khen sua (shirt-sleeve rice)

Variety *Khao khen sua* was introduced to Pek District of Xieng Khouang (in northeastern Laos) from Khun District in the same province during the early 1950s. A farmer from Pek, when visiting a farmer's field in Khun, selected an attractive panicle from the latter's rice field and hid it in his shirt sleeve for the trip back to his own village. On the return journey, the farmer reportedly encountered a French soldier, who shot him. The injured farmer was able to reach the provincial capital, Phonesavan, where he died. Following his death, an old woman noticed the rice panicle hidden in the sleeve of the farmer's shirt. Believing it to be of significance, she took the panicle to her own home, where she kept the seeds and grew them the following season. The woman noted several attractive attributes in the resulting plants, whereupon she further multiplied the seed and distributed some to other households in the village. The resulting variety was given the name *Khao khen sua* (shirt-sleeve rice) to reflect where the woman had obtained the panicle on which the variety was based. Following extensive farmer-to-farmer and village-to-village exchange, the variety is currently widely grown in Pek District of Xieng Khouang. It is a medium-maturity glutinous variety grown under wet-season lowland conditions.

Khao bong do (early bamboo rice)

In the 1960s, a farmer from Nambak District in Luang Prabang in northern Laos visited Xieng Khouang in the northeastern part of the country. During the visit, he saw variety *Khao bong* (bamboo rice) growing in a field and, being impressed by it, took a small quantity of seed with him on his return to Nambak. The variety was evaluated in Nambak and then multiplied, with seed being distributed among other households and villages. It became known as *Khao bong do* (early-maturing bamboo rice). When grown in Nambak, it was reported to mature in 4 months, 1 month earlier than when grown in Xieng Khouang. Farmers reported that it matures 1 month earlier in Nambak than in Xieng Khouang; it was also reported to have larger panicles with well-filled heavy grains when cultivated in Nambak. The earlier maturity when grown in Nambak could have one or more reasons. In Xieng Khouang, this variety is usually grown following a double transplanting practice that is sometimes adopted in northern Laos, whereas in Nambak a single transplanting is adopted. However, the more likely reason is an effect of temperature on maturity time. The area of Xieng Khouang where the variety is grown has an elevation of about 900 m, compared with an elevation of about 350 m for Nambak. The higher elevation in Xieng Khouang is probably associated with significantly lower temperatures in the latter part of the growing season, relative to Nambak, thereby extending the maturity time of most rice varieties. This phenomenon is often observed when varieties developed for the main rice-growing areas in the Mekong River Valley are grown in some areas of northern Laos (Schiller et al 2001). *Khao bong do* has become popular in the Nambak area, not only on account of its relatively early maturity but also because of the ease with which it can be threshed combined with its glabrous leaves, which allow farmers to handle it easily during weeding, harvesting, and threshing. In Nambak and surrounding areas, it is also known as *Khao Xieng Khouang do* (Xieng Khouang early rice).

Khao kai noi **(small chicken rice)**

This variety was first introduced to the northern Lao province of Houaphanh from neighboring Vietnam, and later introduced to Xieng Khouang to the south of Houaphanh. It is currently grown extensively in both Houaphanh and Xieng Khouang. There are different suggested origins for the naming of *Khao kai noi* (small chicken rice). One belief is that it was so named on account of its small grain size, small enough to allow it to be fed to chickens without first being ground or broken. Others attribute the name to the perception that, if the grain is broken in the process of dehulling, the broken pieces of grain are so small as to have little use, even for feeding chickens. A further story about the origin of the name (and the variety) is that a woman in Seula Province of Vietnam found undigested rice grains in the gullet of a chicken. As the grains were small and globular, and differed considerably from the existing varieties, it aroused her curiosity and she then grew plants from these undigested grains. After further seed multiplication, the resulting crop was regarded as having good yield potential, a very high milling recovery, and good eating quality.

Khao kai noi is a rainfed lowland, glutinous, late-maturing rice variety. The grain is strikingly different from that of most other varieties, being short, rounded, and almost globular in shape. The unique feature of the variety is its high milling recovery (about 80%, compared with about 65% for most other varieties). The grain is nonshattering and is difficult to thresh. However, despite this difficulty, it is very highly regarded for its aromatic character and excellent eating quality, on account of which it is sometimes eaten alone without the usual side-dishes. It was reported to be

Table 1. Variant forms of variety Khao kai noi (small chicken rice) and source of collection.

Lao name of variant	English name equivalent	Character	Source of sample	
			Province	Ecosystem
Khao kay noi	Small chicken rice	Standard variety	Northern region	Lowland
Khao kay noi dam	Black small chicken rice	Black glumes	Houaphanh	Lowland
Khao kay noi deng	Red small chicken rice	Red glumes	Houaphanh	Lowland
Khao kay noi khaw	White small chicken rice	White glumes	Houaphanh	Lowland
Khao kay noi leuang	Yellow small chicken rice	Yellow glumes	Houaphanh	Lowland
Khao kay noi lai	Striped small chicken rice	Striped glumes	Houaphanh	Lowland
Khao kay noi hai	Upland small chicken rice	Adapted to upland environment	Houaphanh	Upland
Khao kay noi hom	Aromatic small chicken rice	Aromatic	Houaphanh	Lowland
Khao kay noi hang	Awned small chicken rice	Awned spikelets	Xieng Khouang	Lowland
Khao kay noi/nam yen	Cold (water)-tolerant small chicken rice	Cold-tolerant	Houaphanh	Lowland

Source: Appa Rao et al (Chapter 10).

high yielding under the low-input conditions that prevail in most areas of Laos, with yields of 3 to 4 t ha^{-1} in parts of Xieng Khouang in the northeast and 4–5 t ha^{-1} in Houaphanh in northern Laos.

Based on glume color and other characteristics, nine variant forms of the variety have been identified, with some of the varieties having additional descriptions in the varietal name to reflect some characteristics (Table 1). Variety *Khao kai noi lai* (striped small chicken rice) has glumes with longitudinal red and yellow alternating stripes; *Khao kai noi leuang* (yellow small chicken rice) has yellow glumes, whereas *Khao kai noi deng* (red small chicken rice) has red glumes. *Khao kai noi hang* (awned small chicken rice) has awned spikelets. Of the nine variant forms, *Khao kai noi leuang* is regarded as being the most aromatic. The brown rice of all the variants is generally similar in appearance. In most fields, only one of the forms is grown. In gross morphology, *Khao kai noi* appears to be intermediate between the indica and tropical japonica (javanica) groups.

Khao poum pa (fish stomach rice)

Variety *Khao poum pa* (fish stomach rice) was developed in Sing Sai village in Khoua District of Phongsaly in northern Laos. The origin of this variety is reported to be similar to that of *Khao kay noi*, but with *Khao poum pa* being developed in Laos from rice grains found in the stomach of a fish rather than in the stomach of a chicken as for *Khao kay noi*. The undigested grains were planted and multiplied, with the resulting crop being found to give a superior yield relative to other varieties being grown in the area. Through farmer-to-farmer and village-to-village exchange, *Khao poum pa* is now a well-known variety among farmers and villages near its area of origin in Phongsaly Province. The variety is also known as *Khao khay pa* (fish egg rice), both names reflecting the source of origin of the seed, which formed the basis of the variety.

Khao holo (holo tree rice)

The origins of this variety were reported by farmers to have been based on a single rice plant that a local farmer found growing under a "holo" tree in the village of La Kao in Phongsaly District of Phongsaly Province, one of the most remote northern provinces of Laos. The holo tree is used by one of the ethnic groups of Phongsaly Province, the Phu Noi, as an indicator of relatively high soil fertility and a basis of selection of upland areas for rice cultivation. After seed multiplication and field testing, the single rice plant collected formed the basis of a new traditional variety, which was named *Khao holo*. This variety is still very popular in Phongsaly District where it was developed. It is an upland glutinous aromatic variety of medium maturity.

Farmers' seed multiplication practices for maintenance of varietal purity

Lao farmers produce their own seed of traditional and recently developed modern varieties. For seed purposes, farmers in the lowland environment usually select fields where the crop is growing well, is phenotypically uniform, and, where possible, has not been stressed during growth. Mature grain to form the seed of each variety is harvested separately, bundled, and carried to the threshing floor, where the sheaves of each variety are also kept and threshed separately. After threshing, the seed of each variety is stored in separate containers. As the farmers are able to readily identify the varieties based on their seed characters, they usually do not need to label the containers in which the seed is kept.

Farmers usually rogue off-types on the threshing floor and select uniform panicles for sowing in the subsequent year. The farmers have a clear idea and mental picture of unique varietal characteristics and avoid off-types. Avoiding off-types in the process of panicle harvesting or subsequently on the threshing floor is almost equivalent to mass selection. Lowland farmers repeat the seed selection process once every three years, as they believe that varietal characteristics will be lost and new types will appear if they do not maintain a routine of seed selection.

At harvest time, during the process of panicle selection for seed purposes, upland farmers usually tie a basket around their waist and select large and attractive panicles of distinct types, which are placed in the same basket (Photo 13.3). Some highland farmers harvest panicles along with peduncles; on returning to their house, farmers usually tie the panicles into bundles, dry them in the sun, and then keep them carefully in the house, often hanging them from roof rafters, with particular care being taken to protect them from being damaged by grain moth. Some farmers (particularly those belonging to the Hmong ethnic group) keep the panicles above the kiln, where the smoke keeps away the grain moth. In some areas, the grain of selected panicles is stripped after selection, with the bulk of the panicles being left in the field.

Lao farmers, particularly in the uplands, deliberately maintain a degree of diversity within a particular landrace to provide production stability. Variable populations in upland varieties are maintained by selecting different plant and panicle types found in a single field.

Management of varietal diversity

Enormous varietal diversity existed in Lao rice varieties before the mid-1990s (Schiller et al 2001). This diversity was largely based on the indigenous traditional varieties that had evolved over centuries within Laos, farmer-to-farmer exchange within the country, the introduction of exotic varieties by farmers from neighboring countries, and the introduction of varieties by foreign agencies and institutions (Schiller et al, Chapter 2), combined with the development of new varieties by Lao farmers. Varietal diversity in the indigenous traditional varieties has evolved and accumulated, as rice has been grown under increasingly diverse agroclimatic conditions and ecosystems, and to meet an increasing range of food quality preferences of the diverse range of ethnic groups found in many areas of Laos.

The strategies for farmer management of varietal diversity under upland and rainfed lowland conditions differ considerably. Upland farmers grow varieties that are composed of several phenotypes but that have similar height and phenology. Lowland farmers usually grow several uniform varieties of varying maturity, mainly to distribute the labor requirement, with each variety being grown in individual small plots. Growing several varieties also assists in providing greater production stability by reducing the risks of the impact of climate (mainly drought), pests, and diseases if only one or two varieties are grown. Lao farmers have an extensive and intimate knowledge of different varieties and their characteristics, adaptation, and quality attributes.

Lao rice farmers have not only maintained a wide variety of landraces, but have also continuously evaluated and improved their planting material and exchanged it with others. The tradition of farmers developing and maintaining diversity can still be found in many areas of Laos, particularly in the rainfed upland conditions of northern Laos.

The present management system has been changing fast, particularly since 1993, following the release of the first of a number of improved Lao varieties developed for the lowland environment for the main lowland rice-growing areas in the Mekong River Valley. The release of these "modern varieties" has been associated with the development of agricultural extension services, which, combined, have aimed at quickly achieving national and household rice self-sufficiency, together with improvements in individual rural household income through agricultural diversification. These initiatives have already resulted in rapid and marked changes in rice diversity throughout most of the main rice-growing areas in the Mekong River Valley. By 2000, less than 20% of the main wet-season lowland rice area in this valley was grown with traditional varieties compared with about 95% as recently as 1993, the year in which the first batch of improved Lao lowland varieties was released. Although traditional varieties continue to be used in lowland areas of northern Laos, the erosion of the remaining diversity can be expected as new higher yielding varieties are developed for these areas. Similarly, in upland areas, the diversity can also be expected to be eroded as a result of a combination of the implementation of the national policy for more sustainable agricultural practices in the uplands and the identification of upland varieties with broad adaptability.

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Notes

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CHAPTER 14
Glutinous rice in Laos

J.M. Schiller, S. Appa Rao, P. Inthapanya, and Hatsadong

Laos has the highest per capita production and consumption of glutinous rice in the world. Laos and its people also have a particularly strong cultural affinity for glutinous rice. Although accurate data on planted area and production of glutinous rice are not available (IRRI 2002), it is estimated that, in the 2004 production year, about 85% of the rice produced in Laos was glutinous (Fig. 1, Table 1). Differences exist, between regions and between production systems, in the relative significance of glutinous rice production. These differences reflect a combination of (1) regional differences in the ethnic composition of the population and related differing rice consumption preferences, (2) differences in the relative importance of the different ecosystems in the different regions of the country, and (3) the impact of the relatively recent introduction and adoption of new and improved rice varieties in the different rice-based ecosystems.

The highest proportion of glutinous rice (about 91%) is grown in the dry-season irrigated environment (Table 1); this environment almost exclusively uses improved glutinous varieties released by the Lao National Rice Research Program (NRRP) since 1993. The lowest proportion of total rice cultivation that is glutinous (60%) is in the rainfed upland environment in the northern agricultural region; the lower level of glutinous rice production in this ecosystem reflects the relatively large populations of the Hmong and Mien (Yao) ethnic groups in this region and production ecosystem, both of which produce and consume mainly nonglutinous rice.

Of the 48 recognized ethnic groups in Laos (UNDP 2002), most are predominantly consumers of glutinous rice (Table 2). The Tai-Lao linguistic group, the largest, accounts for more than 65% of the population (Table 3). They largely migrated from southern China, settling in the Mekong valley before the thirteenth century (Hamada 1965, Batson 1991, Simms and Simms 1999). As a group, they are also the largest consumers of glutinous rice, which accounts, on average, for about 90% of their rice intake. The ethnic groups regarded as indigenous to Laos, the Mon-Khmer people (including the Khmu and Lamet in the north, and the Kasseng, Loven, Souay, Katu, and Bru in the south), are all predominantly consumers of glutinous rice. Some of the smaller ethnic groups in the Mon-Khmer language group have the highest levels (about 95%) of glutinous rice consumption in the country. The Tibeto-Burmese groups (Akha,

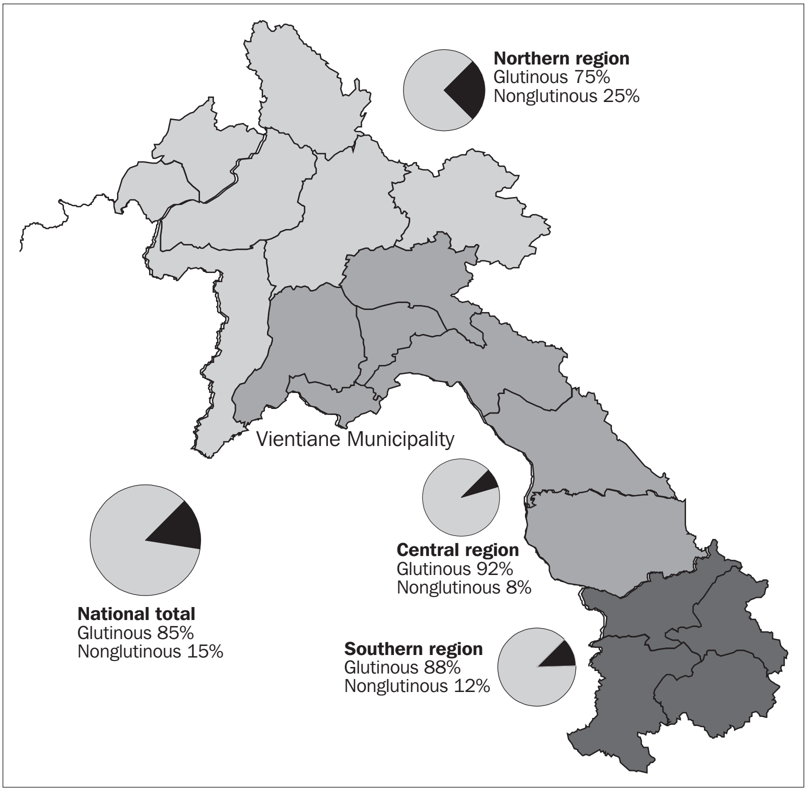

Fig. 1. Relative significance of glutinous and nonglutinous rice production in the different regions of Laos.

Table 1. Relative significance (%) of production of glutinous and nonglutinous rice among the agricultural regions and production environments of Laos.[a]

Production environment	Central region		Southern region		Northern region		Total	
	G	NG	G	NG	G	NG	G	NG
Wet-season lowland[b]	85	15	80	10	80	20	87	13
Rainfed upland	88	12	95	5	60	40	80	20
Dry-season Irrigated	92	8	92	8	90	10	91	9
Total	88	12	92	8	75	25	85	15

[a]Estimates not based on accurate production data, as separate statistics on glutinous and nonglutinous rice production are not collected. G = glutinous, NG = nonglutinous. [b]Part of this area is irrigated during the growing season.

Table 2. Ethnic groups of Laos and their distribution and rice preference.[a]

Ethnic group (general name)	% population (see Source)	Geographic distribution (provinces)[b]	Rice preference (% glutinous)
Lao-Tai (Tai-Kedai) language family (8 groups)			
Lao	52.31	Country-wide	90
Phou Thay	12.30	PhL, LTh, UD, BK, LP, HPh, XKh, VT, VTm, SB, BX, KM, SV, SR, ChS	70
Tai	2.86	UD, LTh, BK, PhL, SB, LP, VTm, VT, XKh	80
Lue			
Nyouan	0.92	LTh, SB, LP, BK, VT, UD	90
Yang	0.09	PhL, LTh, UD, BK	30
Sek	0.06	KM, BX	70
Tay Neua			
Mon-Khmer language family (32 groups)			
Khmu	10.87	PhL, LTh, BK, UD, SB, LP, HPh, XKh, VT, VTm, Ss, BX, KM	90
Katang	2.01	SV, SR, ChS, KM, VTm, SK	80
Makong	1.96	SV, KM, BX, VT, VTm	80
Souay	1.36	SV, SR, ChS, SK, VT, VTm	95
Jrou	0.73	ChS, SR, AtP, SK, VTm	95
Ta Oy	0.68	SR, SK, AtP, ChS, SV	95
Triang	0.66	AtP, SK, SR, SV	95
Tri	0.58	SV, KM	90
Phong	0.50	HPh, XKh, BX, KM, VT, VTm	90
Lavi	0.45	AtP, ChS, SV, VTm	80
Katu	0.40	SK, SR, ChS, SV	90
Lamet	0.40	UD, LTh, BK, HPh	80
Pray	0.38	SB, LP, XKh	80
Halak	0.66	XKh, AtP, ChS, SR, VTm	80
Pacoh	0.36	SR, SV	80
Kriang	0.24	XKh, SR, ChS	90
Cheng	0.12	AtP	–
Nya Heun	0.11	AtP, ChS	70
Ngouan	0.09	AtP, XKh	70
Sam Tao	0.06	LTh, BK	70
Ksingmoun	0.06	HPh, VT, BX	70
Bit	0.04	PhL, LTh, UD	90
Brao	0.01	SK	–
Khmer	0.004	ChS	–
Oy	–	AtP, ChS	80
Sadang	–	AtP	–
Meuang	0.02	HPh, XKh, VT	70
Toum	0.02	KM, BX	80
Yè	–	KM, BX	90
Kri	–	SB, KM, BK	–
Oe Du	–		
Thene	–		

Continued on next page

Table 2 continued.

Ethnic group (general name)	% population (see Source)	Geographic distribution (provinces)[b]	Rice preference (% glutinous)
Sino-Tibetan language family (7 groups)			
Akha	1.40	PhL, LTh, UD, BK	70
Singsily	0.66	PhL, UD, LTh, BK, LP, VT, VTm	90
Lahu	0.45	BK, LTh, UD	90
Sila	0.08	PhL, LTh	90
Lolo	0.03	PhL	85
Hanyi	0.02	PhL	90
Ho	0.10	LTh, PhL, UD, LP, HPh, XKh, VT.VTm, KM, ChS	85
Hmong-Mien language family (2 groups)			
Hmong	3.17	SK, VT, HPh, UD, PhL, BK, SB, LTh, Ss, VTm, KM	40
Mien (Yao)	0.30	PhL, LTh, UD, BK, HPh, XKh, SB, LP, VT, VTm	40

[a]Based on linguistic groupings of UNDP (2002): Lao PDR Human Development Report 2001. [b]PhL = Phongsaly, LTh = Luang Namtha, UD = Oudomxay, BK = Bokeo, LP = Luang Prabang, HPh = Houaphanh, XKh = Xieng Khouang, VT = Vientiane, VTm = Vientiane Municipality, SB = Sayabouly, BX = Borikhamxay, KM = Khammouane, SV = Savannakhet, SR = Saravane, ChS = Champassak, SK = Sekong, AtP = Attapeu, Ss = Saysoumboun Special Zone.
Source: Lao Front for National Construction, Department of the Ethnic Group Social Class, July 1999 (*1985 population census, the last for which the breakup of ethnic groups has been published).

Table 3. Population by ethno-linguistic groupings.

Ethnic grouping	Percentage
Tai-Lao (Tai-Kadai)	
Tai and Neua-Phouan	36.5
Lao	30.0
Austroasiatic (Mon-Khmer)	23.5
Hmong-Mien (Yao)	7.5
Sino-Tibetan	
Tibeto-Burmese	2.5
Chinese Ho	0.2

Source: UNDP (2000).

Lahu, Lolo, Singsily [or Phunoi]) who arrived in Laos via Yunnan or Myanmar, and who now live in areas of Laos bordering Myanmar and China, also mainly consume glutinous rice (Dobby 1958). As noted above, the two main ethnic groups in Laos that are consumers of nonglutinous rice are the Hmong and Mien (Yao). Originating from the Kewichow area of southern China, they migrated to Laos in relatively recent times, during the 19th and early 20th centuries (Batson 1991, UNDP 1997). Before their arrival, probably almost 100% of the rice produced and consumed in the country was glutinous.

Quality characteristics of traditional glutinous rice

Cooking and eating characteristics are largely determined by the properties of the starch that makes up 90% of milled rice, with most of these characteristics being influenced by the ratio of two kinds of starch in the rice grain, amylose and amylopectin (Dela Cruz and Khush 2000). Amylose is the linear fraction of starch, whereas amylopectin is the branched fraction. Amylose content strongly affects the cooking and eating qualities of rice—its cohesiveness, tenderness, color, and gloss (Mackill et al 1996). The terms usually used to reflect the amylose content of rice grain (Dela Cruz and Khush 2000) are

waxy	0–2%
very low	3–9%
low	10–19%
intermediate	20–25%
high	>25%

Amylose is almost absent from glutinous (or waxy) rice. A characteristic of these varieties is that they absorb little water during soaking and steam cooking, and therefore have low volume expansion. The grain of most high-amylose rice varieties shows high volume expansion (up to 400%) during cooking (but not necessarily elongation). Low-amylose rice is moist, sticky, and glossy when cooked (Dela Cruz and Khush 2000, Mackill et al 1996). The texture of the cooked rice is affected by gelatinization temperature (the temperature at which starch starts to soften and starch granules swell irreversibly). Rice that gelatinizes at high temperatures (>74 °C) takes a long time to cook and, when finally cooked, is excessively soft; it also disintegrates when overcooked. Such rice generally requires more water and time for cooking than does rice that has low (<70 °C) or intermediate (70–74 °C) gelatinization temperatures. Such rice is undesirable in all rice markets (Mackill et al 1996). Low gelatinization temperature is the most common property of the preferred waxy rice varieties.

Another characteristic feature of glutinous rice that distinguishes it from the nonglutinous form is that, if the moisture content of the glutinous form is reduced to about 15%, the endosperm becomes opaque and its color changes to milky white or paraffin-like (Watabe 1967). This white appearance comes as a result of the way light is differentially refracted in the starch crystals in the absence of amylose. In nonglutinous rice, the endosperm remains translucent regardless of the moisture content of the grain.

There appears to be relatively little specific information available relating to the relative nutritional value of glutinous and nonglutinous rice. It has been suggested that the higher amylopectin content of glutinous rice and the associated larger molecular size and its branched molecular structure result in it staying longer in the digestive system than nonglutinous rice. This, in turn, is reflected in the belief by glutinous rice consumers that they only feel "full" when they consume glutinous rice; they complain that the consumption of nonglutinous rice results in their becoming hungry again within a short period of time. The volume expansion of glutinous rice relative to nonglutinous rice on being cooked, and the resulting higher weight:volume ratio of glutinous vs nonglutinous rice on consumption, probably explains the effects of perceived differences in "fullness and hunger" between the two types of rice. It is sometimes observed that "the eater of glutinous rice consumes about 25% more rice per day (in calories and weight) than those who eat nonglutinous rice." However, it is also suggested that this relatively higher intake of glutinous rice is associated with a proportionately lower intake of meat and vegetables (reflecting the economic status of many of the glutinous rice consumers) (Ngaosyvanthn and Ngaosyvanthn 1994).

Grain quality characteristics of Lao traditional rice varieties have been studied and reported by Juliano and Villareal (1993). The relative proportions of amylose and amylopectin were found to vary among and within both glutinous and nonglutinous varieties. Among the glutinous varieties, amylose ranged from 2.6% in *Mae hang* (divorced woman) to 4.8% in *Pa lat* (lat fish). The nonwaxy or nonglutinous varieties were found to have an intermediate amylose content, ranging from 21% in *Po kha* (merchant) to 24.5% in *Lep nok* (bird claw), the latter being formerly extensively grown for noodle production in the southern province of Champassak. The glutinous varieties have very low amylose content, ranging from 2.6% to 4.8%. Protein content was found to vary from 6% to 9%, with a mean of 7.4%. In general, glutinous varieties were found to have a lower protein content than nonglutinous varieties. These analyses were undertaken on a very small sample of the great range of germplasm that exists in Laos.

Lao consumers, both urban and rural, are very conscious of the quality of cooked rice. Based on the texture of the cooked grain, farmers classify it as soft or hard; there is a distinct preference for grain that is soft after cooking. The character of the grain after cooking is sometimes reflected in the name given to a variety, such as *Khao gne* (sand rice) and *Khao khang lout hak* (broken jaw rice), both of which suggest that other qualities have been the basis of their selection and maintenance as varieties. Appa Rao et al (2002b) have reviewed how farmers have named their varieties to reflect their different quality characteristics in an extensive collection of traditional varieties made from 1995 to 2000. Keeping quality of rice after cooking is another important attribute, as rice cooked in the morning is often taken to the field in woven bamboo baskets to meet household needs during the working day.

Some traditional varieties are intermediate between glutinous and nonglutinous forms. The eating quality of these intermediate types is considered inferior. Occasionally, these varieties are given names to reflect their poor eating quality: *Khao mangyeng* (rice watched by a dog) was so named because of the belief that even a dog does not like to eat it, but will sit and stare at the rice before eating it reluctantly). One type of nonglutinous-sticky rice (*Khao chao niaw*), although regarded as nonglutinous, becomes sticky after cooking. Other varieties carry in their name a reflection of the floury or powdery nature of the endosperm. Studies of the amylose and amylopectin content of such varieties have yet to be undertaken. Varieties with brittle endosperm, liable to crack on milling, also exist and have names to reflect their characteristics (Appa Rao et al 2002b).

The genetics of glutinous endosperm

Yamanaka (2001) has reviewed the genetics of glutinous endosperm of rice and other cereals. The two major endosperm types, waxy (glutinous) and nonwaxy (nonglutinous), are controlled by a gene at a single locus. This waxy locus is responsible for amylose synthesis and shows tissue-specific expression in the endosperm and pollen. The waxy allele, which is responsible for amylose synthesis, is regarded as the wild type and is genetically dominant. Glutinous rice has naturally occurring mutants, in which the mutant form is the waxy gene. The mutation appears as a deletion in the gene, which results in no amylose being synthesized. The waxy (glutinous) allele, which is associated with a lack of amylose, is regarded as a spontaneous mutant and is genetically recessive. The waxy mutation has been recognized in seven cereals: rice (*Oryza sativa*), maize (*Zea mays*), barley (*Hordeum vulgare*), foxtail millet (*Setaria italica*), Job's tears (*Coix lacryma-jobi*), common millet (*Panicum miliaceum*), and sorghum (*Sorghum bicolor*). These waxy mutants are found specifically in Asia and are believed to have been preferred selections during domestication (Yamanaka 2001).

DNA analysis of collections of traditional glutinous cultivars made during the 1990s from both the upland and lowland environments of Laos has indicated that most traditional glutinous cultivars in the country belong to the tropical japonica varietal group (Glaszmann 1987, Roder et al 1996, Ishikawa et al 2002). In contrast, many of the improved glutinous varieties recently introduced to the main lowland rice-growing area in the Mekong River Valley have been shown to belong to the indica varietal group (Yamanaka 2001). The parentage of of these improved glutinous varieties grown in Laos is based on genetic material from sources other than Laos (Inthapanya et al, Chapter 21).

Origins and diversity of glutinous rice in Laos

It is generally accepted that Laos lies within the primary center of origin and domestication of Asian rice (*Oryza sativa* L.). Within this general region, it is also recognized that the center of origin of glutinous rice is Laos and northeast and northern Thailand (Watabe 1976). Other areas of significant glutinous rice cultivation are also found in the region, such as Shan and Kachin states of Myanmar, the Kwangsi Chuang and Yunnan regions of China, parts of Cambodia that border Thailand and Laos, and mountainous areas of Vietnam that border Laos. Glutinous rice is generally found in those Asian countries with a long history of rice cultivation (Dobby 1994). Several hypotheses have been proposed to explain the origin, spread, and persistence of glutinous rice as a staple crop in this region (Dobby 1958, Watabe 1967, 1976, Golomb 1976, Khush 1997, Yamanaka et al 2001). There is archaeological evidence of early domesticated rice cultivation in northeast Thailand from at least 2,000 BC (Khush 1997, White 1997); this early cultivation is believed to have been based on glutinous genotypes. It is also believed that all early rice cultivation throughout Thailand was based on glutinous genotypes. The gradual shift to nonglutinous rice cultivation and consumption is thought to have commenced at about the beginning of the 15th century (Ngaosyvanth and Ngaosyvanth 1994). This change initially took place in the lower basin of the Chao Phraya River in the area immediately north of the capital, Bangkok. The transition from glutinous to nonglutinous rice consumption was completed for the Central Plains region and part of northeast Thailand by the 18th century. Although Golomb (1976) has proposed that nonglutinous rice preceded glutinous rice in much of the "glutinous zone," little evidence supports such a theory. It is generally acknowledged that the Tai people who moved from their area of origin in southern China had already developed a preference for glutinous rice before moving to what is now Thailand and Laos. However, it remains a matter of conjecture whether this preference for glutinous rice was on account of the superior adaptation of glutinous rice to the cooler growing conditions (and shorter growing period) in the area of origin of the Tai people, as argued by Golomb (1976), or conscious selection based on a taste preference, as proposed by Watabe (1967). The preference of nonglutinous rice by the Hmong and Mien ethnic groups, who also generally live in the more mountainous (and cooler) parts of the region, also contradicts the argument of Golomb of "superior adaptability of glutinous rice to highland environmental conditions." Archaeological evidence (Khush 1997) suggests that glutinous rice was grown extensively throughout the region, including in the lowland environment, and it is probable that the current "glutinous rice zone" is a contraction of the much broader use of glutinous rice in the region, as suggested for Thailand by Ngaosyvanthn and Ngaosyvanthn (1994).

Regional cultural significance of glutinous rice

The change from growing glutinous rice to nonglutinous rice in the central region of Thailand has been associated with certain social or cultural traditions; these have been reviewed by Ngaosyvanthn and Ngaosyvanthn (1994). The early shift from the consumption of glutinous rice was usually associated with the "affluent classes and intelligentsia." Glutinous rice then became regarded as "the staple food for the poor people," and, in parts of Thailand, its consumption often became regarded as "an affirmation of a person's social status and/or regional identity." At one time, government officials were served glutinous or nonglutinous rice in accordance with their rank: lower-ranking officials received glutinous rice, while higher-ranking officials were served the nonglutinous form.

An aversion to the consumption of glutinous rice of those who had made the change to nonglutinous rice is reflected in Thai chronicles of 1827, when the Thai army was marching toward Vientiane to suppress what was regarded as a "renegade neighbor." Ngaosyvanthn and Ngaosyvanthn (1994) report that, in a dispatch to the Royal Court of Bangkok at that time, the following was recorded: "The armies found plenty of glutinous rice along their route to Vientiane, but desperately complained that it was inedible, and a request was made to Bangkok for 'white rice' (nonglutinous rice) to be sent to maintain the fighting strength of the army. Strong ingrained psychosomatic ideas prevented them from consuming glutinous rice, which they blamed for causing constipation, drowsiness, and even laziness. This contrasts with the people in the 'glutinous rice zone,' who have a self-image of being 'hard-working and more solid than nonglutinous rice eaters.' They believe that there is no way a working man could possibly sustain himself on a diet of ordinary rice."

The people of Laos have the highest per capita consumption of glutinous rice in the world. The annual per capita consumption of milled rice in Laos during the 1990s was about 174 kg (IRRI 2002). For the majority of Laotians, more than 90% of the rice consumed is glutinous rice. The people of Laos proudly regard the consumption of glutinous or "sticky" rice as part of their cultural identity. The Lao language expression "to eat" not only means "to eat rice" as in the language of their Thai neighbors, but "to eat glutinous rice." The cultural and national association with glutinous rice is also sometimes reflected in the people of Laos saying that if they did not eat glutinous rice, they would not be Laotian. This identification of the Lao with glutinous rice has often been retained by those Lao who have migrated elsewhere. Ngaosyvanthn and Ngaosyvanthn (1994) report that one of the most popular Lao music bands in the United States was known by the name *Khao niaw* (sticky rice).

Collections and diversity of glutinous rice

Recognizing the great diversity of traditional rice varieties in Laos, particularly glutinous rice, there have been attempts to collect and conserve this rice germplasm. The collecting and conservation attempts can be divided into two periods.

Collections before 1995

From 1970 to 1990, collecting missions supported by USAID, Russia, Japan, and other agencies gathered more than 3,000 samples of cultivated traditional rice (Inthapanya et al 1995). Most of those collections constituted traditional glutinous varieties. However, on account of a lack of appropriate storage facilities in the country, most of the germplasm collected in that period is no longer available. From 1991 to 1994, a further 1,000 samples were collected, mainly from the northern provinces of the country in a joint collecting program of IRRI and the Lao Ministry of Agriculture and Forestry. Although these later collections contained a large proportion of glutinous varieties, they were inadequately documented with passport data.

Collections from 1995 to 2000

Systematic collection of the rice germplasm in Laos began in 1995 in a collaborative project between the Lao Ministry of Agriculture and Forestry (MAF) and the Genetic

Table 4. Relative distribution between environments in Laos of glutinous and nonglutinous samples of traditional germplasm collected between 1995 and 2000.

Endosperm category	Upland environment		Lowland environment		Total	
	No.	%	No	%	No.	%
Glutinous	6,237	84.6	5,042	86.6	11,279	85.5
Nonglutinous	1,134	15.4	779	13.4	1,913	14.5
Total	7,371	100.0	5,821	100.0	13,192	100.0

Source: Appa Rao et al (2002a).

Resources Center (GRC) of IRRI in the Philippines. Between October 1995 and April 2000, a total of 13,192 samples of cultivated rice and 237 samples of six wild rice species were collected throughout the country (Appa Rao et al 2002a). Glutinous rice made up 85.5% of this collection. Overall, 86.6% of the samples collected in the lowlands and 84.6% of the samples collected in the uplands had glutinous endosperm (Table 4). Relatively more nonglutinous types were sampled in the northern agricultural region than in other regions (Fig. 1), reflecting the preference for nonglutinous rice by the Hmong and Yao ethnic groups there (Table 2).

Processing and consumption of glutinous rice

Processing

Traditionally, individual households dehull rice grain manually by pounding sun-dried grain in a wooden mortar using a wooden pestle. In some areas, a foot-operated pestle is used. These techniques still prevail in upland areas and some more remote lowland areas. However, roller mills are now used for dehulling in urban areas and in most lowland villages, particularly in the main rice-growing areas of the Mekong River valley. One or several such mills might serve the needs of an entire village, depending on the size of the village; small individual household mills are not in use.

Normal preparation for consumption of glutinous rice involves soaking the white rice overnight (or for up to 10 hours), followed by steam cooking in the early morning for 30–40 minutes in a woven bamboo basket. Usually, the household consumption needs for the day are met through this single early-morning preparation. More than 95% of the glutinous rice consumed is prepared in this way.

Consumption

The consumption of glutinous rice by the ethnic Tai-Lao of Laos and northeast Thailand has traditionally been associated with the consumption of a pickled raw fish paste called *padek*. The cultural association of the Lao with this traditional food combination is reflected in a popular song called "To eat glutinous rice and padek" (Ngaosynvanthn and Ngaosyvanthan 1994). Although the consumption of rice noodles is popular in urban areas, noodle production is generally based on the use of nonglutinous rather than glutinous grain.

Although probably more than 90% of the glutinous rice consumed is in the form of steamed rice, eaten with one or more side-dishes, a large range of other forms of rice preparation for consumption have been adopted by the people of Laos, with different ethnic groups having their own specialized preparations. Some of the better known of the glutinous rice-based preparations include the following (Photos 14.1 and 14.2):

- *Khao mao* is a soft, aromatic, and tasty form of flaked rice that is usually eaten with small quantities of boiled coconut milk and sugar. A popular preparation of the lowland Lao population group, *Khao mao* is made from "almost ripe rice" that is harvested at the early dough stage; it is prepared by following a process of steam cooking, drying, dehusking, and then being steamed again.
- *Khao haang* (parboiled rice): This is a form of parboiled rice that is made from paddy harvested at the late dough stage, followed by steaming the grain with hulls, dried in sun, dehulled by pounding, and consumed after steam cooking. Some ethnic groups steam the grain while it is still in the panicle. Following steaming, the grain or panicles are sun-dried, then pounded and winnowed to give the parboiled rice. This is either consumed as glutinous rice prepared in the usual way or used to prepare special delicacies or snacks. It is generally believed that parboiling improves taste and quality. However, parboiling is recognized to be time-consuming and requires more fuel than regular rice preparation.
- *Khao waan* (sweet rice): This is a popular snack food that is usually made from parboiled rice. It is prepared using whole dehulled grain, which is cooked in combination with coconut milk, sugar, taro, and/or pumpkin.
- *Kanom piak-poon* (rice cake): This is a flat square or rectangular cake made from a mixture of glutinous and nonglutinous rice. Rice flour is made from grinding the grain of both types of rice. The flour is cooked in a mixture of coconut milk, water, sugar, and salt. After cooking, it is poured into a flat container, cooled, and cut. It is a popular product in local markets.
- *Kanom khok:* Glutinous and nonglutinous rice in proportions of 2:1 are presoaked in water for 4 to 6 hours, and then ground to obtain a free-flowing batter of the desired consistency. Using a metal pan with 9 to 12 cup-like depressions, the batter is poured into the depressions, which are first smeared with pig fat. Grated coconut is usually added to the top of the batter and the pan is then held over a low fire to allow the mixture to cook.
- *Khao tom-phat:* Polished glutinous rice is soaked in water for 4 to 6 hours. The water is decanted and sugar, salt, and coconut milk are added to the rice; the mixture is then boiled. Split mungbean seed, which has been soaked in water for about 12 hours, steamed for 30 to 40 minutes, and subsequently

crushed in a mortar, is added to the cooked rice mixture. This is then wrapped in banana leaves and steam-cooked or boiled for 20 to 30 minutes.

- *Khao tom-kheuang:* Glutinous rice is soaked in water for about 6 hours and the excess water subsequently decanted. The rice is then spread on a banana leaf, to which is added a mixture of small pieces of pork, onion, garlic, pepper, and salt. The resulting mixture is then wrapped in the banana leaf and steamed for 2 to 3 hours.
- *Khao sangkhaya:* Glutinous rice is presoaked in water for 4 to 6 hours, then steamed for 30 to 40 minutes after decanting the water. A mixture of coconut milk, salt, and sugar is added, followed by a further period of steaming for 30 to 40 minutes. This is then consumed in combination with a specially prepared sweet dressing made by steam cooking for about 30 minutes, marinated with a combination of fresh eggs, coconut milk, and flour.
- *Khao niaw deng:* Glutinous rice is presoaked in water for 4 to 6 hours and, following decanting of the water, steamed for 30 to 40 minutes. It is then boiled in a combination of coconut milk, salt, palm sugar, or refined sugar. The viscous mixture is then spread in a flat container to which roasted sesame seed or groundnut grits are added. If refined palm sugar is used in the preparation, the final product is red in color and is called *Khao niaw deng* (glutinous rice, red); if refined sugar is used, the final product is whitish and is called *Khao niaw keo* (glutinous rice, white).
- *Khao kriab:* Glutinous rice is soaked in water for 4 to 6 hours and then steamed for 30 to 40 minutes. Upon cooling, it is made into thin round cakes that are sun-dried. These rice cakes are then deep-fried in oil and immersed in syrup made from palm sugar.
- *Khao lam:* Coconut milk, sugar, and salt are added to presoaked glutinous rice, and the resulting mixture is packed into a piece of hollow bamboo. Sometimes the soaked grain of legumes, yam, or sweet potato pieces is added to the mixture. The bamboo is then roasted over an open fire. On cooling, the inner membrane of the bamboo forms a layer around the cooked rice that separates with the rice when the outer bamboo layer is stripped away. Both white and dark-colored grains are used for this preparation that is popular throughout the country.
- *Kanom-nep:* Glutinous and nonglutinous rice grain are mixed in a proportion of 5:1 and presoaked in water for 4 to 6 hours. After decanting the water, the mixture is ground into a paste and made into egg-size portions. Inserted into each portion is a special mixture of grated coconut and sugar, or each portion is steamed with mungbean flour and sugar. Each portion is then wrapped in a banana leaf and steam-cooked for at least 30 to 40 minutes.
- *Khao kaed (Pok-peuak):* Developing grain that has reached the dough stage is sometimes harvested as individual panicles; the glumes are removed from the spikelets using a nail and the soft grain consumed. Varieties with large grains are preferred for this kind of consumption. Some traditional varieties, such as *Khao lep chang* (elephant nail rice) and *Khao lep mue* (fingernail

rice), have been so named on account of their suitability for consumption in this way.

Fermented beverages

Rice wine: A large range of alcoholic beverages are produced, consumed, and sold throughout Laos, the production of most of which is based on the use of glutinous rice. The consumption of these rice-based alcoholic beverages is a usual part of any traditional Lao social occasion. These beverages are also readily available in most local markets. Rice wine is a requisite part of many ceremonies, especially among the Mon-Khmer.

The most widespread method of alcohol production is to ferment steamed sticky rice with balls of yeast in sealed earthenware pots, which are then kept in the shade. The mixture is allowed to ferment for 3 days to 1 week (the longer the fermentation period, the higher the alcohol content and quality). Different ethnic groups have different recipes for rice-based alcohol production. Members of the Khmu ethnic group usually follow precise traditional recipes that are maintained by families, with different flavors of wine being produced, from bitter to sweet-tasting (Simana and Preisig, Chapter 6).

Rice brandy: Rice brandy is made from rice wine and is produced by distilling the rice wine, using a simple home distillation technique. Although the Khmu drink some rice brandy, it is not as popular as rice wine. Many Khmu communities make rice brandy strictly for ritual purposes. It is generally not consumed in the same way or frequency as rice wine. However, in some northern provinces, this type of alcohol is also served to guests to welcome them and announce them to the house-spirit.

Sweet fermented rice: For the preparation of sweet fermented rice, black glutinous rice is preferred, together with a sweet strain of the fermenting agent. Black rice, when fermented, is more highly regarded than fermented white rice. In producing sweet fermented rice, the rice is first cooked like ordinary glutinous rice. After cooling, the appropriate amount of fermenting agent is added, after which the rice is then put in a jar or bamboo tube, which is then covered. It is allowed to ferment for about 2 days, after which it is ready to eat. Fermented rice is sometimes preferred as a source of energy when upland farmers are engaged in heavy clearing work associated with upland rice cultivation (Simana and Preisig, Chapter 6). It is also sometimes used for animistic rituals by some ethnic groups.

Early introduction and distribution of glutinous varieties

The earliest recorded introductions of improved varieties to Laos took place in the late 1960s and early 1970s (Schiller et al 2001). Some of these introductions were through USAID-sponsored agricultural development projects, and others through a program of collaboration among the governments of Laos, Thailand, and the Philippines. Recent collecting missions (Appa Rao et al 2002a,b) have revealed that some of these introductions are still being used on a limited scale, with the varieties being called by names identified with the programs with which they were introduced, for example, American rice, Philippines rice. These varieties were largely nonglutinous. On account of the preference for the consumption of glutinous varieties throughout the country, these early introductions were grown only on a very limited scale in some areas of rainfed lowland rice cultivation.

Seed multiplication of selected glutinous varieties began in 1964. Three traditional varieties, *Khao do-nang-nuan*, *Khao do-lay*, and *Khao kew-lay*, were the first varieties distributed in the lowlands through the seed multiplication program. Among them, *Khao do-nang nuan* (early maturity, soft lady), an aromatic photoperiod-sensitive variety, was the most popular. In 1971, the varieties *Sanpatong* (a photoperiod-sensitive traditional variety from Sanpatong District in northern Thailand), IR253-100 (an improved variety from the International Rice Research Institute), and *Khao do-hom* (early maturity, aromatic rice), a Lao traditional variety, were also included in the seed multiplication and distribution program. Other glutinous varieties introduced in the late 1970s and 1980s and that were adopted on a relatively large scale included three from the Philippines (IR848-120, IR848-44, and IR789-98) and three from Thailand (RD6, RD8, and RD10). The varieties IR253-100, RD8, and RD10 are still being grown in some provinces. From 1979 to 1989, a number of Vietnamese improved glutinous varieties were introduced and evaluated; the most notable of these was the aromatic japonica-type VN72, and OM80.

Apart from those introductions made through and between government agencies, and selections from among collections of traditional varieties, some varieties from Thailand have been introduced to Laos as a result of farmer-to-farmer exchange between Lao and Thai farmers in the central and southern regions of the country. This seed exchange has almost exclusively been of glutinous genotypes. In the northern agricultural region, there has been similar farmer-to-farmer exchange of lowland varieties, involving Vietnam and China. Most of the varieties obtained from China have been nonglutinous, while those from Vietnam have included both glutinous and nonglutinous varieties. The overall level of adoption of varieties introduced in this manner in the north of the country has been much less than in the central and southern regions.

Early improvement of glutinous varieties for the lowland environment

The first crosses aimed at improving glutinous varieties for Laos were made in 1976 at the Salakham Rice Research and Seed Multiplication Station in Vientiane Municipality. Established in 1955, Salakham Station was the first research station to be established in the country (Schiller et al 2001). The first rice crosses were between the Thai traditional glutinous variety *Sanpatong* and IRRI variety IR848-120; the aim of the cross was to produce varieties with the yield potential of IR848-120 while having the grain quality of *Sanpatong*. Several Salakham lines were subsequently established, but only one, Salakham 1-3-2, demonstrated a yield potential comparable with that of IR848-120. A second set of crosses was made, based on the parental lines *Khao mae-hang* (divorced woman rice), a traditional Lao variety with large panicles, and IR2823-103, a nonglutinous line introduced from IRRI. These crosses aimed at producing a series of high-yielding glutinous lines with a combination of desired plant type and resistance to brown planthopper (BPH). Many promising glutinous fixed lines were established; however, most did not have the yield potential of IR2823-103. A third series of crosses was made based on the Lao traditional glutinous variety *Ea-khao* and IR2823-103; however, no fixed lines were established from the progeny of these crosses. No improved varieties were released as a result of these early breeding initiatives.

Recent developments in the improvement of glutinous varieties

A systematic varietal improvement program for the lowland environments of Lao PDR started in 1991 in collaboration with the International Rice Research Institute. Initial emphasis was on the development of improved glutinous varieties for both the rainfed lowland and irrigated environments. From 1993 to 2004, 14 improved glutinous varieties were released by this program. Many of these varieties have been readily accepted by smallholder rice farmers in the Mekong River Valley. In 1990, less than 5% of the rainfed lowland rice in the Mekong River Valley, the main rice-growing area of the country, was being planted with improved varieties. Along with variety improvement, requirements for the use of nutrients for sustainable rice production were established (Schiller et al 1998). However, by 2000, more than 70% of the area was being planted with improved glutinous varieties, the majority of which were those released by the Lao national rice research program (Schiller et al 2000, Shrestha 2002). Details on these varieties are reported by Inthapanya et al in Chapter 21.

Erosion of Lao traditional glutinous rice varieties

Lowland environment

Following the release of improved Lao glutinous rice varieties in 1993 for the lowland environment (both rainfed and irrigated), there has been a rapid replacement of many of the traditional lowland varieties by improved varieties in provinces in the central and southern regions of the Mekong River Valley, with the rate of replacement accelerating since about 1996 (Schiller et al 1999) and with the availability of technology for increasing yield even in drought-prone areas. The replacement of traditional varieties by improved varieties has been less marked in the northern agricultural region. However, this reflects a lack of improved varieties suited to the agroclimatic conditions in this region, rather than the reluctance of farmers to adopt new varieties. It can be anticipated that, as better-performing improved varieties are identified for the northern region, they will quickly replace most of the traditional varieties still being grown in the early 2000s. However, perhaps the rate of loss will be slower than in lowland areas of the Mekong River Valley because of the greater ecological and ethnic diversity in the northern agricultural region. In lowland areas of the Mekong River Valley, it is expected that there will be a trend toward increased production of nonglutinous rice and the adoption of improved nonglutinous varieties, reflecting increased consumption of this form of rice in the larger urban centers of Laos, together with greater export opportunities for specialized nonglutinous varieties of rice, rather than glutinous ones.

Combined, these factors will inevitably result in the further depletion of the traditional glutinous rice germplasm base in the lowland environment.

Upland environment

In the rainfed upland environment, the erosion of the diversity of both glutinous and nonglutinous rice varieties can be expected as a result of changes in agricultural production in this environment. Current government policy for the upland environment is to focus on the development and promotion of more ecologically sustainable forms of agriculture (Roder et al 1994, UNDP 2000). Theoretically, the implementation of this policy will result in the eventual cessation of rice cultivation under the slash-and-burn shifting cultivation systems (Chazée 1994) that have been the basis of most traditional upland rice cultivation. However, it is also acknowledged that alternative production systems capable of generating the cash income required to enable communities in the upland areas to purchase rather than produce their own rice needs have yet to be developed. In the medium term, it can be anticipated that most upland communities will continue to grow upland rice in order to meet most of their rice consumption requirements. However, this production can also be expected to be within the context of agricultural production systems that are more stable than the slash-and-burn shifting cultivation that has prevailed in the past. The screening of upland varieties collected during 1995-2000 (Appa Rao et al 2002a) has already started, with the aim of identifying varieties able to perform well in the changed cropping environment of short fallow periods, generally lower soil fertility, and potentially higher disease (particularly nematodes) and pest incidence. Testing of some of this material has already begun under upland farming conditions. It can therefore be expected that the current situation with a high level of biodiversity of upland varieties in areas of upland cultivation will change to one in which fewer higher-yielding varieties will be grown on smaller areas. Yamanaka (2001) has shown that, in upland areas of neighboring Thailand, the introduction and use of modern varieties has resulted in significant genetic contamination (by both improved upland and lowland varieties) of the traditional landraces that have continued to be grown. This genetic erosion of traditional varieties in the uplands of Laos can be expected to occur in a way similar to that reported in Thailand.

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CHAPTER 15

Diversity of wild and weedy rice in Laos

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The first scientific study of wild rice (*Oryza* spp.) in Laos was undertaken by the Japanese scientist Hamada, in 1957 and 1958 (Hamada 1965). In subsequent decades, collections of traditional cultivated rice and wild *Oryza* genetic resources have been conducted by Vaughan (1989), Appa Rao et al (1996, 1997, 1998, 1999a,b), and Sato et al (1994, 2001). These surveys have reported five *Oryza* species in Laos: *O. granulata, O. nivara, O. officinalis, O. ridleyi*, and *O. rufipogon*. Of these, *O. rufipogon* and *O. nivara* have the AA genome and are part of the primary gene pool of rice. *O. officinalis* has the CC genome, *O. granulata* has the GG genome, and *O. ridleyi* is a tetraploid species with the HHJJ genome. *O. officinalis, O. granulata*, and *O. ridleyi* are in the secondary or tertiary gene pools of rice and cannot be easily used in rice breeding. Of the five *Oryza* species found in Laos, *O. rufipogon* and *O. nivara* are particularly significant from the viewpoint of rice breeding and conservation of genetic resources.

Description of wild and weedy rice distributed in Laos

O. rufipogon

O. rufipogon (AA genome) (Table 1, Fig. 1A) is believed to be one of the ancestors of cultivated rice. Currently, it is generally accepted that *O. rufipogon* was the progenitor of the japonica ecotype of rice (Yamanaka et al 2003, Cheng et al 2003). This perennial species grows in full sunlight and is often seen in the lowland plains of Laos. It has also been found at the fringe of paddy fields in Bokeo Province in the remote north of the country (Sato 1994). In the Vientiane Plain in the central agricultural region, large populations of *O. rufipogon* are often seen at the edge of paddy fields, in roadside ditches, and in naturally occurring depressions. This species is usually found in areas where there are large fluctuations in the water level (from 50 to 200 cm). It flowers in the last quarter of the year, from October to December, suggesting that it is photoperiod-sensitive (Fig. 2). The regenerative ability from each node is high. Culms of *O. rufipogon* can extend up to 4 m, depending on water depth of the habitat. *O. rufipogon* is highly heterozygous and has high genetic diversity, a high outcrossing rate (30% to 60%), and low fixation index (Barbier 1989, Kuroda et al

Table 1. List of species in the genus *Oryza* in Laos.

Species	Ecotype[a]	Chromosome no. (2n)	Genome group	Geographical distribution in Laos	Geographical distribution in World
O. sativa L.	A/P	24	AA	Throughout Laos	Worldwide
O. rufipogon Griff.	P	24	AA	Throughout Laos (mainly in central and southern regions)	Asia, Oceania
O. nivara Sharma et Shastry	A	24	AA	Throughout Laos (mainly in central and southern regions)	Asia
O. officinalis Wall ex Watt	P	24	CC	Khammouane and Savannakhet provinces	Asia
O. ridleyi Hook. f.	P	48	HHJJ	Champassak Province	Asia
O. granulata Nees et Arn. ex Watt	P	24	GG	Luang Prabang, Oudomxay, and Saravane provinces	Asia
Weedy rice	A	24	AA	Central and southern regions	Worldwide

[a]A = annual type, P = perennial type, A/P = perennial-like type.
Sources: Vaughan (1994), Appa Rao et al (1998).

2003a,b). Some strains of this species from Thailand have been found to have a high level of resistance to tungro viruses and have been used in the breeding programs of the International Rice Research Institute (IRRI).

O. nivara

O. nivara (AA genome) (Table 1, Fig. 1B) is primarily confined to mainland South and Southeast Asia. Recent research suggests that it may be an ancestor of indica cultivars of rice (Yamanaka et al 2003, Cheng et al 2003). It is an annual species that grows in full sunlight and it is found across the lowland plains of Laos. It has also been reported in Houaphanh and Bokeo provinces in the north of the country (Appa Rao et al 1999a). It is found at the edges of fishing ponds and roadside ditches that are seasonally dry (Sato 1994). *O. nivara* propagates by seeds. It flowers over an extended period, from July to November (Fig. 2). The plant is short (< 1.5 m), and does not exhibit the floating ability of *O. rufipogon*. Although recent studies, particularly those based on DNA analyses, have shown that *O. nivara* and *O. rufipogon* are differentiated in both the nuclear and organelle genomes (Chen et al 1993, Cheng et al 2003), there are no reproductive barriers among *O. nivara, O. rufipogon*, and cultivated rice (*O. sativa*) (Oka 1988, Vaughan and Morishima 2003). Compared with *O. rufipogon, O. nivara* has lower genetic diversity, a lower number of heterozygous loci, lower outcrossing rate (5% to 20%), and higher fixation index in a population because of its being predominantly inbred (Barbier 1989, Kuroda et al 2003a). A gene for grassy stunt virus resistance has been found in this species, which has been transferred to cultivated rice (Chang et al 1975, Brar and Khush 1997).

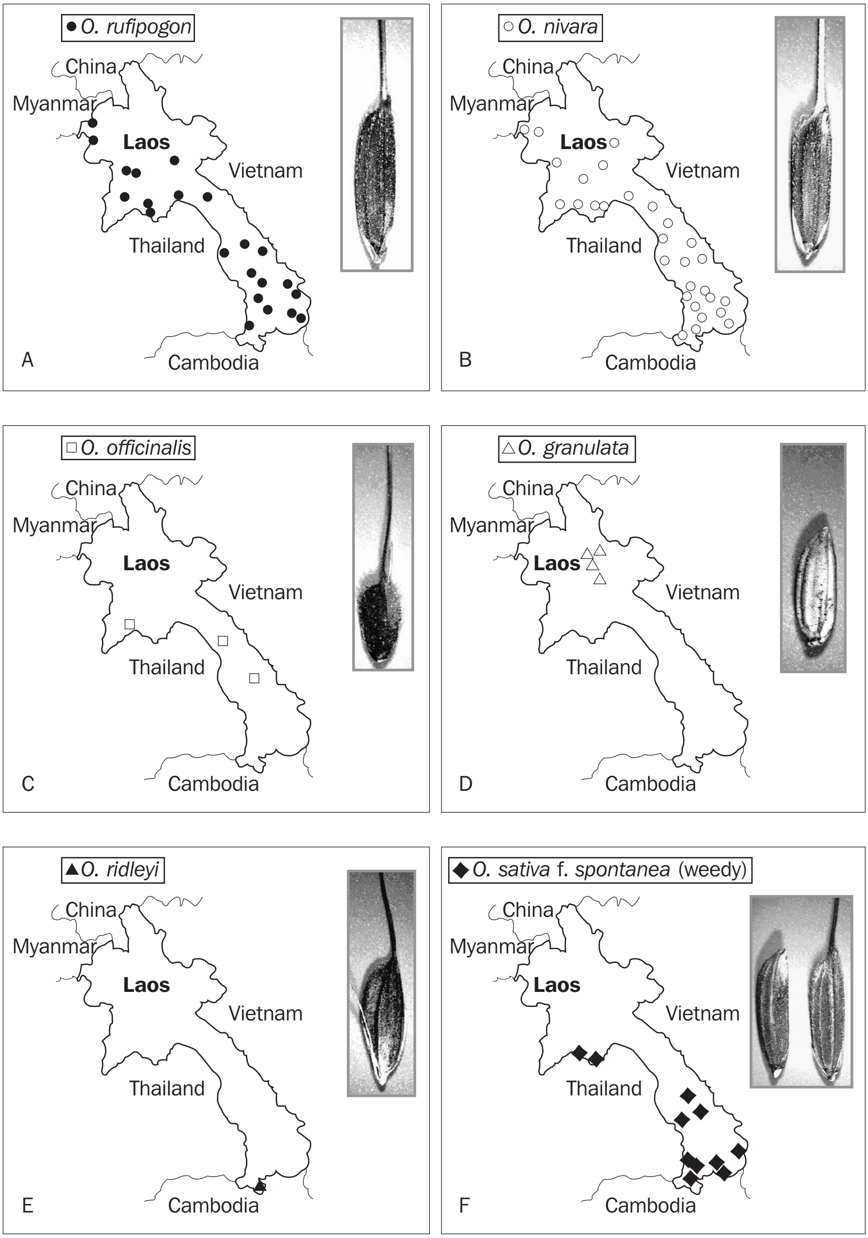

Fig. 1. Geographical distribution and view of spikelet of wild rice (A) *Oryza rufipogon*, (B) *O. nivara*, (C) *O. officinalis*, (D) *O. granulata*, and (E) *O. ridleyi*, and (F) weedy rice.

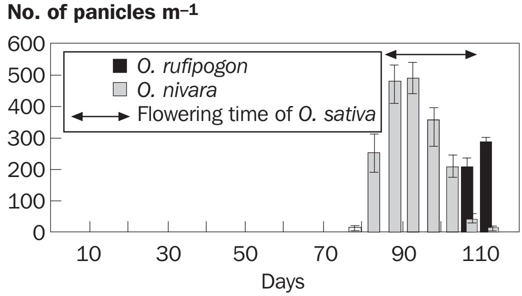

Fig. 2. Flowering time of wild rice (*Oryza rufipogon, O. nivara*) and cultivated rice (*O. sativa*) on the Vientiane Plain of Laos. Flowering times of *O. rufipogon* and *O. nivara* were recorded at a swamp in Thong-Mang and roadside ditch in Nalom village, respectively.

O. officinalis

O. officinalis (CC genome) (Table 1, Fig. 1C) has a wide distribution in tropical Asia. In Laos, this species has been recorded in Mahaxai District of Khammouane Province, in Phonehong District of Vientiane Province in a roadside ditch, and in Atsaphangthong District of Savannakhet Province in a rainfed lowland rice field (Appa Rao et al 1998). It is reported to flower in early August (Appa Rao et al 1998). *O. officinalis* is usually found in full sunlight and occasionally in half-shaded conditions. Its habitat varies from forest margins to open grassland, and from seasonally dry to permanently wet environments. Its habit of herbaceous clumps can produce culms up to 3 m (Vaughan and Morishima 2003). The Chinese name of this species is "medicinal rice," although the reason for this connotation is unclear. Strains of *O. officinalis* have been found to have a high level of resistance to several pests and diseases (Brar and Khush 1997). Brown planthopper resistance from a Thai strain of *O. officinalis* has been transferred to rice, and lines from this cross have been released as varieties in Vietnam (Brar and Khush 1997).

O. granulata

O. granulata (GG genome) (Table 1, Fig. 1D) is distributed widely across Asia. In Laos, it is found mainly in the northern agricultural region, particularly in the provinces of Luang Prabang, Oudomxay, and Xieng Khouang; it has also been recorded in the southern province of Sekong (Appa Rao et al 1998). This species is generally found in shaded, upland forested habitats in hilly and mountainous regions of the country. It is photoperiod-insensitive and flowers year-round. Its panicles are nonbranching and the awns are less than 6.4 mm long (Vaughan and Morishima 2003). A low level of genetic diversity within populations and high differentiation among populations have been reported (Gao et al 2000). It is very difficult to cross with rice, but hybrids with rice have been reported through the embryo rescue technique (Brar and Khush 1997).

O. ridleyi

O. ridleyi (HHJJ genome) (Table 1, Fig. 1E) has been recorded in only a single location in Champassak Province in southern Laos (Appa Rao et al 1998). It was found to be growing in shaded conditions under bamboo and trees on the bank of a canal where the water was generally stagnant. It is reported to flower in September. Panicles have very few erect primary branches and the species also has erect or semierect dark green leaves (Vaughan and Morishima 2003). Seed production is very low and propagation is mainly through rhizomes, which remain dormant during the dry season. It is reported to be resistant to stem borers.

Weedy rice

In Laos, weedy rice (AA genome) (Table 1, Fig. 1F) (often called *O. sativa* f. *spontanea*) is generally the result of interspecific hybridization between wild and cultivated rice. Weedy rice is common in the central and southern plain regions of the country, where *O. rufipogon* and *O. nivara* are frequently observed (Appa Rao et al 1998). Several populations, which appeared to be intermediate forms between wild and cultivated rice, have been observed. They have characteristics similar to those found in both wild and cultivated rice. Until flowering, the weedy intermediate forms resembled the cultivated forms in most characters (culm size, leaf blade length and width) and in gross morphology. After flowering, their panicle and grain characteristics differ, making distinction easy. In the Vientiane Plain, weedy rice can be found in and around rice paddies. The characteristics of weedy rice are numerous. Weedy plants found in paddy conditions have wild rice-specific traits such as small grain, nonglutinous endosperm, spikelets with long awns, red pericarp, and open panicle shape. Interspecific hybridization between cultivated rice and both *O. nivara* and *O. rufipogon* is common. Weedy rice has successfully been used as a source of cytoplasmic male sterile lines for hybrid rice.

O. rufipogon, O. nivara, and weedy rice in the Vientiane Plain in central Laos

Distribution and ecology

Most previous field observations of wild rice have covered wide areas over relatively short periods (Morishima et al 1980, 1984, 1987, 1991, Sato et al 1994, 2001). Long-term field surveys focusing on areas of rich biodiversity are needed to understand the sustainable conservation of wild rice biodiversity in its natural habitats. The Vientiane Plain is an area of particularly rich diversity in the Asian common wild rice *O. rufipogon* and *O. nivara*. The Plain was the focus of a year-long survey and intensive study of this wild rice in 2002.

Geography and climatic conditions of the Vientiane Plain

The Vientiane Plain (3,000 km^2) is located in central Laos and is bordered by the Mekong River to the south and by mountains to the west, north, and east (Fig. 3). The Plain accounts for about 6% of the total area and 11% of the population of Laos. The topography of the area undulates from 160 to 200 m above sea level. The Namngum

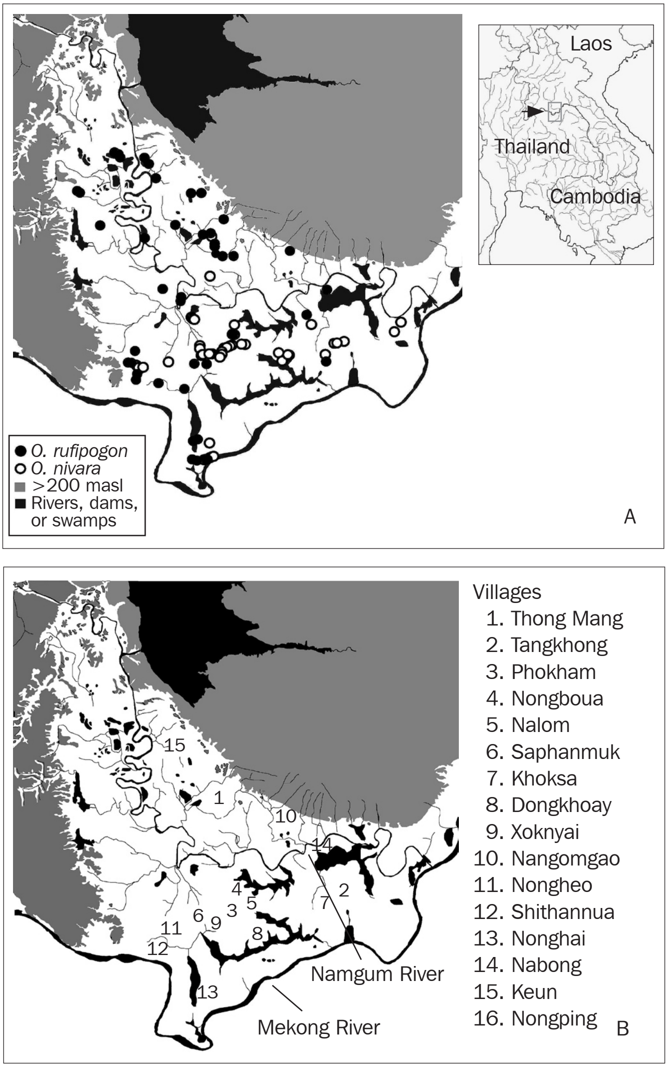

Fig. 3. Geography and distribution of (A) wild rice populations and (B) villages (used only in the text) on the Vientiane Plain of Laos.

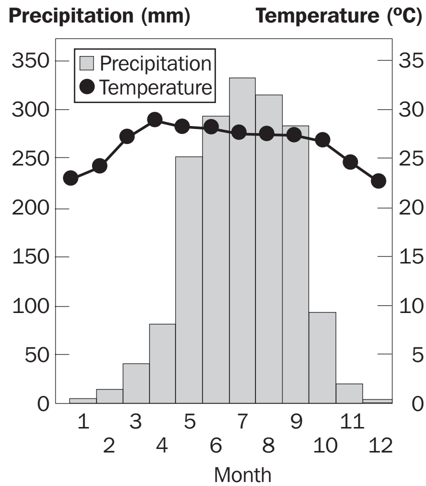

Fig. 4. Precipitation and temperature averaged by month over the past 10 years on the Vientiane Plain of Laos.

River is the main river that runs from the north to southeast across the Plain, and it has a complex pattern of tributaries along its course. The climate of the Plain can be broadly described as humid tropics containing two seasons: a dry season from November to March and a wet (monsoon) season from April to October (Fig. 4).

Distribution of *O. rufipogon* and *O. nivara*

Oryza rufipogon and *O. nivara* are common throughout the Vientiane Plain. A total of 110 sites of wild rice populations constituting 46 of *O. rufipogon* and 64 of *O. nivara* have been recorded (Fig. 3). Populations of *O. rufipogon* were scattered throughout the Plain. In contrast, populations of *O. nivara* were mainly found adjacent to major roads. The populations of *O. rufipogon* and *O. nivara* were generally found to be isolated from each other by distances of at least 100 m, with the exception of one site where both *O. rufipogon* and *O. nivara* populations were found in different parts of the same swamp in the village of Nongboua in Xaythany District of Vientiane Municipality.

Habitat differences

The habitat differences of *O. rufipogon* and *O. nivara* reflect the different levels of water conditions to which they are adapted (Oka 1988). *O. rufipogon* is found at sites where flooding is to a depth of up to about 200 cm (Fig. 5A), whereas *O. nivara* occurs in habitats where the water depth is to about 50 cm (Fig. 5B). In general, *O. nivara* populations are associated with annual plant species, while those of *O. rufipogon* are associated with perennial species.

Oryza rufipogon is found in the places with the greatest water depth, whereas *O. nivara* is found in areas where the water is shallow. Natural rainfall accounts for

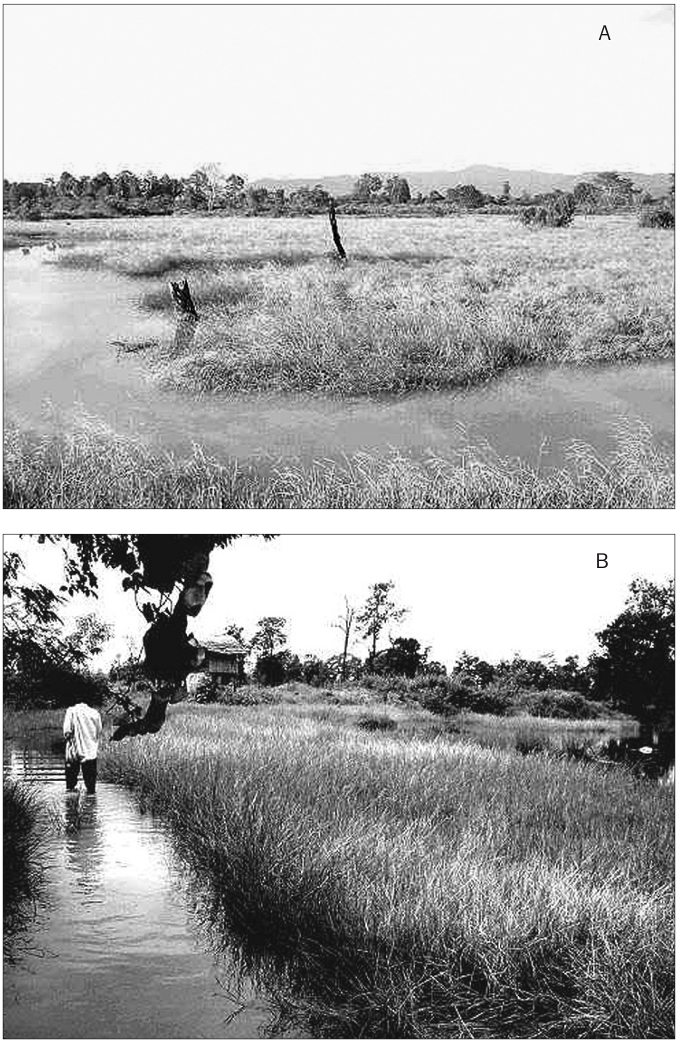

Fig. 5. Views of the habitat of wild rice populations late in the rainy season: (A) *Oryza rufipogon* was observed in a deepwater area in Thong-Mang village and (B) *O. nivara* was found in a shallow-water area in Tangkhong village.

most of the water source in habitats of wild rice populations (77% for *O. rufipogon* and 87% for *O. nivara*). Seasonal fluctuations in water level can therefore be expected to affect the distribution of wild rice. No populations were found in artificial reservoirs or along main rivers; relatively higher water-level fluctuations in these areas might be responsible for this.

In relation to the site characteristics of wild rice habitats, 70% of *O. rufipogon* populations were found in deep swamps where soil moisture remains year-round. In contrast, 72% of *O. nivara* was observed in roadside ditches that have only standing water in the wet season. Other studies also suggest that populations of annual types of wild rice (*O. nivara*) are adapted to unstable transient habitats compared with perennial types of wild rice (*O. rufipogon*) (Barbier 1989).

The mean population size for *O. rufipogon* was found to be generally greater than for *O. nivara*. Although all the *O. nivara* populations were less than 1.0 ha in area, 33% of the *O. rufipogon* populations were found in patches of more than 1.0 ha. Several very large populations were also found, including a 600-ha population at Nongkhoay in Thoulakhom District of Vientiane Province and a 500-ha population at Salakham village in Hadxaifong District of Vientiane Municipality. This suggests that the Vientiane Plain contains large areas of habitats more favorable to *O. rufipogon* than to *O. nivara* populations.

Life-history traits

The life histories of *O. nivara* and *O. rufipogon* in the Vientiane Plain were found to differ in a number of ways. In reference to reproductive strategies at the start of the rainy season, plants from clones and seeds were observed in *O. rufipogon* populations (Fig. 6A), whereas only seed-derived juveniles were observed in *O. nivara* populations (Fig. 6B). Maximum plant height at the flowering stage was 150 cm for 63.6% of the *O. rufipogon* populations, whereas only 4.1% of the *O. nivara* populations reached a height of 150 cm. Plant height reflects the adaptation of these two species to habitats with different water levels.

The flowering period of the two species in the Vientiane Plain was also clearly different. Generally, *O. nivara* plants flower from July to November, with most (87%) plants reaching maturity during September. In contrast, *O. rufipogon* plants flower from the end of October to the end of January, with 95% of the plants reaching maturity during December (Fig. 2). After flowering, *O. rufipogon* plants produce culms from each node for the next generation, whereas plants of *O. nivara* wither and die after flowering, even in areas with a favorable moisture regime. It was apparent that *O. nivara* plants allocate their energy producing seeds, whereas *O. rufipogon* plants can allocate energy reserves for both seed production and culms for the next generation.

Human influence

The *O. rufipogon* and *O. nivara* populations on the Vientiane Plain were usually located near roads and paddies. Approximately 92% of the *O. nivara* populations and 59% of the *O. rufipogon* populations were found close to roads. Most populations of both species were also found at the edges of rice fields—84% of the *O. rufipogon* popula-

Fig. 6. Views of the reproductive system of wild rice in the beginning of the rainy season: (A) both clone and seed propagation observed in an *O. rufipogon* population, Thong-Mang village, and (B) only seed propagation observed in an *O. nivara* population, Phokham village.

Table. 2. Local names and meaning of wild rice (*Oryza rufipogon* or *O. nivara*) and weedy rice on the Vientiane Plain of Laos.

Name	Species	Meaning
Nyaa khaw kyee nok	*Oryza nivara* or *O. rufipogon*	Rice that comes from bird droppings
Nyaa khaw nok	*Oryza nivara* or *O. rufipogon*	Rice eaten by birds
Khaw maa nyeen	Weedy rice	
Nyaa khaw kyee nok ped	*Oryza nivara* or *O. rufipogon*	Rice that comes from wild duck (*Anas* spp.) droppings
Nyaa khaw kyee nok khaw	*Oryza nivara* or *O. rufipogon*	Rice that comes from wild pigeon (*Streptopella* spp.) droppings
Nyaa khaw nok ped	*Oryza nivara* or *O. rufipogon*	Rice eaten by *Anas* spp.
Nyaa khaw nok khaw	*Oryza nivara* or *O. rufipogon*	Rice eaten by *Streptopella* spp.

tions and 77% of the *O. nivara* populations, respectively. In areas where cultivated rice and wild rice are sympatric, spontaneous hybridization may occur between wild and cultivated rice. Although some populations are found isolated from residential areas, the effect of human habitation is to convert many of the habitats that wild rice occupies to other uses.

The relationship between wild rice and human activities

Awareness and naming of wild rice

Most of the Lao farmers are aware of their environment and can accurately describe the natural vegetation and the wild rice (Table 2). All the village representatives interviewed in 46 villages in the Vientiane Plain were found to be aware of wild rice and its location in relation to the village. The only exception to this was with three villagers living within 5 km of the capital city, Vientiane. However, only one elderly resident was aware that wild rice is the ancestor of cultivated rice, having learned this in the form of a story related to him when he was young. Most of the village respondents recognized wild rice to be "a favorite grass for water buffalo," the buffalo being common on the Vientiane Plain.

Wild rice as a famine food in the past

The people of Asia have a history of collecting seeds of wild rice for human consumption (Oka 1988, Harlan 1992). Discussions with members of five villages on the Vientiane Plain revealed clear memories of wild rice being used as a food.

Xoknyai village. This is a well-known village established more than 200 years ago. A respondent in the village related the story of his grandparents collecting wild rice in times of famine. The harvested seeds were dehulled in a mortar and the brown rice was boiled or steamed for consumption. Near this village exists a large population of *O. rufipogon* covering about 500 ha.

Khoksa (Navay) village. The informant was the head of the village, who had moved from the neighboring village of Navay. His grandparents had narrated stories to him of the collection and consumption of wild rice in times of famine in his former village of Navay.

Nangomgao village. The informant was the head of a young men's association, and the village has a history of more than 200 years. According to the respondent, wild rice seeds were collected and eaten until 20 years ago, when rice production was reported to have stabilized. Wild rice was harvested before maturity using a sickle. After harvest, the panicles were stripped of their seeds and the kernels were steamed and eaten. Near the village was a large population of *O. rufipogon* covering more than 200 ha.

Nongheo village. The informant was the head of the village, who had moved from another district several decades ago. His grandparents told him of periods when, in times of famine, they had harvested wild rice using a sickle, threshed the seeds in a mortar, and eaten the kernels.

Shithannua village. This village is in a residential area. However, an old villager who originally lived in the southern province of Champassak related a story of wild rice use in southern Laos. He reported that villagers, in times of famine, collected wild rice by swinging a basket over the panicles. They ate the rice after steaming, and sometimes used it to make noodles. According to the informant, the taste and flavor of wild rice were acceptable. It was reported that wild rice had continued to be collected until about 20 years ago, when production of traditional rice had improved.

Based on these reports, it appears that people in Laos had a custom of consuming wild rice until about 20 years ago. However, the villagers were generally unable to indicate which of the wild rice species was the source of the grain consumed in the past. It is occasionally still eaten out of curiosity. There is a tendency for existing wild rice populations on the Vientiane Plain to be associated with the larger older villages.

The co-evolution of buffalo and wild rice

The water buffalo (*Bubalus bubalis*) is native to tropical Asia. The average number of buffaloes per 1,000 people in Laos (195) is the highest of any country in the region. Water buffaloes need access to water in which to immerse their bodies to adjust their temperature. Swamps and roadside ditches, where wild rice is often abundant, are the preferred places for water buffaloes to immerse themselves.

On the northern part of the Vientiane Plain is a particularly large swamp (about 600 ha) containing *O. rufipogon,* which is called Nong Khouay, or "water buffalo swamp." Villagers living nearby have noted the association of the use of the swamp by water buffaloes and the development of wild rice, suggesting a potentially important role of the water buffalo in the distribution of wild rice from place to place. Water buffaloes can often be seen grazing on wild rice (Fig. 7) and wild rice is clearly an important food for these animals, a fact that is well recognized by Lao farmers. By grazing mature wild rice seeds and moving from swamp to swamp, the buffaloes disperse the seed through dung and hooves to new habitats. Wild rice seeds are also occasionally found germinating in water buffalo dung. There appears to be a symbiotic and co-evolutionary relationship between water buffaloes and wild rice. Water buf-

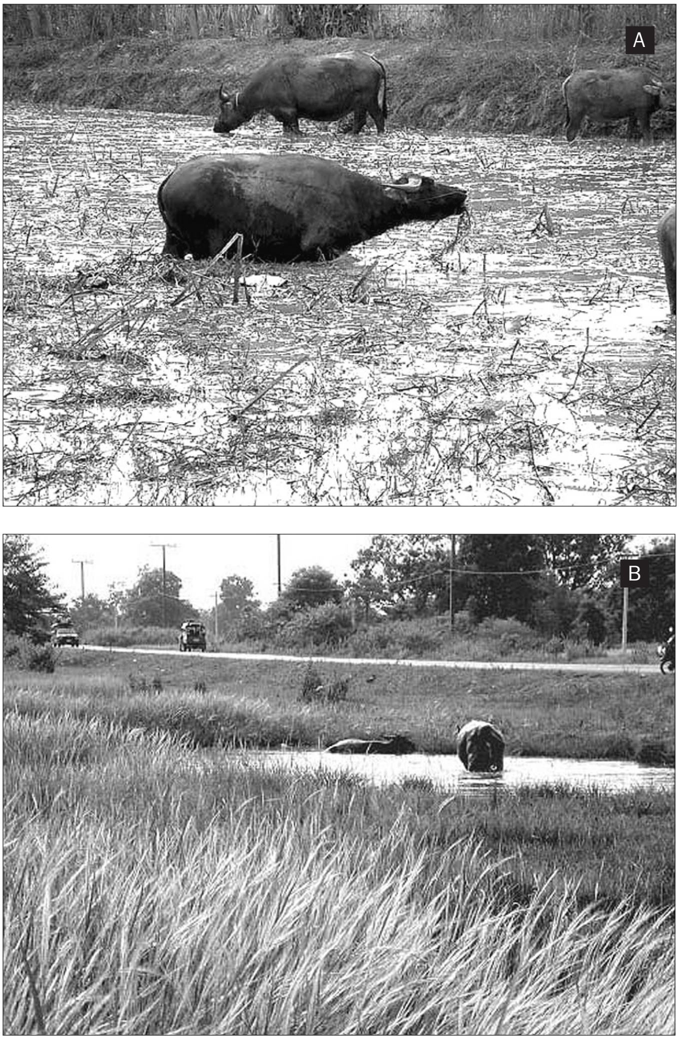

Fig. 7. Cross-section of typical land use of (A) swamp and (B) roadside ditch wild rice habitats on the Vientiane Plain.

faloes may be particularly important in the distribution of *O. rufipogon* that grows in deepwater swamps. However, cattle, ducks, and goats may be more important in the dispersal of *O. nivara* that occurs in shallower ditches and ponds, as these animals do not spend time in deep water.

Fisheries and wild rice, and wild rice habitats

Fish production is an important activity, particularly in rural Laos, as freshwater fish provide one of the main sources of protein for a large proportion of the rural population. In Lao villages, common usage rules, such as the prohibition of fishing and the regulation of fishing methods, are established for each village. These rules are useful for the conservation of native fish and the rules apply from the period of spawning to adulthood. There is an important relationship between wild rice and fish production. Wild rice populations function as a nursery for young fish and provide protection or a hiding place from predators. Fish provide nutrients to the wild rice in the form of their excreta. Roadside ditches and swamps serve as a passageway for native fish to move from their dry-season habitat to wild rice habitats and rice fields during the wet season. The conservation of such wetlands serves both in helping to conserve the wild rice populations and in helping support the fishery industry on the Vientiane Plain of Laos.

Sustainable conservation of wild rice biodiversity

Wild rice as a host of pests and diseases

Wild rice is a host of several rice pests and diseases. Gall midge (*Orseolia oryzae*) is one of the important pests of rice in Laos that appears to have increased in significance in recent times. Not only cultivated rice but also perennial species of wild rice, such as *O. rufipogon*, and weeds such as *Leersia hexandra* are potential hosts of gall midge during the dry season.

Weedy rice

Spontaneous interspecific hybrids between cultivated rice (*O. sativa*) and AA genome *Oryza* species (*O. nivara* and *O. rufipogon*), often called weedy rice (Fig. 8A, B), are of common occurrence in the southern and central regions of Laos. Wild rice and cultivated rice can exchange genes freely. The gene flow from wild rice to cultivated rice reduces the quality and quantity of cultivated rice. Farmers on the Vientiane Plain view wild rice as an aggressive weed when it invades their rice fields. However, in recent times, the significance of weedy rice on the Vientiane Plain has declined. A reason for this decline has been the relatively recent (since the mid-1990s) development and distribution of seed of improved rice varieties throughout the main rice-growing areas of Laos. Although the gene flow from wild rice to cultivated rice does not occur at high frequency, it is difficult to remove weedy rice once it contaminates improved rice varieties. For farmers who own paddies near wild rice populations, it is recommended that rice seed be changed for better-quality seed every few years.

Fig. 8. Views of weedy rice in wild rice habitats: (A) a plant showing characteristics of awnless, nonshattering, and large number of seeds per panicle; (B) two clumps of weedy plants showing characteristics of high stature and their necks of spike were bending owing to high fertility and weak-shattering traits.

Genetic erosion of wild rice

Although wild rice is common across tropical Asia, particularly mainland South and Southeast Asia, in many areas the rapid economic development, particularly urban development, that is taking place is altering the natural ecosystems that include the natural habitat of wild rice. The impact of such development has been clearly shown in Thailand, where, over a ten-year period, the rate of reduction of the biomass (size of population × cover rate) has been estimated at 21% for *O. rufipogon* and 79% for *O. nivara* (Sato 1994). Among the five *Oryza* species found in Laos, it is also *O. rufipogon* and *O. nivara* that are at greatest risk, on account of their habitats being mostly found in agroecosystems where human activity is frequently observed (Oka 1988).

On the Vientiane Plain of Laos, large-scale paddy cultivation in association with irrigation development and residential land development projects has been increasing. These developments are destroying the natural wild rice habitats. For example, a half of the area of swamp containing a wild rice population in the village of Keun, about 60 km from the capital, Vientiane, has been converted into rice paddies in the past decade. Some wild rice populations in the suburbs of Vientiane have been destroyed in recent land development initiatives (Fig. 9A, B). Irrigation developments near annual wild populations of *O. nivara* are endangering these populations and are a potential threat to the ecological replacement of these species with perennial plant species.

Conservation of the wild rice resources of Laos

For cultivated rice, genebanks are available for *ex situ* conservation at national and international centers. These genebanks are already playing an important role in the conservation of the Laotian genetic resource base for traditional cultivated rice (Jackson 1997). *Ex situ* conservation can be effective for the conservation of some wild *Oryza* species and as an insurance against population destruction in the wild. However, some *Oryza* species cannot be adequately maintained *ex situ*. This is particularly true for low-seed-producing outcrossing forms, such as some ecotypes of *O. rufipogon*. These *Oryza* species require large populations to maintain their genetic integrity, and *in situ* conservation is a more appropriate approach than *ex situ* conservation for such material. The genetic dynamism of natural populations of wild rice requires conservation in nature or *in situ*. Consequently, attempts have been made to establish an *in situ* conservation site in Laos. This began at Thong-Mang village on the Vientiane Plain in 1996. This site was established after discussions with local village officials, representatives of the Lao Ministry of Agriculture and Fisheries, and advisers from Japan. The site is a pond of about 1.5 ha and is surrounded by forest. Ecological population genetic observations of this wild rice population have been conducted based on repeated surveys since 1991 to elucidate the dynamics of wild rice populations on the Vientiane Plain. Some of the wild rice observations reported in this chapter are based on these studies. Laos is rich in diversity of the wild relatives of rice. Of the five species of the genus *Oryza* recorded in Laos—*O. nivara, O. rufipogon, O. officinalis, O. ridleyi*, and *O. granulata*—it is *O. ridleyi* that is found least frequently and that needs the most immediate attention to prevent its complete disappearance from the country. The *ex situ* conservation facilities that have been established in the past

Fig. 9. An example of habitat destruction of a wild rice population near Vientiane City, Saphanmuk village: (A) June 2002 and (B) November 2002.

decade near the capital Vientiane need to be strengthened to allow increased *ex situ* conservation of wild rice, while at the same time improving the *in situ* conservation initiatives. Spontaneous interspecific hybrids between cultivated rice (*O. sativa*) and AA genome *Oryza* species (*O. nivara* and *O. rufipogon*), often called weedy rice, are of common occurrence in the southern and central regions. These offer considerable scope for the conservation and use of rice genetic resources in Laos.

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Notes

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CHAPTER 16

Arthropod communities of the lowland rice ecosystems in the Lao PDR

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Rice is the most important crop in Laos, being grown on more than 80% of the cultivated area. Total annual rice production in 2004 was reported to be 2.529 million tons, with the wet-season lowland environment accounting for about 78% of national production. Dry-season irrigated rice cultivation in the 2003-04 cropping season was undertaken on about 78,000 ha, and accounted for about 13.5% of production. Approximately 74% of wet-season production comes from the lowland environment in the central and southern agricultural regions.

Unlike much of the rice-producing area in the rest of Asia, until about the mid-1990s, rice cultivation in all environments of Laos was based on relatively few inputs apart from family labor. Even fertilizer inputs were limited until the latter half of the 1990s. Planting, weeding, harvesting, and threshing were all done manually. Mechanized land preparation and the use of mechanical threshers are relatively recent innovations in the main lowland rice-growing areas in the Mekong River Valley. Production in much of the remainder of Laos remains largely based on traditional practices.

Pesticide (insecticides, fungicides, herbicides, etc.) use in most rice environments in Laos has been low, and it has only been relatively recently that pesticides have become available in local markets. In comparison with other countries in the region, in the early 2000s, insecticide use in most lowland rice areas in Laos was still at a very low level. As a result, the arthropod communities in the rice environments of Laos have remained relatively undisturbed. Reports on the diversity of the arthropod communities in the rice environments have also been rare. The first published report giving some detail of the arthropods of Laos was that of Dean (1978), who undertook a pest survey in the country in the period 1973-75, in which was included a list of some pests and natural enemies. However, this study focused on just one locality and was limited in its scope.

This chapter reports on the results of a detailed study of the arthropod community of the rainfed lowland and irrigated rice ecosystems in Laos undertaken in 1995. The study covered six provinces representing the northern, central, and southern agricultural regions of the country. The purpose was to highlight the great biodiversity that exists in the arthropod communities of rice ecosystems in Laos.

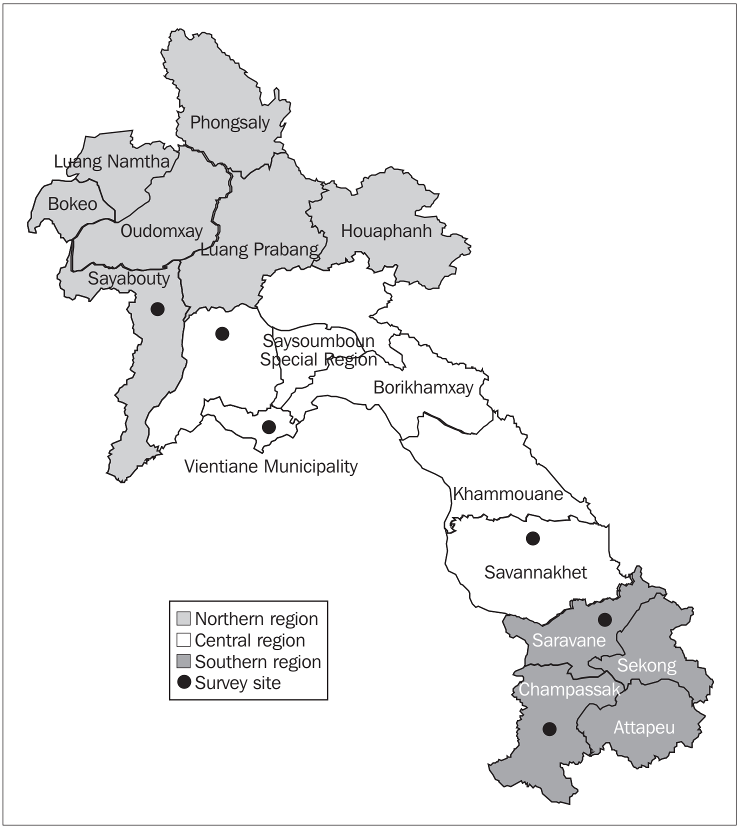

Fig. 1. Survey of arthropod communities in wet-season lowland rice environments.

Survey methodology

Survey sites

The six provinces covered by the survey were Sayabouly in the northern region, Vientiane Municipality, Vientiane Province, and Savannakhet in the central region, and Champassak and Saravane in the southern region (Fig. 1). Two districts were surveyed in Sayabouly Province, Phiang (4 villages) and Sayabouly (1 village). In Savannakhet, sampling was done in three districts—Khantabouly (3 villages), Asphangthong (1 village), and Outhomphong (1 village). Sampling in Champassak was done in four districts—Pakse (3 villages), Sanasomboune (1 village), Soukhouma (1 village), and Champassak (1 village). In Saravane, Vientiane Province, and Vientiane Municipality, sampling was done in only one district within each province. Within each village targeted by the study, three farmers' fields were chosen for the detailed surveys. Site selection was done with the help of collaborators in the Lao National

Table 1. Sampling sites and number of samples from each site, 1995 wet season.

Locality	No. of districts	No. of villages	No. of fields	No. of sampling sites
Northern region				
Sayabouly Province	2	5	15	600
Central region				
Vientiane Municipality	1	2	3	120
Vientiane Province	1	1	3	120
Savannakhet Province	3	5	15	600
Southern region				
Saravane Province	1	1	3	120
Champassak Province	4	6	18	720
Total	12	20	57	2,280

Rice Research Program Network. Farmers and farming areas were selected that did not have a history of any pesticide use at the time of the survey.

Sampling methods

Sampling was done three times during the crop cycle—30, 55, and 80 days after transplanting (DT) during the 1995 wet-season cropping cycle. The sampling sites and the number of field samples from each site are summarized in Table 1.

Arthropod samples were collected using the D-Vac and Blower-Vac suction machines and sweep net. The D-Vac machine used was an 18-kg backpack vacuum insect collector (D-Vac Model 24), powered by a Tecumesh 3-horsepower, 2-cycle engine and regular gasoline (Fig. 2). The Blower-Vac machine used was similar to that described by Arida and Heong (1992).

On each sampling date, three D-Vac, 10 Blower-Vac, and one sweep-net sample were collected from each of 57 fields. D-Vac samples were obtained from 10 hills selected at random within the selected field, with approximately 2 minutes' time of suction from each hill. In the study, one D-Vac sample constituted a total catch from 10 hills. To collect samples with the Blower-Vac, the enclosure was dropped over the rice plant (covering 4 hills at the early crop stage at 20 × 20-cm distance, but fewer hills as the crop matured). Arthropods collected from the Blower-Vac were sucked starting from a nylon net sleeve, then the air column, the plant surfaces, and finally the water surface. The time spent for the collection was approximately 2–3 minutes. Sweep-net samples were collected by making 10 sweeps of the plant canopy while walking diagonally across the field. Sweep nets were used only at 55 DT.

Sorting, counting, and identification

Samples were placed in labeled vials, preserved in 75% ethyl alcohol and brought to the Crop Protection Laboratory at the National Agricultural Research Center in Vientiane Municipality for sorting, counting, and identification. Each specimen was identified to its lowest possible taxon based on previously published keys. Each ar-

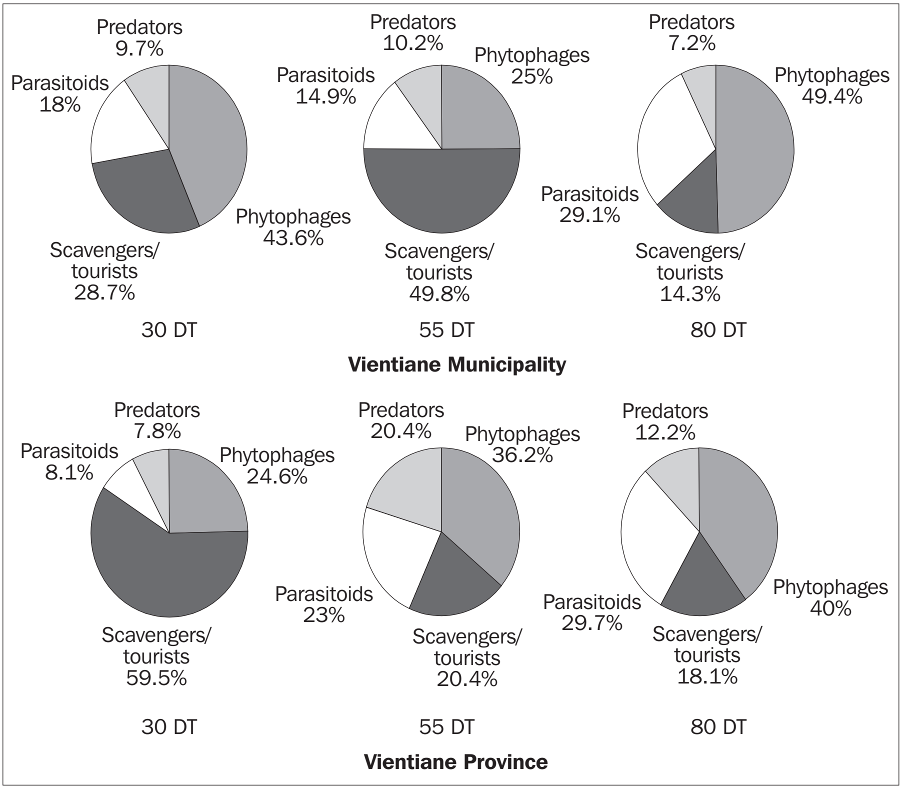

Fig. 2. Percent composition of the arthropod guilds collected in rainfed lowland rice ecosystems in Vientiane Municipality and Vientiane Province, 1995 wet season. DT = days after transplanting.

thropod species was grouped into one of four guilds: herbivores, predators, parasitoids, and detritivores (scavengers/tourists after Norman and Southwood 1982). Sorting, counting, and identification were done in Laos, with the raw data being entered into electronic form (Excel spreadsheet) for analysis and archiving.

Arthropod diversity

Taxonomic richness and abundance relations

A total of 391,713 individual organisms were collected in this study. Champassak yielded the greatest total abundance, followed by Sayabouly, Savannakhet, Saravane, Vientiane Province, and Vientiane Municipality (Table 2). Sayabouly recorded the greatest number of species, followed by Savannakhet, Champassak, Vientiane Province, Vientiane Municipality, and Saravane. Because the number of sampled fields differed among the provinces, the average data were standardized across sites as average number of individuals per field. The average number of individuals per field

Table 2. Arthropod counts by province and crop age (days after transplanting, DT) in the rainfed lowland rice ecosystem, 1995 wet season.

Locality	Crop age (DT)	Total arthropod counts	Av per field	% composition
Northern region				
Sayabouly Province	30	47,911	3,194	39.7
	55	33,045	2,203	27.9
	80	38,288	2,552	
Total		119,244		
Central region				
Vientiane Municipality	30	4,145	1,382	28.5
	55	4,732	1,577	34.2
	80	5,172	1,724	37.3
Total		14,049		
Vientiane Province	30	4,623	1,541	25.6
	55	7,642	2,547	42.5
	80	5,752	1,917	31.9
Total		18,017		
Savannakhet Province	30	15,448	1,030	22.7
	55	28,604	1,907	42.1
	80	23,936	1,596	35.2
Total		67,988		
Southern region				
Saravane Province	30	13,963	4,654	5701
	55	3,110	1,037	12.7
	80	7,391	2,457	20.3
Total		24,464		
Champassak Province	30	46,823	2,601	31.6
	55	69,962	3,860	47.0
	80	31,649	1,758	20.3
Total		148,434		

was highest in Champassak, followed in decreasing order by Saravane, Sayabouly, Vientiane Province, Vientiane Municipality, and Savannakhet (Table 2).

Across the six sites, 763 arthropod taxa belonging to 592 genera, 202 families, and 18 orders were determined. Aside from the arthropods collected, 17 species of non-arthropods (nematodes, snails, fish, and frogs) were also collected.

The herbivore group constituted 23.9% of all the arthropods collected. Predators and parasitoids represented 12.5% and 16.9%, respectively, of the samples, while the scavengers/tourists were almost one-half (46.7%) of the total individuals collected (Table 3). Predators and parasitoids, when combined, had higher total counts than the herbivores.

Arthropod abundance also varied over the growing season. The scavengers/tourists guild was the dominant guild at 30 DT for all sites except Vientiane Municipality, where this guild was highest at 55 DT. In decreasing order of abundance, they were

Table 3. Percent composition of the different arthropod guilds collected in rainfed lowland rice ecosystems by province and crop age, 1995 wet season.

Locality	Crop age (DT)	Herbivores	Natural enemies (predators and parasitoids)	Detritivores
		Arthropod composition (%)		
Northern region				
Sayabouly Province	30	25.4	27.0	47.5
	55	37.8	39.4	22.8
	80	23.7	40.0	36.3
Central region				
Vientiane Municipality	30	43.6	27.7	28.7
	55	25.0	25.1	49.8
	80	49.4	36.3	14.3
Vientiane Province	30	24.6	15.9	59.5
	55	36.2	43.4	20.4
	80	40.0	41.9	18.1
Savannakhet Province	30	18.2	24.9	56.8
	55	30.7	44.7	24.6
	80	20.5	37.6	41.9
Southern region				
Saravane Province	30	4.2	4.2	91.6
	55	23.1	33.0	43.9
	80	7.8	16.5	75.7
Champassak Province	30	10.7	15.3	74.0
	55	18.5	21.0	60.5
	80	34.9	36.4	28.7
Overall % composition		23.9	29.4	46.7

followed by herbivores, parasitoids, and predators. In Sayabouly, herbivores constituted 25.4% of the samples collected, parasitoids 17.7%, predators 9.3%, and detritivores 47.5%. At 55 DT, an increase in the number of predators, parasitoids, and herbivores was observed; however, scavengers declined to almost one-half the number at 30 DT. At 80 DT, the herbivores and predators decreased but parasitoids and detritivores increased.

Similar trends were observed in Savannakhet. Herbivores collected constituted 18.2%, predators 12.2%, parasitoids 12.7%, and detritivores 56.7% of the samples at 30 DT. At 55 DT, the number of herbivores increased to 30.7% but predators and parasitoids almost doubled their number at 30 DT, whereas detritivores decreased to 24.6%. The percentage of predators and parasitoids decreased slightly at 80 DT; herbivores also decreased while detritivores increased.

In Vientiane Municipality, 43.5% of the samples at 30 DT were herbivores. Predators and parasitoids were low (9.7% and 18%, respectively) and detritivores were 28.7%. However, this latter group constituted 49.8% of the samples at 55 DT.

Herbivores at 80 DT increased to almost double their number at 55 DT but parasitoids had a twofold increase at 80 DT over those at 30 and 55 DT. Detritivores also decreased and predators were least abundant at 80 DT.

Results obtained from Vientiane Province showed that the herbivore group increased as the crop matured, from 24.6% at 30 DT to 40% at 80 DT. Parasitoids followed the population trend of the herbivores and predators, reaching peak abundance at 80 DT (Fig. 2). Detritivores decreased with crop age.

Detritivores dominated the samples collected at 30 DT in both Champassak and Saravane. This group showed a continuous decline to 80 DT in Champassak but in Saravane the increase continued after 80 DT. The herbivore group was relatively low in both provinces at all sampling dates, with the exception of 80 DT in Champassak. In most cases, the increase in the number of predators and parasitoids coincided with the increase in the number of herbivores. Generally, the herbivores, predators, and parasitoids were more abundant at 55 DT than at either 30 or 80 DT.

Guild composition

Herbivores. Herbivores were represented by seven orders: Hemiptera, Diptera, Thysanoptera, Coleoptera, Orthoptera, Lepidoptera, and Trichoptera (Table 4). These belonged to 57 families, 180 genera, and 237 species. Hemipterans constituted 86.5% of all herbivores collected, followed by Diptera (6.1%), Thysanoptera (3.3%), Coleoptera (1.9%), Orthoptera (1.4%), Lepidoptera (0.8%), and Trichoptera (0.01%).

Hemipterans belonged to 18 families, 62 genera, and 92 species, the most abundant species being in the families Cicadellidae (30 species) and Delphacidae (18 species). Among the cicadellids, *Nephotettix virescens* (Distant), *Empoascanara* spp., *Thaia* spp., *Recilia dorsalis* (Motschulsky), and *Nephotettix nigropictus* (Stål) were the most abundant. *Sogatella furcifera* (Horvath), *S. vibix*, and *Nilaparvata lugens* Stål dominated the delphacids, with *N. lugens* only around a quarter that of *S. furcifera*.

Dipterans were found to belong to 7 families, 22 genera, and 28 species. This group was dominated by whorl maggots, *Hydrellia philippina* Ferino, *Notiphila* spp., *Psilopa* sp., and *Paralimna* sp. (Ephydridae); the rice gall midge, *Orseolia oryzae* (Wood-Mason); and *Cantarina* spp. (Cecidomyiidae).

Thrips (Thysanoptera), although more abundant than beetles (Coleoptera), were found to belong to only three families. Among the thrips, 17 species were found, dominated by *Thrips* spp., *Haplothrips* spp., and *Stenchaetothrips biformis* (Bagdall).

Ten families, 39 genera, and 42 species of beetles were identified. *Nanophyes* spp. and *Bagous* spp. (Curculionidae) were the most abundant, followed by *Chaetocnema* spp. (Chrysomellidae), *Aeloderma brachmana* (Elateridae), and *Callosobruchus* spp. (Bruchiddae).

Other orders were Orthoptera, Lepidoptera, and Trichoptera. Among the Orthoptera, *Oxya* spp. (Acrdidae) and *Eucyrtus concinnus* (Gryllidae) were the most abundant. Thirteen families in 30 genera and 37 species represented the order Lepidoptera, but they occurred only in small numbers. Only one species of Trichoptera was collected.

Table 4. Composition of the different arthropod guilds collected in the rainfed lowland rice ecosystem, 1995 wet season.

Guild	Order	%	No. of families	No. of genera	No. of species
Herbivores	Hemiptera	86.5	18	59	88
	Diptera	6.1	7	22	28
	Thysanoptera	3.3	3	12	17
	Coleoptera	1.9	10	39	42
	Orthoptera	1.4	5	14	20
	Lepidoptera	0.8	13	30	37
	Trichoptera	0.01	1	1	1
Predators	Aranea (spiders)	35	18	67	91
	Diptera	31	9	19	23
	Hemiptera	19	20	41	52
	Coleoptera	7.7	14	46	55
	Odonata	2.8	2	6	8
	Others	4.5	4	19	24
	Dermaptera		1	1	1
	Hymenoptera		1	1	1
	Mantodea		1	1	1
	Neoroptera		3	6	9
	Orthoptera		1	1	1
	Pseudoscorpionida				
Parasitoids	Hymenoptera	98.0	21	112	164
	Diptera	1.3	5	12	15
	Strepsiptera	0.3	2	3	4
	Acarina	0.4	2	3	3
	Nematoda		1	5	5
Detritivores	Diptera	58	19	43	49
	Collembola	39.5	4	6	6
	Acarina	1.5	2	3	3
	Others	1.3			

Predators. Aranea (spiders) constituted 35% of the predators collected (Table 4). Spiders were found in 18 families, 67 genera, and 91 species. Orb weavers (Tetragnathidae) yielded the highest count of individuals, but Araneidae had the highest count of species. Of the orb weavers, *Tetragnatha* spp. [*T. javana* (Thorell), *T. virescens* Okuma, and *T. maxillosa* Thorell] and *Dyschiriognatha* spp. were the most abundant. *Atypena formosana* Oi (Linyphiidae) was also common. Among hunting spiders, *Pardosa pseudoannulata* (Boesenberg and Strand) (Lycosidae) was the most common, followed by *Clubiona* spp. (Clubionidae) and *Oxyopes* sp. (Oxyopidae).

Nine families were represented in the order Diptera with 19 genera and 23 species. Families Ceratopogonidae (*Nillobezzia* sp., *Stillobezzia* sp., and *Culicoides* sp.), Empidae (*Drapetis* spp.), and Dolicophodidae were the most abundant.

The most common species among the Hemipteran predators were *Cyrtorhinus lividipennis* (Miridae), *Microvelia* spp. (Veliidae), *Mesovelia* spp. (Mesoveliidae), and *Limnogonus* sp. (Geridae) in order of their abundance. These predaceous species were reported to attack eggs and nymphs of all hoppers, although *N. lugens* were often preferred (Heong et al 1990, 1991). This could be one of the reasons for the low population of *N. lugens*.

Fifty-five species of predaceous beetles were found, belonging to 46 genera and 14 families (Table 4), although in all cases they were recorded in low numbers. The more common species were *Stilbus* sp., *Micraspis* spp., *Scymnus* sp. (Coccinellidae), *Paederus* spp., *Oligota* sp. (Staphylinidae), and *Ophionea* spp. (Carabidae).

Among the Odonata, *Agriocnemis* spp. (Coenagrionidae) was the most abundant, although eight species in six genera and two families were represented in the samples. The orders Hymenoptera, Orthoptera, Dermaptera, Mantoidea, and Neuroptera occurred only in small numbers.

Parasitoids. The parasitoid group was from four orders and 98% of all the individuals belonged to order Hymenoptera (Table 4). The other parasitic orders, Diptera, Strepsiptera, and Acarina, constituted 2%. A total of 164 species in 112 genera and 21 families represented the hymenopterans. The most abundant of these species were *Oligosita* spp. and *Paracentrobia* spp. (Trichogrammatidae), followed by *Gonaocerus* spp., *Anagrus* spp. (Mymaridae), *Tetrastichus* spp. (Eulophidae), *Telenomus* spp. (Scelionidae), and *Platygaster* spp. (Platygasteridae). Most of these parasitoids attack eggs of leafhoppers and planthoppers, whereas the other parasitoids listed attack eggs and larvae of stem borers and other Lepidoterans. *Platygaster* spp. parasitize larvae and pupae of the rice gall midge, *Orseolia oryzae* (Wood-Mason).

Detritivores. The most abundant in this group were the flies (Diptera) (58%) and springtails (Collembola) (39.5%). Among the flies, Chironomidae (genera *Chironomus, Cryptochironomus*, and *Tanytarsus*) were the most abundant, followed by Dolicopodidae, Culicidae, and Chloropidae. Other groups of scavengers and tourists belonged to the orders Ephemeroptera, Blattoidea, Coleoptera, and Acarina, and phyla Nematoda, Crustacea, fishes, and snails (*Pila* sp.).

Between-site comparisons

Champassak yielded the greatest total arthropod counts, followed by Sayabouly, Savannakhet, Saravane, Vientiane Province, and Vientiane Municipality. However, the largest number of species (572) was recorded in Sayabouly and then in decreasing order Savannakhet (532), Champassak (473), Vientiane Province (311), Vientiane Municipality (258), and Saravane (253) (Table 5). The fewer species found from the latter three localities might be attributed to the fewer sampling sites (3 fields in each locality). The occurrence of different species in different provinces followed similar patterns. Variations were more distinct in the number of individuals collected per species.

Sayabouly gave the highest number of species of herbivores (170), whereas Savannakhet had the most predators (200). For parasitoids, Sayabouly again yielded the highest number of species (152), followed by Savannakhet (125). Saravane had

Table 5. Herbivore (H) and natural enemy (NE) abundance ratio in the rainfed lowland ecosystem in Laos, 1995 wet season.

Locality	Crop age (DT)	H:NE ratio
Northern region		
Sayabouly Province	30	1:1.1
	55	1:1.0
	80	1:1.7
Central region		
Vientiane Province	30	1:0.6
	55	1:1.2
	80	1:1.2
Vientiane Municipality	30	1:0.6
	55	1:1.0
	80	1:0.7
Savannakhet Province	30	1:1.4
	55	1:1.6
	80	1:1.6
Southern region		
Saravane Province	30	1:1.0
	55	1:1.4
	80	1:2.1
Champassak Province	30	1:1.4
	55	1:1.4
	80	1:1.0

the fewest species of herbivores, whereas Vientiane Municipality yielded the least for parasitoids and predators.

The dominant species of phytophagous Diptera, whorl maggots (*Hydrellia* spp. and *Notiphila* spp.), were most abundant in Sayabouly and least abundant in Saravane. The rice gall midge (*Orseolia oryzae*) was also most abundant in Sayabouly. Among the Cicdellidae (Hemiptera), *N. virescens* was the most abundant in Champassak, whereas, in Sayabouly, it was *Empoascanara* sp. For delphacids, *S. furcifera* was the most abundant in Champassak and *N. lugens* in Sayabouly. Although the same species were found at the other sites, they were collected in lesser numbers.

At all the sites, the spiders *Tettragnatha* spp. were the most abundant, followed by *A. formosana* (Linyphiide), *C. japonicola* (Clubionidae), and *P. pseudoannulata* (Lycosidae). Sayabouly yielded the most abundant spiders, followed by Champassak and Savannakhet. *Cyrtorhinus lividipennis* (Miridae), *Microvelia* spp., and *Mesovelia* spp. were the most abundant among the predaceous Hemiptera at all sites, but were particularly abundant in Sayabouly, Champassak, and Savannakhet. Among the parasitoids, *Oligosita* spp. (Trichogrammatidae), *Gonatocerus* spp., and *Anagrus* spp. (Mymaridae) were the most abundant at all sites. These species attack eggs and nymphs of leafhoppers and planthoppers, but have a preference for *N. lugens*. This may be another reason for the low population of *N. lugens* at the sites surveyed. The average number of taxa for all the sampling dates was highest for predators, followed by herbivores, parasitoids, and scavengers.

Herbivore-natural enemy relationships

For each site and sampling date, herbivore (H) to natural enemy (NE) ratio was calculated (Table 5). In Sayabouly, ratios at 30 and 55 DT were similar, 1:1.1 and 1:1, respectively. However, at 80 DT, the ratio increased to 1:1.7; the average H:NE ratio for the province was 1:1.3. The H:NE ratio at 30 DT in Vientiane Province was low (1:0.6) but increased to 1:1.2 at 55 DT and 80 DT. In Vientiane Municipality, H:NE ratios were 1:0.6 at 30 DT, 1:1 at 55 DT, and 1:0.7 at 80 DT. In Savannakhet, the ratio increased with crop age from 1:1.4 at 30 DT to 1:1.6 at 55 DT and 1:1.8 at 80 DT (Table 5). Saravane had a higher ratio at 80 DT (1:2.1) than at 30 DT (1:1). Champassak showed a 1:1:3 average ratio.

In most samples, natural enemies outnumbered herbivores. The lowest ratio of natural enemies to herbivores was obtained in Savannakhet, followed by Saravane, Sayabouly, Champassak, Vientiane Province, and Vientiane Municipality. These results revealed a more favorable scenario for the pest situation when compared with the results obtained by Heong et al (1991), in which more herbivores than predators were found in Cabanatuan (9:1), Los Baños (5:1), and Banaue (2:1) in the Philippines.

Comparison of arthropod communities in irrigated and rainfed rice ecosystems

Results reported in the study for the rainfed lowland environment showed similarities to those of the dry-season irrigated ecosystem for Laos (Inthavong et al 1996). The guild composition of both ecosystems was similar. During the dry-season study, detritivores also dominated the population of arthropods, with the predominant species being chironomids and collembolans. The seasonal patterns of abundance of the herbivores were similar to those of the predators and parasitoids, with arthropods increasing with crop age. The herbivore population was generally low at the early stage of crop growth, reaching a peak at 49 and 63 DT. Predators followed the same population pattern of herbivores. Parasitoids increased at 35 DT, with a further gradual increase to 63 DT. The combined population of predators and parasitoids exceeded that of herbivores. In the dry-season study, the herbivore Hemiptera was dominated by *Thaia* spp. and *Empoascanara* spp. These two species were also abundant in the rainfed lowland study, but with *Nephotettix* spp. the most abundant. The occurrence and abundance of parasitoids and predators were found to be similar in both ecosystems.

Discussion

According to a 1994 survey, approximately 47% of Laos was under forest cover, including 19% under dense forest cover, one of the highest coverage rates in Asia (MAF 1999). This forest cover provides a diverse patchwork of natural vegetation that is a potentially rich source of natural enemies. A large proportion of the lowland rice fields have been developed for agricultural use in relatively recent times. Patches of trees and other vegetation are often observed around or within the rice paddies. These patches are important habitats that may serve to maintain populations of beneficial arthropods, especially during the 6-month fallow period. Nonrice habitats (i.e., bunds around rice paddies) are important sources of early-arriving predators such as spiders (Arida and Heong 1994) and *Cyrtorhinus lividipennis* Reuter (Bentur and Kalode 1987). Spiders are also found residing in soil crevices in the paddy or on bunds (Arida and Heong 1994) and on rice straw bundles or straw piles in the paddy or bunds (Shepard et al 1989) during the fallow period. Parasitoids taxonomically identical to species attacking eggs of rice hoppers (i.e., *N. lugens*) also parasitize hopper species on wild hosts during fallow periods (Way and Heong 1994). Lao farmers often leave piles of rice straw in the field after harvest. This practice is one way of preserving natural enemy abundance in the field during the fallow period.

Although considerable between-site variability in arthropod species richness and abundance was found in the study, proportional membership in different guilds did not vary much across sites. Herbivores yielded the highest number of species at 55 DT at all sites. Predator species found were also highest at 55 DT except in Savannakhet, for which the greatest abundance was at 80 DT. Among parasitoids, the largest number of species was observed at 55 DT except in Vientiane Province, Champassak, and Saravane, where it was highest at 80 DT.

At all sites, predators and parasitoids outnumbered herbivores. This situation could be the result of the low use of insecticides in the country and it provides a great opportunity to maximize naturally-occurring biological control.

High populations of green leafhoppers (*N. virescens* and *N. nigropictus*) were found but were not causing any problems, even though these species are important vectors of tungro disease of rice (Rivera and Ou 1985) and transitory yellowing (Hsieh et al 1970). These diseases have not been reported in Laos. Likewise, the low population of brown planthopper (BPH) is a reason for a lack of "hopperburn" and grassy stunt and ragged stunt virus diseases, both vectored by BPH. The whitebacked planthopper (*S. furcifera*) is also an important sap-sucking species, though not a disease vector.

The rice gall midge (*Orseolia oryzae*) was found at all survey sites. However, several species of known parasitoids of gall midge were also found. These included *Platygaster* spp., which are egg and larval parasitoids, *Neanastatus* spp. (pupal parasitoid), and *Propicrocystus minificus, Eurotoma* sp., *Tetrastichus* sp., *Telenomus* sp., and *Trichopria* sp. (larval and pupal parasitoids). These and other species of parasitoids attacking the rice gall midge were reported by Kobayshi (1986) and Barrion et al (1996). The presence of such beneficial species in Lao rice fields is one indicator of natural checks on gall midge infestation.

Inthavong et al (1996) reported that, for the Lao irrigated environment, detritivores dominated rice arthropod samples, especially during the early growth stage. This conforms with results of studies in Indonesia (Settle et al 1996), in the Philippines (Schoenly et al 1996a,b), and in the rainfed lowland component of this study in Laos, where populations of detritivores peaked at close to 30 DT. Most detritivores found in the Indonesian study were chironomid larvae, as was the case of this study. Other species included Collembolans (Sminthuridae and Entomobryiidae).

The early occurrence of scavengers/tourists in Laos, Indonesia, and the Philippines provided an abundant and consistent food source for the early-arriving generalist predators while predator populations grew. Some predators and parasitoids became established by 30 DT and continuously increased to 55 DT. Parasitoids increased their colonization up to 80 DT, whereas predators either declined or remained the same. Such trends are consistent with the study of Heong et al (1991), which reported peaked abundances of parasitoids and predators between 40 and 50 DT. At the Lao sites, as populations of herbivores increased, so did predators and parasitoids. This was particularly apparent for cicadellids, delphacids, and the rice gall midge and their respective predators and parasitoids. Total counts of predators and parasitoids at the sampling sites were always greater than herbivore counts. This situation of natural enemies outnumbering herbivores may contribute to the relatively infrequent occurrence of pest problems reported in Laos. A study conducted by Heong et al (1991) in the Philippines showed a reverse pattern. Herbivores were more abundant than predators, ranging from 9:1 to 2:1 ratios at three of their study sites; one site had more predators than herbivores (2:1).

The higher population of natural enemies in Lao rice fields could be attributed to the absence of chemical pesticide use. Studies conducted in the Philippines have showed that natural enemy abundance was much greater in unsprayed plots than in sprayed plots (Schoenly et al 1996a,b). Outbreaks of BPH in several tropical Asian countries have been associated with the widespread and intensive use of insecticides (Heinrichs et al 1982, Heinrichs and Mochida 1984, Kenmore et al 1984). In Laos, where few insecticides are used on rice, outbreaks of insect pests are relatively infrequently reported.

Farmers in Laos perceive the rice gall midge (*Orseolia oryzae*) and rice stem borers (yellow and striped) to be potentially significant damaging pests to their rice crop (Rapusas et al 1997). However, experiments conducted in farmers' fields from 1993 to 1996 (Lao-IRRI 1994, 1995, 1996) failed to demonstrate significant yield losses caused by these pests. Although there have been occasions when gall midge has been known to cause damage, such losses have generally occurred in relatively small areas located near forest. These areas also have high populations of wild rice (*Oryza rufipogon*), an alternate host of the rice gall midge. During the fallow period, this insect aestivates on wild rice and on ratoons of *O. sativa* Linn.

Brown and Southwood (1983) have shown that trophic diversity can increase with successional age, while proportions of species in different guilds remain unchanged. Strong et al (1977) showed that herbivore diversity and abundance are related to host-plant composition, plant architecture (Lawton 1983), geography (Hendrix et al 1988), and environmental fluctuations. In tropical rice ecosystems, however, arthropod communities may vary more with cropping patterns, varieties, and cultivation practices than with season or geography. The predominance of nonrice habitats within or around rice paddies may have contributed to the abundance and diversity of the natural enemy populations inhabiting Laos rice fields. Furthermore, as pesticide use in Laos is minimal, there were no chemical perturbations in the rice ecosystem other than those coming from fertilizer inputs. Lao farmers have, until recently, planted a wide range of rice cultivars, with individual farmers planting 3–4 varieties. This may provide a diverse array of habitat sites and preferences for rice-associated arthropods.

Summary of findings

Arthropods collected were categorized into four guilds: herbivores, predators, parasitoids, and detritivores. Samples yielded a total of 391,713 individuals. Across sites, 763 species of arthropods belonging to 592 genera, 202 families, and 18 orders were found. Detritivores were the most abundant (46.7%), followed by herbivores (23.9%), parasitoids (16.9%), and predators (12.5%). Detritivores were the most common at 30 DT, whereas predators, parasitoids, and herbivores were the most abundant at 55 DT.

The herbivores belonged to 57 families, 180 genera, and 237 species. Spiders constituted 35% of the total predators, followed by Dipterans and Hemipterans. Some 98% of the parasitoids were Hymenopterans. The other 2% belonged to Acarina, Diptera, and Strepsiptera. Hymenopteran parasitoids were dominated by species of the families Trichogrammatidae and Mymaridae (important parasitoids of hopper eggs), Eulophidae and Scelionidae (attack stem borer eggs), and Platygasteridae (attack eggs and larvae of the rice gall midge).

Similar successional patterns in the populations of herbivores, predators, and parasitoids were observed across sites. High populations of predators and parasitoids coincided with high populations of herbivores at 55 DT. Generally, more natural enemies (predators and parasitoids combined) than herbivores were collected. The predominance of natural enemies coincided with the country's low insecticide inputs for rice, thus permitting maximum use of natural biological control agents. Moreover, the predominance of nonrice habitats within and around rice paddies contributed sources and sinks of natural enemy populations.

Implications for rice integrated pest management

An important principle of pest management is to maximize natural biological control. The results of studies in the rainfed and irrigated environments have demonstrated the existence of a mechanism that supports high levels of natural biological control in Laos. It is therefore important that these existing natural biological control agents be conserved by maintaining their natural habitats, especially during the seasons when rice is not cropped, and continuing the current practice of minimal insecticide use. However, as rice production targets increase, and as production is intensified with an expansion of irrigation area and increased fertilizer use, increased pesticide use might be expected to follow. These practices will inevitably change not only the rice ecosystem but also neighboring (nonrice) landscapes in the country.

A recent analysis of farmers' beliefs and practices in Laos showed that farmers beliefs and attitudes toward insects and insecticide use are similar to those in other Asian countries (Heong et al 2002). Farmers strongly believe that insects will decrease production. Lao farmers are potentially vulnerable to becoming victims of insecticide misuse as in many Asian countries that implemented rice intensification programs.

Strategic plans in research, education, extension, and policies related to pest management and pesticide use will need to be developed and implemented in order to avoid the mistakes of the Green Revolution.

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Notes

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Appendix I. Arthropod inventory.

PHYTOPHAGES

Coleoptera

Apionidae

Apion sp.***

Bostrichidae

Unidentified Bostrichidae *

Bruchidae

Callosobruchus sp. ***
Mylabris sp. **
Unidentified Bruchidae **

Buprestidae

Unidentified Buprestidae **

Chrysomelidae

Aulocophora sp.***
Aulocophora cf femoralis ***
Basilepta sp. **
Chaetocnema basalis (Baly) ***
Chaetocnema spp. ***
Colpodes sp. **
Dicladispa armigera (Olivier) ***
Galerucinae **
Hispa stygia (Chapuis) **
Hispellinus sp. **
Leptinotarsa sp. **
Luperodes sp. **
Luperomorpha sp. **
Medythia sp. **
Monocerus sp. **
Monolepta signata Olivier ***
Monolepta sp. ***
Oulema sp. **
Phylotreta sp. **
Psylliodes sp.***
Rhyparida sp. **
Unidentified Chrysomelidae A **
Unidentified Chrysomelidae B **

Cucujidae

Cryptolestes pusillus (Schoener) **

Curculionidae

Bagous sp. ***
Echinocnemus sp. ***
Hydronomidius sp. **
Nanphyes sp. ***
Sitophilus sp. **
Sitophilinae **
Unidentified Curculionidae A ***
Unidentified Curculionidae B **

Elateridae

Aeoloderma brachmana (Candeze) ***
Unidentified Elateridae ***

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* = recorded in irrigated lowland rice ecosystem (DS) only,
** = recorded in rainfed lowland rice ecosystem (WS) only,
*** = recorded in both rainfed and irrigated rice ecosystems.

Languridae
Langura sp. **

Pselaphidae
Unidentified Pselaphidae **

Tenebrionidae
Unidentified Tenebrionidae **

Diptera
Agromyzidae
Agromyza sp. **
Pseudonapomyza sp. *
Unidentified Agromyzidae ***

Cecidomyiidae
Cantarina sp. **
Cantarina nom. rev. *sorghicola* (Coquillet) **
Orseolia oryzae (Wood-Mason) ***
Orseolia sp. **

Chloropidae
Chlorops sp. **

Ephydridiae
Brachydeutera sp. *
Ephydra sp. ***
Hydrellia griseola (Fallen) ***
H. philippina Ferino ***
Hydrellia sp. nov. ***
Notiphila sp. **
N. dorsopunctata Wiedemann***
N. similis de Meijere ***
Paralimna sp. ***
Psilopa spp. ***
Psilopinae **
Unidentified Ephydridae A **

Muscidae
Atherigona sp. ***
Unidentified Muscidae **

Tephritidae
Spathulina sp. ***
Unidentified Tephritidae **

Tipulidae
Tipula sp. ***
Unidentified Tipulidae A ***
Unidentified Tipulidae B **
Unidentified Tipulidae C **

Hemiptera
Aleyrodidae
Unidentified Aleyrodidae ***

Alydidae
Leptocorisa sp. ***
L. acuta (Thunberg) ***
L. oratorious (Fabricius) ***
Riptortus sp. **

Berytidae
Unidentified Berytidae **

Cercopidae
Clovia sp. ***
Unidentified Cercopidae **

Cicadellidae
Amrasca sp. **
Balclutha spp. ***
Cicadulina bipunctata (Melichar) **
Cicadulina sp. 1 **
Cicadulina sp. 2 **
Cofana spectra (Distant) ***
Cofana inimaculata (Signoret) ***
Deltacephalus sp. ***
Deltacephalus samuelsoni Knight ***
Empoascacini sp. **
Empoascanara sp. ***
E. nana Dworakowska & Pawar **
Exitianus sp. **
E. indicus (Distant) **
Hecalus morrisoni (Thomson) **
Macrosteles sp. ***
M. striifrons (Anufriev) ***
Nephotettix sp. **
N. malayanus Ishihara & Kawase ***
N. nigropictus (Stål)***
N. parvus Ishira & Kawase ***
N. virescens (Distant) ***
Recilia dorsalis (Motschulsky)***
R. distincta (Motschulsky) ***

Scaphoideus morosus Melichar **
Thaia ghauri Dworakowska ***
T. oryzivora Ghauri **
Ugyops sp. *
Unidentified Cicadellidae. **

Cixiidae
Oliarus sp. **
Unidentified Cixiidae **

Delphacidae
Harmalia sp. ***
H. anacharsis Ghauri **
Nilaparvata bakeri Muir **
N. lugens (Stål) ***
Opinconsiva sp. ***
O. dodona (Fennah) ***
Perigrinus maidis (Ashmead)**
Perkinsiella sp. **
Sardia rostrata (Melichar) **
Sogatella furcifera (Horvath) ***
S. kolophon (Kirkaldt)**
S. vibix (Haupt) **
Sogatella sp. **
Stenocranus sp. **
Tarophagus sp. **
Tagosodes pusanus (Distant) ***
Toya propinqua (Fieber) ***
Toya sp. ***

Derbidae
Proutista moesta (Westwood) **
Unidentified Derbidae **

Dictyoparidae
Dictyophara sp. **

Lygaeidae
Cletus sp. **
Cymmoninus sp. **
C. turaensis (Paiva) ***
C. basicornis (Motschulsky) ***
Cymodema sp. **
Horridipamera sp. ***
Nysius nr. vinitor Bergroth ***
Pachybrachius sp. **
P. nietneri (Dohnn) ***
Pachygrontha sp. **
Paromius piratoides Costa **
Unidentified Lygaeidae A ***
Unidentified Lygaeidae B **

Meenoplidae
Nisia nervosa (Mutschulsky) **
Nisia sp. ***

Miridae
Campylomma sp. **
Halticus minutus Reuter **
Halticus sp. **

Pentatomidae
Eysarcoris sp. **
E. ventralis Distant ***
Pygomenida sp. **
Unidentfied Pentatomidae **

Plataspidae
Unidentified Plataspidae **

Pseudococcidae
Unidentified Pseudococcidae A **
Unidentified Pseudococcidae B **

Psyllidae
Unidentified Psyllidae **

Tingidae
Belenus sp. ***
Unidentified Tingidae **

Lepidoptera
Arctiidae
Utethesia sp. **
Unidentified Arctiidae **

Gelechiidae
Sitotroga sp. **

Geometriidae
Geometrid larva **
Unidentified Geometriidae **

Hesperidae
Parnara sp. ***
P. gutatta Bremer & Gray *

Pelopidas mathias (Fabricius) ***
Pelopidas sp. **

Lasiocampidae
Unidentified Lasiocampidae **

Lymantriidae
Lymantria sp. **
Unidentified Lymantriidae **

Noctuidae
Chrysodexis chalcites Esper **
Mocis frugalis (Fabricius) **
Mocis sp. **
Mythimna rosilinea (Walker) **
M. separata (Walker) ***
Naranga aenescens (Moore) ***
Rivula atimeta (Swinhoe) **
Rivula sp. **
Sesamia inferens (Walker) **
Spodoptera mauritia acronyctoides (Guenee)***
Unidentified Noctuidae **

Pieridae
Pieres rapae crucivora Boisduval **

Psychidae
Clania sp. **

Pterophoridae
Unidentified Pterophoridae ***

Pyralidae
Bradina sp. **
Chilo auricillus Dudgeon **
C. suppressalis (Walker) ***
Cnaphalocrocis/Marasmia spp. ***
Nymphula sp. **
N. depunctalis (Guenee) ***
Scirpophaga incertulas (Walker) ***

Satyridae
Melanitis leda leda Cramer **
Pothanthus sp. **
Unidentified Satyridae **

Ypomomeutidae
Unidentified sp. **

Orthoptera
Acrididae
Acrida sp. ***
Acrida willemsie Dirsh **
Ailophus sp. **
Oxya hyla intricata (Stal) ***
O. japonica japonica (Thunberg) ***
Oxya spp, ***
Patanga succinata (Linn) **
Unidentified Acrididae **

Gryllidae
Ducetia sp. **
Eucyrtus cuncinnus (de Haan) ***
Oecanthus sp. **
Plebeiogryllus sp. ***
Teleogryllus sp. ***

Pyrgomorphidae
Atractomorpha sp. ***
A. crenulata (Fabricius) ***
A. psittacina (de Haan) **

Tettigoniidae
Phaneroptera sp. **

Tetrigiidae
Euparatettix sp. **
Paratettix sp. **
Unidentified Tetrigiidae ***

Thysanoptera
Aelothripidae
Unidentified Aelothripidae **

Phaeothripidae
Unidentified Phaeothripidae A ***
Unidentified Phaeothripidae B ***

Thripidae
Caliothrips sp. **
Chirothrips sp. ***
C. manicatus (Haliday) **
Chleothrips sp. **
Eliothrips sp. **

Frankiniella sp. ***
Haplothrips sp. ***
H. aculeatus (Fabricius) ***
H. ganglbaueri Schmutz ***
Scirtothrips sp. ***
Stenchaetothrips sp. **
S. biformis (Bagnall) ***
Thrips palmi Kamy **
Thrips tabaci **
Thrips sp. ***
Unidentified Thripidae A **
Unidentified Thripidae B ***

Trichoptera
Unidentifed Trichoptera **

PREDATORS
Araneae

Orb weavers
Araneidae
Araneus inustus (C.L. Koch) ***
Araneus sp. **
Argiope sp. ***
A. bruenichii **
A. catenulate (Doleschall) ***
Cyclosa sp. **
Cyrtophora sp. ***
Gea subarmata Thorell **
Gea sp. **
Laninia sp. **
Neoscona theisi (Walckenaer) **
Singa harmata (Clerck)**
Singa sp. **
Unidentified Araneidae **

Lyniphiidae
Atypena formosana (Oi) ***
Erigona sp. ***
Linyphia sp. **
Unidentified Lyniphiidae A **
Unidentified Lyniphiidae B **

Metidae
Leucauge decorata (Blackwall) ***
Metinae sp. **
Taylorida striata Thorell **
Tylorida sp. **
Unidentified Metidae **

Philodromidae
Thanatus sp. **
Tibellus sp. **

Tetragnathidae
Dyschiriognatha sp. ***
Tetragnatha sp. ***
T. ceylonica Cambridge **
T. javana (Thorell) ***
T. mandibulata Walckenaer ***
T. maxillosa Thorell ***
T. nitens (Audouin) ***
T. virescens Okuma ***
Unidentified Tetragnathidae **

Theridiosomatidae
Wendilgardia sp. **
Unidentified Theridiosomatidae **

Uloboridae
Uloborus sp. **

Hunters
Clubionidae
Castianera sp, **
Chiracanthium sp. **
Clubiona drassodes O.P.Cambridge **
C. japonica Boesenberg & Strand ***

Gnaphosidae
Zelotes sp. **
Unidentified Gnaphosidae **

Lycosidae
Arctosa sp. **
Hippasa sp. **
H. holmerae Thorell **
Pardosa bimanica Simon **
P. pseudoannulata (Boesenberg & Strand) ***
P. sumatrana (Thorell) **
Pardosa sp. **
Pirata sp. ***
Trochosa sp. ***

Oonopidae

Oonops sp. **

Unidentified Oonopidae **

Oxyopidae

Oxyopes sp. **

O. javanus thorell ***

O. lineatipes (C.L. Kock) ***

O. macilentus C.L. Kock **

Pisauridae

Dolomedes sp. ***

Perenethis sp. **

Unidentified Pisauridae A **

Unidentified Pisauridae B **

Salticidae

Bianor hotengchiehi Schenkel ***

Bianor sp. ***

Harmochirus sp. **

H. brachiatus (Thorell) **

Marpissa sp. **

Mymarachne sp. ***

Rhene sp. **

Plesippus sp. **

P. paykulli (Audouin) ***

Salticus sp. **

Salticus sp. (tiger-like) **

Unidentified Salticidae ***

Scytodidae

Scytodes thoracica (Latreille) **

Sparrasidae

Heteropoda sp. **

Olios sp. **

Unidentified Sparrasidae**

Theridiidae

Chrysso sp. **

Coleosoma blandum Cambridge **

C. flavidanum **

Conopistha sp. **

Dipoena sp. ***

Rhompea sagana (Doenitz) **

Theridion sp. ***

T. octomaculatum Boesenberg & Strand **

Unidentified Theridiidae ***

Thomisidae

Camaricus sp. *

Runcinia sp. ***

Thomisus sp. **

Xysticus sp. **

Unidentified Thomisidae ***

Acarina

Cunaxidae

Cunaxa sp. **

Unidentified Cunaxidae ***

Hydrachnidae

Hydrachna sp. **

Unidentified Hydrachnidae ***

Mesostigmatidae

Unidentified sp. **

Phytoseidae

Unidentified sp. **

Trombiculidae

Unidentified Trombiculidae **

Coleoptera

Anthicidae

Anthicus sp. ***

Formicomus sp. ***

F. braminus (La Ferte Senectere) ***

Unidentified Anthicidae A ***

Unidentified Anthicidae B **

Carabidae

Anoplogenius sp. ***

Batoscelis sp. **

Chlaenius sp. **

Cicindella sp. **

Drypta sp. **

D. japonica (Bates) **

Egadroma sp. **

Ophionea sp. ***

O. indica (Thunberg) **

O. interstitialis Schymidt-Goebel **

O. ishii Habu **

Selena sp. **

Stenius sp. **
Unidentified Carabidae A ***
Unidentified Carabidae B **

Cleridae
Unidentified Cleridae ***

Coccinellidae
Brumoides sp. ***
Coccinella repanda Thunberg ***
Harmonia octomaculata (Fabr.) *
Micraspis discolor (Fabr.) ***
M. vincta (Gorham) ***
Paracymnus sp. **
Scymnus sp. ***
Unidentified Coccinelidae **

Dysticidae
Agabus sp. **
Cybister sp. ***
Laccophilus sp. **
Rhantus sp. **
Unidentifed Dysticidae ***

Gryinidae
Unidentified Gryinidae **

Halyplidae
Peltodytes sp. **

Hydraenidae
Hydraena sp. ***
Unidentified Hydraenidae ***

Hydrophilidae
Berosus sp. **
Stemolophus sp. **
Unidentified Hydrophilidae ***

Melyridae
Apalochrus sp. ***
A. rufofasciatus Pic ***

Mordellidae
Unidentified Mordellidae **

Phalacridae
Stilbus sp. ***

Spercheidae
Sphercus sp. **

Staphylinidae
Oligota sp. **
Paederus sp. **
P. fuscipes Curtis **
P. tamulus Erichson ***
Philonthus sp. ***
Stenus sp. ***
Stilcopsis sp. ***
Unidentified Staphylinidae A ***
Unidentified Staphylinidae B **

Diptera
Asilidae
Unidentified Asilidae **

Ceratopogonidae
Culicoides sp. **
Dasyhelea sp. **
Nilobezia sp. ***
Nilobezia-like, red-brown
Nilobezia-like, light brown
Stilobezia sp. **
Unidentified Ceratopogonidae ***

Chloropidae
Anatrichus pygmaeus (Loew) ***
Anatrichus sp. **
Unidentified Choloripidae **

Dolicopodidae
Syntretus sp. **
Unidentified Dolicopodidae A (blue) **
Unidentified Dolicopodidae B (yellow) **
Unidentified Dolicopodidae C **

Empidae
Drapetis sp. 1 ***
Drapetis sp. 2 ***

Ephydridae
Ochthera brevitibialis de Mejere ***

Platystomatidae
Poecilotraphera taeniata (Macquart) ***

Stratiomyidae
Microchryza sp. *

Syrphidae
Epistrophe sp. ***
Vulbocela sp. **
Unidentified Syrphidae ***

Hemiptera
Anthocoridae
Orius sp. ***
O. tantillus (Motschulsky) ***
Unidentified Anthocoridae **

Belostomatidae
Diplonychus rusticus (Fabr.) **

Corixidae
Micronecta sp. **
M. quadristrigata Breddin**

Dipsocoridae
Unidentified Dipsocoridae **

Gerridae
Gerris sp. ***
G. adelaides Dohrn **
Limnogonus sp. ***

Hebridae
Hebrus sp. ***

Hydrometridae
Hydrometra spp. ***

Leptopodidae
Unidentified Leptopodidae **

Lygaeidae
Geocoris sp. **
Graphotesthus sp. ***

Mesoveliidae
Mesovelia vittigera (Horvath) ***

Miridae
Creontiades sp. ***
C. pallidifer **
Cyrtorhinus lividipennis Reuter ***
Deraecoris sp. **
Proboscidocoris sp. ***
Tytthus chinensis (Stål) ***
Unidentified Miridae A ***
Unidentified Miridae B **

Nabidae
Nabis sp. **
Stenonabis sp. ***
S. tagalicus (Stål) ***
Unidentified Nabidae **

Nepidae
Ranatra sp. **
R. diminuta Montadon **

Notonectidae
Anisops spp. ***
Enithares sp. **
Unidentified Notonectidae **

Ochteridae
Ochterus sp. **
O. marginatus (Latreille) **

Pentatomidae
Eurydema sp. **
Zincrona caerulea (Linne) **

Plataspidae
Coptosoma sp. **

Pleidae
Paraplea sp. **
Plea sp. **
P. liturata **
Unidentified Pleidae **

Reduviidae
Polytoxus sp. ***
Scipinia sp. **
S. horrida Stål **
Staccia sp. **
Unidentified Reduviidae **

Veliidae
Microvelia sp. ***
M. douglasi atrolineata Bergroth ***
M. douglasi Scott **
Unidentified Veliidae A **
Unidentified Veliidae B **

Hymenoptera
Formicidae
Anoplolepis sp. ***
Camponotus sp. **
Diacamma sp. ***
Monomorium sp. **
M. floricola **
Oecophylla smarginata (Fabr.) **
Pheidole sp. **
Plagiolepis sp. **
Polyrachis sp. **
Solenopsis sp. A ***
Solenopsis sp. B **
Tapinoma sp. ***
Tetramorium ninatum (Nylander) **
Tetramorium sp. A **
Tetramorium sp. B **
Technomyrmex sp. **
Unidentified Formicidae **

Mutillidae
Unidentified Mutillidae **

Sphecidae
Unidentified Sphecidae **

Vespidae
Ropalida sp. ***
R. cyathiformis (Fabricius) ***
Vespa sp. **
Unidentified Vespidae **

Mantodea
Mantidae
Unidentified Mantidae **

Neuroptera
Chrysopidae
Unidentified Chrysopidae **

Odonata
Coenagrionidae
Agriocnemis spp. ***
Coenagrion sp. ***
Ischnura senegalensis (Brauer) ***

Libelludidae
Diplacodes sp. **
D. trivialis Fabr. ***
Neurothemis sp. **
N. tullia tullia (Drury) ***
Orthethrum sp. ***

Orthoptera
Gryllidae
Anaxipha sp. ***
Metioche sp. **
M. vittaticolis (Stål) ***

Tettigoniidae
Conocephalus longipennis (de Haan) ***
C. maculatus (de Guillou) ***
Euconocephalus sp. **
Euconocephalus varius (Walker) **
Unidentified sp. *

Tridactylidae
Tridactylus sp. **

Pseudoscorpionida
Pseudoscorpionidae
Unidentified Pseudoscorpionidae **

PARASITOIDS
Acarina
Hydrachnidae
Hydrachna sp. **
Unidentified Hydrachnidae **

Tarsonemidae
Unidentified Tarsonemidae ***

Diptera
Phoridae
Megaselia spp. ***
Unidentified Phoridae **

Pipunculidae
Pipunculus sp. ***
P. mutillatus Loew **
Tomosvaryella sp. ***
T. inazumae (Koizumi) **
T. oryzaetora (Koizumi) **
Unidentified Pipunculidae *

Sarcophidae
Unidentified Sarcophidae **

Sciomyzidae
Sepedon sp. ***

Tachnidae
Argyrophylax sp. **
Halidaya luteicornis (Walker) **
Siphona sp. ***
Unidentified Tachinidae A ***
Unidentified Tachinidae B **

Hymenoptera
Aphelinidae
Aphelinus sp. **
Aphytis sp. **
Encarsia sp. ***
Unidentified Aphelinidae **

Bethyliida
Goniozus sp. **
G. nom. rev. *triangulifer* Kieffer **

Braconidae
Aphidius sp. **
Aspilota sp. ***
Bracon chinensis (Szepligeti) ***
B. onuki Watanabe ***
Bracon sp. ***
Cotesia spp. ***
Cubochelonus sp. **
Diatrella sp. **
Euopius sp. ***
Exoryza schoenobii (Wilkinson) ***
Hygroplitis russatus (Haliday) **
Macrocentrus sp. **
M. philippinensis Ashmead **
Opius barrioni Fisher **
Opius sp. ***
Rogas sp. ***
R. narangae Rohwer **
Tropobracon sp. ***
T. schoenobii (Viereck) ***
Unidentified Braconidae A ***
Unidentified Braconidae B ***

Ceraphronidae
Aphanogmus sp. ***
A. fijiensis (Ferriere) ***
Ceraphron sp. ***
Ceraphron sp. A **
Ceraphron sp. B **

Chalcididae
Antrocephalus sp. **
Brachymeria sp. **
B. excarinata Gahan ***
B. lasus (Walker)**
Unidentified Chalcididae **

Cypinidae
Eucoilidea sp. ***
Unidentified Cypinidae *

Diapriidae
Spilomicrus sp. **
Trichopria sp. ***
Trichropia sp. 1 ***
Trichropia sp. 2 **
Unidentified Diapriidae *

Dryinidae
Echthrodelphax sp. **
E. fairchildii Perkins **
Haplogonatopus sp. ***
Neogonatopus sp. **
Pseudogonatopus sp. ***
Tetrodontochelys sp. **
Unidentified Dryinidae ***

Elasmidae
Elasmus sp. A***
Elasmus sp. B **
Elasmus sp. C **

Encyrtidae
Anagyrus sp. ***

Copidosoma sp. **
Copidosomopsis sp. ***
C. nacoleiae (Eady) ***
Encyrtus sp. **
Unidentified Encyrtidae A ***
Unidentified Encyrtidae B **

Eulophidae
Diglyphus sp. **
Eotetrastichus sp. **
E. beatus **
E. formosanus ***
Euplectus sp. **
E. chapadae (Ashmead) ***
Hemiptarsenus sp. **
H. cf. semialbiclavus Girault ***
Norbanus sp. ***
Pediobius sp. **
Stenomesius sp. **
Sympiesis sp. ***
Tetrastichus sp. ***
T. howardii (Olliff) **
T. schoenobii Ferriere ***
Unidentified Eulophidae ***
Unidentified Tetrastichinae **

Eupelmidae
Eupelmus sp. **
Neanastatus sp. ***
Neanastatus sp. A **
Neanastatus sp. B **

Eurytomidae
Eurytoma sp. ***
E. braconidia (Wilkinson) ***

Ichneumonidae
Amauromorpha sp. ***
A. accepta metathoracica (Ashmead) **
Astomaspis sp. **
A. metathoracica **
Casinaria sp. **
Charops sp. **
Coccygomimus sp. **
Goryphus sp. ***
Itoplectis narangae (Ashmead) **
Leptbatopsis sp. **
Linella sp. ***
Metopius rufus (Ashmead) **
Metopius sp. **
Paraphylax spp. **
Stenobracon sp. **
Strepsimallus sp. **
Temelucha stangli (Ashmead) ***
Temelucha sp. **
Temelucha-like **
Theronia sp.**
Vulgichneumon leucaniae Uchida **
Xanthopimpla punctata (Fabr.) *
X. flavolineata (Cameron) ***
X. stemmator (Thunberg) **

Mymaridae
Acmopolynema sp. **
Anagrus spp. ***
Anaphes sp. **
Arescon sp. **
Gonatocerus spp. ***
Mymar sp. **
M. taprobanicum Ward ***
Polynema sp. **
Stephanodes sp. **
Unidentified Mymaridae **

Platygasteridae
Inostema sp. **
Platygaster sp. ***
P. foersteri (Gahan) **
P. oryzae (Cameron)**

Pteromalidae
Obtusiclava sp. **
Panstenon nom. rev. *collaris* Boucek **
Panstenon sp. ***
Propicrcystus sp. **
P. minificus (Girault) **
Trichomalopsis spp. ***
Unidentified Pteromalidae **

Scelionidae
Baeus spp. ***
Ceratobaeus sp. ***
Fusicornia sp. **
Gryon sp. **
G. nixoni Masner ***
Idris spp. ***

Macrotelia sp. **
Platyscelio sp. ***
Psix sp. **
Scelio sp. **
Telenomus sp. ***
T. dignoides Nixon ***
T. rowani (gahan) ***
Trimorus sp. **
Unidentified Scelionidae A ***
Unidentified Scelionidae B ***
Unidentified Scelionidae C **

Tiphiidae
Unidentified Tiphiidae **

Torymidae
Podagrion sp. **
Unidentified Torymidae ***

Trichogrammatidae
Epoligosita sp. **
Megaphragma sp. **
Oligosita sp. nov. A **
Oligosita sp. nov. B **
Oligosita spp. ***
O. aesopi Girault **
O. consanguinea Girault **
O. naias Girault **
Paracentrobia sp. ***
P. andoi (Ishii) ***
Trichogramma sp. ***
T. chilonis Ishii ***
T. japonicum Ashmead ***
Trichogrammatoidea sp. **
Unidentified Trichogrammatidae ***

Strepsiptera
Elenchidae
Elenchus sp. **
E.yasumatsui Kifune & Hirashima **

Halictophagidae
Halictophagus sp. **
Unidentified Strepsiptera **

Nematoda
Mermithidae
Hydromermis sp. **
Unidentified Mermithidae **
Unidentified nematode **
Nematode on BPH **
Unidentified Nematoda **

SCAVENGERS (Detritivores) and TOURISTS

Acarina
Oribatidae
Oribatid mites **
Unidentified Oribatidae **

Uropididae
Unidentified Uropididae **

Blattodea
Blatellidae
Blatella sp. **
Unidentified Blatellidae **

Coleoptera
Chrysomellidae
Altica cyanea (Weber) ***

Inoplepidae
Unidenified Inoplepidae **

Ptinidae
Unidentified Ptinidae ***

Collembola
Entomobryiidae
Entomobrya sp. **
Unidentified Entomobryiidae **

Isotomidae
Isotoma sp. **
Unidentified Isotomidae **

Poduridae
Unidentified Poduridae **

Sminthuridae
Sminthurus sp. ***

Diptera

Anthomyiidae

Unidentified Anthomyiidae **

Calliphoridae

Calliphora sp. **

Unidentified Calliphoridae

Celyphidae

Unidentified Celyphidae

Chironomidae

Chironomus spp. ***

Cryptochironomus spp. ***

Smittia sp. **

Tanytarsus sp. **

Unidentified Chironomidae A ***

Unidentified Chironomidae B **

Chloropidae

Conioscinella sp. **

C. griseicollis (Becker)**

C. inequalis Becker **

Stelescerulus ensifer (Thomson) **

Unidentified Chloropidae **

Culicidae

Aedes sp. **

Anopheles sp. **

Culex sp. **

Unidentified Culicidae **

Diopsidae

Unidentified Diopsidae **

Drosophilidae

Banded Drosophilidae **

Yellow Drosophilidae **

Drosophila sp. **

Unidentified larva **

Unidentified Drosophilidae **

Ephydridae

Discomyza sp. **

Scatella sp. ***

Unidentified Ephydridae A **

Unidentified Ephydridae B **

Heliomyzidae

Unidentified Heliomyzidae **

Mycetophilidae

Unidentified Mycetophilidae ***

Muscidae

Musca domestica **

Musca sp. **

Unidentified Muscidae **

Psychodidae

Psychoda sp. **

Unidentified pupa **

Unidentified Psychodidae **

Pergotidae

Unidentified Pergotidae

Scatopsidae

Unidentified Scatopsidae **

Simuliidae

Unidentified Simuliidae **

Stratiomyidae

Hemetia illucens (L.) **

Odontomyia sp. **

Unidentified Stratiomyidae **

Tabanidae

Chrysops sp. **

Tabanus sp. **

Unidentified Tabanidae **

Tephritidae

Rhabdochaeta sp. **

Unidentified pupa **

Unidentified Diptera **

Ephemeroptera

Baetis sp. **

Hymenoptera

Apidae

Apis sp. **

Others

Crustacea

- *Cypris* sp. **
- *Cypris*-like **
- *Cyclops* **
- *Eucyclops* **
- *Daphnia*-like **
- Species A-H **

Crab **

Fish **

Snails **

- *Pila* sp. **

Tadpoles **

Earthworms **

CHAPTER 17

Pests and diseases of the rice production systems of Laos

B. Douangboupha, K. Khamphoukeo, S. Inthavong, J. Schiller, and G. Jahn

Until the early 1990s, rice production in Lao PDR (Laos) was based on traditional production systems with minimum inputs apart from labor. Because of the relative isolation of the country, the Green Revolution of the late 1960s and 1970s had relatively little impact on rice production systems in Laos. Until the mid-1990s, there was little use of chemical pesticides in most areas of agricultural production. Studies by Rapusas et al (1995, 1997) (refer also to Chapter 16) about this time showed a much greater diversity in the communities of insects in the rice environments of Laos than was found in other countries of the region where insecticide use had become routine in rice production systems. Some of the insect species found in Laos are pests, but most are harmless or beneficial species (Shepard et al 1995).

Pests and diseases, although present in Lao rice production systems, are generally not regarded as major constraints to yield, although some pests, such as the rice gall midge (RGM) (*Orseolia oryzae* (Wood-Mason)), can significantly affect yields on a year-to-year and area-specific basis (Inthavong 1999). However, some recent changes in traditional rice production practices are believed to have brought about increased pest and disease problems, with the greatest changes and greatest impact taking place in the lowland environment. This chapter reviews the importance and recent changes in the status of the major pests and diseases of rice in Laos.

The lowland rice environment

Changes in agricultural systems in lowlands

Before the 1960s, rainfed rice cultivation was the single most important rice production system in the country, with 100% of varieties grown being traditional cultivars, which were cultivated using traditional methods. Little information is available on rice pest and disease problems during that period. It has only been since 1990 that systematic studies have been undertaken on insect pests and diseases (and other production constraints) in the rice environments of Laos. The most recent plant protection research has concentrated on the rainfed lowland environment, as this has been, and remains, the dominant rice ecosystem in Laos.

Improved high-yielding varieties were first used on a limited scale in intensified rice systems in the late 1970s, making their impact mainly in areas where irrigation facilities were available. Changes in agricultural practices can sometimes result in increased pest and disease problems. Several examples can be cited from Laos. Some of the higher-yielding improved rice varieties are more susceptible to insect pests and diseases than traditional cultivars. The release of the high-yielding variety Thadokham-1 (TDK-1) in 1993 was associated with an epidemic of bakanae disease (caused by *Gibberella fujikuroi*). The variety RD10, first introduced from Thailand in the late 1970s, was susceptible to stem borer. Since 1986, brown planthopper (BPH) (*Nilaparvata lugens* (Stål)) and rice bug (*Leptocorisa oratorius*) (Fabricius) have caused serious damage to dry-season irrigated rice crops in several provinces in the central and southern agricultural areas (particularly in the provinces of Vientiane (and Vientiane Municipality), Borikhamxay, Khammouane, and Saravane). In contrast, maturity time rather than susceptibility is often the determining factor in rice bug outbreaks. The adoption of improved early-maturing varieties in some areas of lowland rice cultivation has sometimes been associated with increased rice bug damage (Lao-IRRI 2000). The significant expansion in the area of irrigated rice cultivation since the mid-1990s in the central and southern agricultural regions, allowing both wet-season and dry-season rice cropping, has provided conditions favorable for the carryover of pests from season to season.

Pests and diseases in the lowland rice environment

The lowland rice environment in Laos consists of a combination of wet-season rainfed and dry-season irrigated rice cultivation. More than 80% of the lowland rice-growing area in the wet season is located in the central and southern agricultural regions of the country. Farmers have generally cited drought and poor soil fertility as the major constraints to production and yields in wet-season rice cultivation in these areas (Schiller et al 2001). Until relatively recently, insect pests and diseases have generally not been regarded as major production constraints in the wet-season rainfed lowland environment. Insect pests probably cause more damage to lowland rice crops than diseases (Rapusas et al 1995). Serious pest and disease outbreaks that have periodically caused significant declines in yields and total production have included outbreaks of BPH in parts of Vientiane Province and Vientiane Municipality in dry-season irrigated areas in 1998; rice bug (*L. oratorius*) damage in Saravane Province in 1998; RGM damage in Atsaphangthong District of Savannakhet Province in the 1992 wet season, and in several districts of the same province in 2005; rice blast in Hadsayphong District of Vientiane Municipality in 1995; and neck blast in parts of Khammouane Province in 2005.

The occurrence of significant pest and disease problems is often related to the prevailing weather conditions. Outbreaks of RGM and armyworms are generally associated with high rainfall in the wet season. Drought conditions during the period of seeding the rice crop at the beginning of the wet season can often be associated with a higher than usual incidence of rice thrips. Very warm weather in the period of dry-season irrigated rice cultivation can lead to BPH and stem borer outbreaks. Sheath blight is often a problem if rain is received during the maturation phase of dry-season irrigated rice crops.

Some recent pest problems of Laos have been the result of intentional or accidental introductions of exotic species. The rapid spread of golden apple snail (*Pomacea canaliculata*) since 1992 and the outbreak of bakanae disease in 1993 are examples of exotic species that, following their introduction, have subsequently achieved pest status in Laos. Among significant weed species currently found in Laos are two that were also relatively recently introduced: the water hyacinth (*Eichhornia crassipes* Martius) and the giant sensitive plant (*Mimosa pigra* L.), both of which originated from South America (Napomphet 1992, Miller and Pickering 1980) and became major weeds in Laos, following their introduction and establishment in neighboring countries, from where they then spread to Laos.

The insect pests and diseases that have been recorded in the lowland environments of Laos, and their relative importance, are listed in Table 1. The major pests of lowland rice environments are described in the following sections.

Rice gall midge (*Orseolia oryzae*) (Wood-Mason)

With the exception of the Philippines and Malaysia, the Asian rice gall midge is a serious rice pest of all rice-producing countries in South and Southeast Asia (Gagne 1985). It is the most consistently reported cause of yield loss due to insects in the wet-season rainfed lowland environment of Laos (Lao-IRRI 1997). However, in areas of double cropping it has not been reported to be an important pest.

RGM damage has been recorded in many parts of Laos, but particularly in the provinces in the central and southern agricultural regions, including Vientiane, Borikhamxay, Khammouane, Savannakhet, Saravane, and Champassak. It has also been reported in the more northern provinces of Sayabouly and Xieng Khouang (Inthavong 1999, Inthavong et al 2004). Gall midge damage can reduce grain yield of wet-season lowland crops in Laos by 30–60% (Inthavong et al 2004). Detailed studies on the gall midge problem in the rainfed lowland environment have been undertaken in Savannakhet Province in the lower part of the central agricultural region of Laos. The RGM breeds on host plants in May, migrates to the seedbeds of wet-season crops in May or June, and is transferred during transplanting to paddy fields in June or July. Generally, RGM infestations become apparent between July and September, with peak damage toward the end of August and early September (Fig. 1). In recent times, particularly high RGM incidence and damage were recorded in areas of rainfed lowland cropping in Laos in the wet seasons of 1999, 2000, and 2005. The degree of RGM damage in any year is closely related to rainfall distribution and time of planting (Hikada et al 1994, 1996, Lao-IRRI 1996, 2001). Early wet-season plantings (May) are generally associated with low levels of infestation. Later plantings (in June and July) often enter the tillering stage of crop development when weather conditions are favorable to the buildup of gall midge populations; when combined with higher than average rainfall in September and October, RGM damage and yield loss can be very severe (Lao-IRRI 1999).

Table 1. Insect pests and diseases found in the lowland rice production systems of Laos.

Region	Common name	Scientific name	Period of crop growth	Ranking[a] Wet-season crops	Dry-season crops
Northern					
	Pests				
	Ants	*Solenopsis geminate*	Sowing	+	+
	Golden apple snail	*Canaliculata incertulas*	Seedling	+++	+++
	Asian rice gall midge	*Orseolia oryzae*	Tillering	+++	++
	Black bugs	*Scotinophara* spp.	Tillering	+	+
	Brown planthopper	*Nilaparvata lugens*	Tillering-harvest	+++	+++
	Grasshopper	*Oxya* spp. and *Acrida* spp.	Seedling-ripening	++	+
	Hispa	*Dicladispa armigera*	Tillering	+	+
	Rats	*Rattus* sp. *and Mus* sp.	Sowing, reproductive	+++	+++
	Rice bug	*Leptocorisa oratorius*	Reproductive	++	++
	Stem borers	*Chilo suppressalis*	Tillering	++	++
		Scirpophaga incertulas	Tillering	++	++
	Thrips	*Balothrips biformis*	Seedling	++	++
	Diseases				
	Bakanae disease	*Fusarium moniliforme*	Tillering	++	++
	Brown spot	*Helminthosporium oryzae*	Tillering-reproductive	++	++
Central					
	Pests				
	Golden apple snail	*Canaliculata incertulas*	Seedling	+++	+++
	Armyworm	*Spodoptera mauritia*	Seedling-panicle	++	+
	Asian rice gall midge	*Orseolia oryzae*	Tillering	+++	++
	Brown planthopper	*Nilaparvata lugens*	Tillering-harvest	+++	+++
	Caseworm	*Nymphula litura*	Tillering	+	+
	Cutworm	*Spodoptera litura*	Seedling-tillering	+	+
	Leaffolder	*Cnaphalocrocis medinalis*	Tillering	+	+
	Rice bug	*Leptocorisa oratorius*	Reproductive stage	+++	+++
	Stem borers	*Chilo suppressalis*	Tillering	++	++
		Scirpophaga incertulas	Tillering	+	+
		S. innotata, Sesamia inferens	Tillering	+	+
	Thrips	*Balothrips biformis*	Seedling	++	++
	Whitebacked planthopper	*Sogatella furcifera*	Tillering	++	+
	Whorl maggot	*Hydrellia philippina*	Tillering	+	+
	Zigzag leafhopper	*Recilia dorsalis*	Tillering	++	++
	Diseases				
	Bacterial leaf blight	*Xanthomonas campestris*	Maximum tillering-reproductive stage	++	++
	Bakanae disease	*Fusarium moniliforme*	Tillering	++	++
		Gibberella fujikuroi	Tillering	++	++

Continued on next page

Table 1 continued.

Region	Common name	Scientific name	Period of crop growth	Ranking*	
				Wet-season crops	Dry-season crops
	Blast	*Pyricularia oryzae*	Seedling-reproductive stage	++	++
	Brown spot	*Helminthosporium oryzae*	Tillering-reproductive stage	++	++
	False smut	*Ustilaginoidea virens*	Flowering-maturing	+	+
	Foot rot	*Erwinia chrysanthemi*	Maximum tillering-reproductive stage	+	+
	Leaf streak	*Xanthomonas campestris*	Tillering-reproductive stage	+	+
	Narrow brown leaf spot	*Cercospora oryzae*	Tillering-reproductive stage	++	++
	Sheath blight	*Rhizoctonia solani*	Maturing	+	+
	Sheath rot	*Sarocladium oryzae*	Booting	++	++
	Stem rot	*Helminthosporium sigmoideum*	Reproductive stage	++	++
Southern					
	Pests				
	Golden apple snail	*Canaliculata incertulas*	Seedling	+++	+++
	Armyworm	*Spodoptera mauritia*	Seedling-panicle	++	+
	Asian rice gall midge	*Orseolia oryzae*	Tillering	+++	++
	Brown planthopper	*Nilaparvata lugens*	Tillering-harvest	+++	+++
	Caseworm	*Nymphula litura*	Tillering	+	+
	Cutworm	*Spodoptera litura*	Seedling-tillering	++	++
	Leaffolder	*Cnaphalocrocis medinalis*	Tillering	+	+
	Rice bug	*Leptocorisa oratorius*	Reproductive stage	+++	++
	Stem borers	*Chilo suppressalis*	Tillering	++	++
	Thrips	*Balothrips biformis*	Seedling	++	++
	Whitebacked planthopper	*Sogatella furcifera*	Tillering	++	+
	Whorl maggot	*Hydrellia philippina*	Tillering	+	+
	Zigzag leafhopper	*Recilia dorsalis*	Tillering	++	++
	Diseases				
	Bacterial leaf blight	*Xanthomonas campestris*	Maximum tillering-reproductive stage	++	++
	Bakanae disease	*Fusarium moniliforme*	Tillering	++	++
		Gibberella fujikuroi	Tillering	++	++
	Blast	*Pyricularia oryzae*	Seedling-reproductive stage	++	++
	Brown spot	*Helminthosporium oryzae*	Tillering-reproductive stage	++	++

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Table 1 continued.

Region	Common name	Scientific name	Period of crop growth	Ranking*	
				Wet-season crops	Dry-season crops
	False smut	*Ustilaginoidea virens*	Flowering-maturation	+	+
	Foot rot	*Erwinia chrysanthemi*	Maximum tillering-reproductive stage	+	+
	Leaf streak	*Xanthomonas campestris*	Tillering-reproductive stage	+	+
	Narrow brown leaf spot	*Cercospora oryzae*	Tillering-reproductive stage	++	++
	Sheath blight	*Rhizoctonia solani*	Maturation	+	+
	Sheath rot	*Sarocladium oryzae*	Booting	++	++
	Stem rot	*Helminthosporium sigmoideum*	Reproductive stage	++	++

[a]+++ = very important, ++ = important, + = relatively unimportant.
Source: Modified from Sounthone et al (1995).

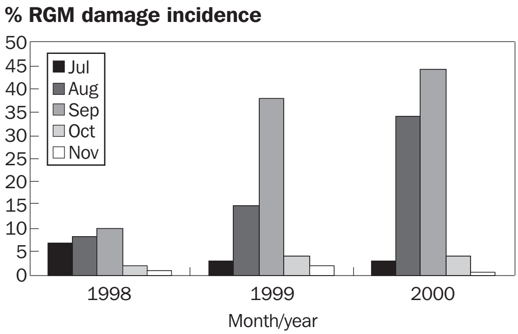

Fig. 1. Damage incidence of RGM in the 1998, 1999, and 2000 wet-season lowland rice crops of Savannakhet Province of Laos (Source: Lao-IRRI 2001).

Studies on levels of varietal susceptibility to RGM undertaken in an area with chronic levels of RGM infestation in Savannakhet Province in central Laos in the wet seasons of 1999, 2000, and 2001 have shown a wide range in susceptibility of both recommended improved and traditional varieties (Table 2). Traditional variety *Muangna* (originating from northern Laos) has shown a high level of resistance, with less than 5% of damaged tillers, relative to more than 50% of tillers being damaged in susceptible varieties in the same growing seasons. A further 17 entries were classified as having moderate levels of resistance, with 6% to 15% of tillers damaged; included among these are varieties RD6, CR203, CR23, IR66, NGS19, and the traditional

Table 2. Classification of recommended and promising varieties for rice gall midge resistance in the rainfed lowland environment of Savannakhet Province, 1999-2001.

Varieties and promising lines	WS 1999	WS 2000	WS 2001
1. TDK1	MS[a]	MS	MS
2. TDK2	MS	MS	MS
3. TDK3	MS	MS	MS
4. TDK4	MS	MS	MS
5. TSN1	MR	MS	MS
6. PNG1	MR	MR	MS
7. RD10	MS	MS	MS
8. RD6	MR	MR	MR
9. RD8	MR	MR	MR
10. RD23	MR	MR	MR
11. NSG19	MR	MS	MR
12. NTN1	MS	MS	MS
13. CR203	MR	MR	MR
14. IR66	MR	MR	MR
15. KDML105	MS	MS	MS
16. Muangna	R	R	RM
17. Ise	MS	MR	R
18. Phuamalai	MS	MS	MS
19. Dokmai	MS	MS	S
20. Dokphao	MS	MS	MS
21. Luakhat	MS	S	MS
22. Takhet	MS	MS	MS
23. Naiteng	MS	MS	MS
24. Iphon	MS	S	S
25. Hom Nangnuan	MR	MS	MS
26. IR70220-UBN-3-TDK-4-1	R	MR	MS
27. IR57514-SPN-299-2-1-1	R	MS	MR
28. IR68101-TDK-1-B-1-1	R	MR	MR
29. IR70824-TDK-44-B-B-1-2	MR	MR	MR
30. LNT-1	MR	MR	MR
31. IR68101-TDK-B-B-33-1	MR	MS	MR
32. IR66396-APA-51-3R-0	MR	MS	MS
33. IR68105-TDK-B-B-22-1	MR	MS	MR
34. IR71514-TDK-6-1-3	MR	MS	MS
35. IR71514-TDK-9-1-2	MR	MR	MR
36. IR57514-PMI-5-B-1-2	MR	MS	MR
37. IR68105-TDK-B-B-27-1	MS	MS	MS
38. IR68101-TDK-B-B-33-3	MS	MS	MS
39. IR-UBN8-4-TDK-B-B-7-1	MS	MS	MR
40. IR68102-TDK-B-B-7-1	MS	MS	MS
41. IR46346-KKN-1-2-1-3	MS	MR	MR
42. SPT84276-PAN-33	MS	MS	MS
43. IR253-100	S	MS	MS
44. TDK-5	S	MS	S
45. TDK94017-60-1	MS	MS	MS

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Table 2 continued.

Varieties and promising lines	WS 1999	WS 2000	WS 2001
46. TDK94017-1-1	MS	MS	MS
47. TDK94018-21-3	MS	MS	MS
48. TDK94018-21-4	MS	MS	S
49. TDK94018-38-2-2	MS	MS	MS
50. TDK94018-50-1	MS	MS	MS
51. TDK94019-1-2	MR	MS	MR

[a]WS = wet season, R = resistant (1–5% damaged tillers), MR = moderately resistant (6–15% damaged tillers), MS = moderately susceptible (16–50% damaged tillers), S = susceptible (>51% damaged tillers) (Standard evaluation system, IRRI 1985).
Source: Lao-IRRI (1999, 2000, and 2001).

varieties *Ise* and *Hom-Nangnuan*. Two lines, IR253-100 and SK12-117-2-2, were classified as being susceptible, with levels of tiller damage exceeding 50%. Among the Lao improved varieties, the greatest level of RGM tolerance was shown by Phone Ngam-1 (PNG1) (moderate resistance) and Thasano-1 (TSN1). The improved Lao varieties in the Thadokham (TDK) series—TDK1, TDK2, TDK3, and TDK4—all showed moderate levels of susceptibility and their planting should be avoided in areas where RGM infestation and damage are a chronic problem.

Natural enemies of RGM have been reported in several countries. The hymenopterous parasitoids are Plastygasterids, Eupelmids, Preromalids, Eurytomyts, Eulophids, Scelionids, Ichneumonids, and Braconids. They have been reported to be the most important parasitoids of RGM in South and Southeast Asia (Kobayashi et al 1990, 1991, 1994, Hikada et al 1996, Jahn and Bunnarith 2004). In Laos, three species of hymenopterous parasitoids are important natural enemies of RGM: *Plastygaster oryzae* (Cameron), *Plastygaster foresteri* (Gahan), and *Neanastatus grallarius* (Masi). *Ophionia indica* (Thumberg) (Carabidae), a predator of RGM, also occurs in Laos (Lao-IRRI 1999, 2001).

Several weed species have been reported as alternate hosts of RGM in Laos, including the wild rice *Oryza rufipogon* and the weeds *Cynodon dactylon* and *Leersia hexandra* (Lao-IRRI 2001) (Fig. 2). These alternate hosts are similar to those found in Thailand and Cambodia (Hikada et al 1996, Jahn and Bunnarith 2004). As forest and wild rice habitats decline with agricultural development, the incidence of RGM might also be expected to decline.

Rice stem borers

Four different species of rice stem borer are associated with rice cultivation in Laos: *Chilo suppressalis, Scirpophaga incertulas, S. innotata,* and *Sesamia inferens*. However, of these, only two, *C. suppressalis* and *S. incertulas*, appear to be economically important. Field observations suggest that, under Lao conditions, stem borer infestations are greater in improved varieties relative to traditional varieties, and that the level of infestation is greatest under conditions of high nitrogen fertilizer application

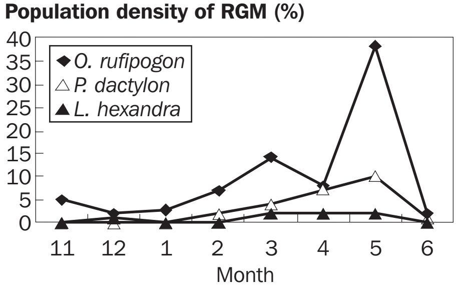

Fig. 2. Alternative host plants of RGM in the 1999 and 2000 dry season in Savannakhet Province of Laos (Source: Lao-IRRI 2001).

(Lao-IRRI 1993, 2002). Nitrogen application rates are known to affect the body size, population size, survival, and intrinsic rate of increase of several rice pests (Jahn et al 2001, 2005, Preap et al 2001, Jahn 2004, Lu et al 2004).

The glutinous variety RD10, which originated from Thailand, is known to be susceptible to stem borer damage in all areas of Laos where it has been grown. In contrast, the nonglutinous variety CR203, which originated from Vietnam, has shown resistance to stem borer damage. Since 1998, the incidence of stem borer damage has increased in both irrigated and rainfed conditions (Lao-IRRI 1999, 2004). However, no evidence has shown that stem borer is a consistent cause of significant yield loss. Deadheart and whitehead incidence have generally been recorded at less than 3% at 30 DAT and less than 7% before harvest in studies; these rates are regarded as being too low to cause any real economic loss. Although yield losses of 50% due to deadheart have occasionally been reported by farmers, such losses remain unverified ((Lao-IRRI 1993 1994, 1995, 1996, 1997, 2002, 2003). Most improved varieties currently being distributed in Laos appear to have reasonable tolerance of stem borer damage, and can generally compensate for it.

Rice bug (*Leptocorisa oratorius*) (Fabricius)

Until recently, Lao farmers have not considered rice bug, *L. oratorius*, as a major pest. It appears to have developed pest status in both the irrigated and rainfed lowland environments since 1995, in association with the intensification of rice cultivation as a result of an expansion of the irrigable rice area available for double cropping. Rice bugs have been reported in areas of lowland rice cultivation in many provinces, but particularly in the central and southern agricultural regions in the Mekong River Valley (Vientiane Municipality and the provinces of Vientiane, Borikhamxay, Khammouane, Savannakhet, Saravane, Champassak, and Attapeu, Lao-IRRI 1999). Rice bug infestations and damage have also been reported in the northern provinces of Luang Prabang and Sayabouly. Rice bug damage occurs during the milky stage of rice development and damaged panicles produce unfilled grains and an increased percentage of small

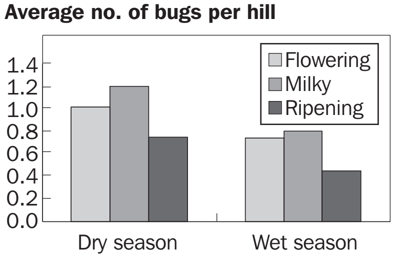

Fig. 3. Rice bug density at flowering, milky, and ripening stages of rice in the wet and dry seasons of 2000, Vientiane Province.

and broken grain during milling (Dale 1994, Lao-IRRI 1999). Rice bugs reduce yield, grain quality, and seed germination rates (Jahn et al 2004).

Rice bug is generally a more important pest in areas of irrigated cropping than in areas of wet-season rainfed cultivation. Their population (and associated damage) is generally higher in dry-season cropping environments than in the wet season (Fig. 3). Reliable quantitative information on the rice bug problem in Laos is limited. Some studies began in 1999 and 2000 to quantify the importance and economic impact of the problem. Early-flowering (and therefore earlier-maturing) varieties are generally more susceptible to rice bug damage; medium-maturity and later-maturity varieties generally have lower levels of infestation and damage. Generally, the medium- and later-maturity types are more widely grown (Douangboupha et al 2000).

During the early part of the wet season, rice bugs survive on a large range of host plants that are usually found as weeds in areas adjacent to rice fields or in nearby forests. They then migrate from these host plants to the rice paddies in late August, feeding on the rice plants to produce the first generation of insects that attack early-flowering rice varieties in August and September. These insects then produce a second generation, which continues to cause damage until November, after which the population usually shows a marked decline, reflecting a lack of food after harvest of the rice crop. The remaining survivors then once again move to alternate host plants. The population increases once again where a second (dry-season irrigated) rice crop is grown. Mature rice bugs are observed in the rice paddies only during March; they breed there and attack the rice in April. No varieties with resistance to rice bug damage have been identified in Laos. It is generally acknowledged that the ecology and biology of the rice bug must be better understood before it can be effectively managed under Lao conditions.

Brown planthopper (*Nilaparvata lugens*) (Stål)

The brown planthopper (BPH) (*N. lugens*) has long been recognized as an economically important rice pest in Laos. The first report of BPH in rice crops in Laos was in 1956 from Phiang District of Sayabouly Province, where dry-season rice cultivation under irrigated conditions was first attempted in the country. Subsequently, there were few reports of outbreaks until the 1980s, when there was a further expansion of dry-season irrigated rice cultivation in other provinces in the Mekong River Valley. The most significant BPH outbreaks were recorded in areas of dry-season rice cultivation in the early 1990s in the Vientiane Plain. These outbreaks were associated with the widespread use of the BPH-susceptible variety RD10 from Thailand, in association with increased nitrogen fertilizer use. The more serious outbreaks have been associated with areas of "hopper burn" in the period before harvest. It has been difficult to correlate the frequency of outbreaks to specific environmental parameters. The greatest damage has been recorded under generally high-temperature conditions during April, when dry-season irrigated crops are approaching maturity. The most recent significant outbreaks were recorded in dry-season crops in 1998, in Vientiane Municipality and Borikhamxay Province. The Lao improved glutinous variety *Thadokkham 1* (TDK1), which was first released in 1993, initially showed a reasonably high level of BPH resistance under farmers' field conditions. However, more recently, it has shown susceptibility to what are believed to be new BPH biotypes. A later improved Lao variety, TDK3, released in 1997, has also shown a high level of BPH tolerance.

Golden apple snail (*Pomacea canaliculata*) (Lamarck)

In Laos, the golden apple snail, *Pomacea canaliculata* (Gastropoda: Ampullariidae Lamarck), is a well-known invasive alien species. It was first introduced to Asia through Taiwan in 1980 from South America (Halwart 1994) for human consumption (Naylor 1996), and then subsequently introduced to many other countries in the Southeast Asian region (Jahn et al 1998, Carlsson 2004). It was first introduced to Laos from Thailand in 1991 by a Lao farmer in Sikhotabong District of Vientiane Municipality. As a result of flooding in the 1992 wet season, the snail escaped from fish ponds and quickly established itself in four additional districts. Farmers in Xaythany District of Vientiane Municipality also independently reported the presence of the snail in areas of irrigated and rainfed rice cultivation in 1991. It would therefore appear that there was a simultaneous introduction of the snail to more than one locality of Vientiane Municipality. By 2000, it had become established in 10 provinces. In northern Laos, the snail was first recorded in areas of irrigated rice cultivation of La District of Oudomxay Province and Sing District of Luang Namtha Province in 1994; the source of the snail in these areas is believed to have been China.

The golden apple snail, locally known as "*the big mouth snail"* on account of its appetite and capacity to cause damage, is regarded as potentially constituting one of the greatest economic threats to the agricultural wetlands of Laos. Both juveniles and adults defoliate the rice plant from the young seedling until the maximum tillering stage; they also damage other aquatic vegetation.

Lao farmers have developed some botanical pesticides that have proven to be reasonably effective for the control of the golden apple snail. Included among these is the use of papaya leaf and pineapple bard (Douangboupha et al 2002). In experimental plots of the National Agricultural Research Center in Saythany District of Vientiane Municipality in 2002-03, it was demonstrated that an application of bitter nut and ebony fruit (*dios piros mollis*) at 90 kg ha^{-1} gave effective control of the golden apple snail (Lao IRRI 2004). Farmers in Vientiane Municipality have also reported that the application of bitter nut (locally known as *mak khe*w) after transplanting in both the wet and dry seasons reduced the population of golden apple snail and minimized damage. In areas of heavy infestation, the raising of ducks is often used to assist with the control of infestations of, and damage by, the snail.

The upland rainfed environment

Slash-and-burn agriculture has traditionally been the major production system used in the upland environment. Rice is the major upland crop, followed by maize. In recent years, an increasing diversification of cropping activities has developed in the upland environment, including the planting and cultivation of nontimber forest crops. All are grown under rainfed conditions. Although official government policy is to reduce and eventually stop slash-and-burn agriculture in the uplands, and to move to more sustainable forms of agricultural production, most crop production still takes place in the slash-and-burn system, and is concentrated on slopes with altitudes ranging from 300 to 800 m. The upper limit for rice cultivation is around 1,500 m. Despite the recent rapid adoption of improved rice varieties in lowland rice environments, upland rainfed rice cultivation is still almost exclusively based on the use of traditional varieties. In the traditional rainfed upland rice cultivation systems, farmers rate their most important production constraints (in decreasing order of importance) as being weeds, rodents, insufficient rainfall, lack of available land, insect pests, insufficient labor, poor soil fertility, erosion, wild animals, and diseases (Roder 2001). *Chromolaena odorata*, an American weed species introduced to Lao PDR in the 1930s, and *Mimosa invisa* dominate the weed population during the cropping and first fallow phase. Another introduced weed species, *Ageratum conyzoides,* although less dominant, has shown a strong association with root-knot nematode *Meloidogyne graminicola* (Roder et al 1992).

Many insect pests and diseases in uplands are considered to be economically important (Table 3). The following pest species are also found in the lowland rice environment: the rice bug (*L. oratorius*), grasshoppers (*Oxya* spp. and *Acrida* sp.), cutworm (*Spodoptera litura*), leaffolder (*Cnaphalocrocis medinalis*), and rodents (*Rattus* and *Mus* spp.). Others such as white grub (Scarabaeidae: *Leucophilolis* sp. and *Heteronychus* sp.) and root aphids (Aphididae: *Tetraneura nigriabdominalis* Sasaki) affect only upland rice cultivation.

In some areas of upland rice cultivation of Laos, farmers rate white grub as their most important pest problem. Arraudeau and Vergara (1988) reported many species of white grubs or scarab beetles, which feed on living roots as larvae but not as adults. In the tropics, they have a 1-year life cycle. Adults start to emerge from the soil after the first heavy rains of the rainy season. They lay eggs at the same time as farmers sow upland rice. Rice passes its most susceptible stage and damage is mostly avoided when white grubs are small. After several months, the long-lived larvae of white grubs become large enough so that two or three larvae can denude the root system of mature

Table 3. Occurrence of insect pests and diseases in rainfed upland rice production systems in Laos.

Common name	Scientific name	Crop growth period	Ranking[a]
Pests			
Ants	*Solenopsis geminata*	Sowing	++
Root aphid		Tillering	++
Armyworm	*Spodoptera mauritia,*	Seedling-panicle	++
	Mytthimna separate	Seedling-panicle	++
Grasshopper	*Oxya* spp. and *Acrida* spp.	Seedling-ripening	+++
Greenhorn caterpillar	*Melanitis ledaissmene*	Seedling-maximum tillering	+
Green semilooper	*Naranga aenescens*	Seedling-maximum tillering	+
Crickets	*Euscyrtus concinnus*	Seedling-tillering	+
Cutworm	*Spodoptera litura*	Seedling-tillering	++
Leaffolder	*Cnaphalocrocis medinalis*	Tillering	++
Mealy bugs	*Brevenia rehi*	Tillering	+
Mole cricket	*Grillotalpa africana*	Seedling-tillering	+
Planthopper		Tillering	+
Rats	*Rattus* sp. and *Mus* sp.	Sowing, reproductive	+++
Rice bug	*Leptocorisa oratorius*	Reproductive	++
Rice skipper	*Pelopidas mathias*	Seedling-maximum tillering	+
Small brown planthopper	*Laodelphax striatellus*	Maximum tillering-reproductive	++
Stem borers	*Chilo suppressalis,*	Tillering	+
	C. polichrisus,		
	Scirpophaga incertulas,	Tillering	++
	S. innotata, Sesamia inferens	Tillering	++
Stink bugs	*Nezara viridula*	Milky	+
Termites		Tillering-reproductive stage	+++
White grubs		Tillering	+++
Diseases			
Bacterial leaf blight	*Xanthomonas campestris*	Maximum tillering-reproductive stage	+++
Blast	*Pyricularia oryzae* Cav.	Seedling-reproductive stage	+++
Brown spot	*Helminthosporium oryzae*	Tillering-reproductive stage	+++
Leaf streak	*Xanthomonas campestris*	Tillering-reproductive stage	+
Narrow brown leaf spot	*Cercospora oryzae*	Tillering-reproductive stage	++
Sheath blight	*Rhizoctonia solani*	Maturation	+
Sheath rot	*Sarocladium oryzae*	Booting	++
Stem rot	*Helminthosporium sigmoideum*	Reproductive stage	++

[a]+++ = very important, ++ = important, + = relatively unimportant.
Sources: Modified from Rapusas et al (n.d.), Arraudeau and Vergara (1988).

rice. This intensity of damage is rare, but wilting occurs when root loss is combined with water stress. White grubs need damp soil to survive and they pass the unfavorable dry season 1–2 m underground. The first heavy rains of the season (20–30 mm d^{-1}) stimulate the grubs to resume activity. After several weeks, they develop into pupae and adults, eventually digging their way to the surface and flying to nearby trees to seek food and mates. Grasslands may support large populations; therefore, white grubs can be more abundant in newly planted upland rice fields that were previously fallow. White grub incidence was monitored in upland areas of northern Laos in the 1990s (in Luang Prabang Province in 1992 and 1993, and in Oudomxay Province in 1992). Damage was observed as early as 3 weeks after seeding (WAS) in Luang Prabang. Damaged hills were recorded as increasing from 26% m^{-2} at 3 WAS to 52% at 7 WAS; however, thereafter, the level of damage declined as the crop matured. In Oudomxay, the level of white grub damage decreased steadily as the crop matured (Roder 2001).

The buildup of root aphids (along with nematodes) is considered a major cause of the significant decline in rice grain yield observed in upland rice, when grown on the same land for more than 3 years. Like many homopterans, root aphids are tended by ants. The recent practice of intercropping pineapple with upland rice in some areas of northern Laos is regarded as potentially able to cause increased root aphid infestations, as well as mealy bug infestations in pineapple crops, as it is generally well known that ants tend both mealybugs and aphids (Jahn et al 2003).

Rodents have always been a chronic problem in upland rice production, with varying levels of damage being common in most years in most upland areas of Laos. The severity of the problem varies with locality and between seasons. Singleton and Petch (1994) documented some perceptions and data on rodent problems in the upland rice environment of Laos. In recent years, there has been increasing use of rodenticides by upland farmers in their effort to reduce the potential impact of rodents on crop production and postharvest rodent-related losses. Many of these rodenticides present a major health risk to nontarget animals and to humans. Recent research funded by the Australian Center for International Agricultural Research (ACIAR) and undertaken on a collaborative basis between NAFRI and CSIRO has provided a better understanding of the different rodent species in Laos, the ecology of some of the major rodent pests, and the history of outbreaks (see Aplin et al, Chapter 19 in this volume). A total of 53 species of rodents have been identified in Laos, 14 of which are regarded as potential agricultural pests, with 4 to 8 spcies causing significant damage to agricultural crops. Management strategies being tested are concentrating on community actions based on a basic understanding of the ecology of the major pest species. Although good progress has been reported in protecting grain stores and in reducing the impact of rodents in and around villages, the most severe impact on farmer livelihoods occurs during the occasional eruptions of rodent populations. These outbreaks often lead to individual farmers losing more than 50% of their crop (Singleton and Petch 1994). An analysis of the patterns of these rodent outbreaks indicates that many may occur in response to bamboo flowering rather than major climatic events such as El Niño Southern Oscillation cycles (Douangboupha et al 2000). The rodent-related studies are ongoing. It is recognized that, for the development of effective control strategies, further studies and information are required on the seasonal dynamics of the breeding of the main pest species, their habitat use, and the development of improved community-based control strategies.

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Notes

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CHAPTER 18

Determinants of insecticide-use decisions of lowland rice farmers in Laos

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In Lao rice production, pests and diseases are minor constraints compared to other agronomic factors such as infertile soils, unavailability of water, floods, and general lack of farmers' crop management knowledge (Schiller et al 2001). Yields in farming areas of the lowland environment in much of Laos, even under irrigated conditions, have remained relatively low for improved Lao varieties, despite their demonstrated yield potential in appropriate management conditions. Although insect pests are not perceived as a significant yield constraint in many areas of Laos, there are suggestions that farmers are prepared to rapidly adopt the use of insecticides if they become more readily available at reasonable prices. Current attitudes of farmers toward insects and pesticides seem to favor this adoption (Heong et al 2002) and thus Lao farmers can potentially fall victim to insecticide misuse just like farmers elsewhere in Asia, such as Indonesia, the Philippines, Vietnam, and Thailand. Integrated pest management (IPM) programs in these countries have thus concentrated on pesticide reduction through training (Matteson 2000) and media campaigns (Escalada et al 1999).

An earlier study on farmers' insect management beliefs and practices (Heong et al 2002) examined the qualitative elements of farmers' beliefs and how they can influence practices. This study was conducted in two irrigated areas, Vientiane Municipality (n = 101) and Vientiane Province (n = 99), and two rainfed areas, Savanneket Province (n = 150) and Champassak Province (n = 150). The results of the study indicated that most Lao farmers strongly believe that insects will decrease yields and about 56% were using insecticides; the main chemicals used were methyl parathion, diazinon, and monocrotophos, which are highly hazardous to human health. There was also strong local social pressure favoring pesticide use. In this chapter, we revisited the data set and applied a psychometric model, the theory of reasoned action (TRA, Ajzen and Fishbein 1980), to understand farmers' insecticide-use decisions and to explain such behavior.

Explaining farmers' decisions using a psychometric model

Farmers' insecticide use is the result of conscious decisions to respond to an insect attack that is perceived to be causing loss. Rice farmers are often described as irrational and lacking sufficient knowledge to make good judgments. Studies on human judgment and choices have, however, shown that economic models have been unable to account for how people actually make decisions (Slovic et al 1977, Simon 1978). Most violate prescriptive principles because decision making is behavioral in nature. A group of sciences concerned with understanding and improving decision-making, called decision sciences (Kleindorfer et al 1993), has recently emerged and begun to explore the behavioral aspects of decisions. To better understand the determinants of farmers' insecticide-use decisions, models from psychology have been adopted.

The psychometric model used in the study reported in this chapter is the theory of reasoned action (TRA), developed by Fishbein and Ajzen (1975) and Ajzen and Fishbein (1980). It provides a theoretical framework to explain a person's behavior. This model was adopted to understand the components of farmers' insecticide spray decisions. The TRA assumes that attitudes toward spraying and perceived social pressures are important determinants of farmers' decisions to spray. Attitudes toward spraying are, in turn, affected by spraying beliefs and their outcome evaluations. Perceived social pressures, termed subjective norms (SN), are influenced by the individual farmer's normative beliefs and his/her motivation to comply.

Methodology

Focus group discussions

Two focus group discussions (FGD) were undertaken to develop survey questions. These FGDs were conducted in farmers' homes using an inquiry format, which involved discussions on how farmers perceive and respond to insects in their crops. The approach sought to avoid leading questions and prompting for responses, with questions asked in no fixed order.

Questionnaire development

Independent variables were measured using five-point semantic differential scales. All points on these scales were described with a corresponding statement and presented to farmers using a prompt chart. The number of insecticide sprays individual farmers applied in a season was also measured and used as the independent variable. Seven belief statements (b_i) related to insect pest control were used to measure attitude toward spraying. These were "All insects can cause loss in yields," "There is a need to kill all insects in the crop," "Applying insecticides will increase yields," "Insecticides will kill natural enemies," "Some insects are beneficial to rice yields," "Insecticides are harmful to health," and "Insecticides can cause more pest problems." Farmers were then asked to evaluate the importance of each item (e_i) using another five-point semantic differential scale from "completely unimportant" to "very important." The measure for attitude toward spraying (SP) was computed as the sum of the products of belief and evaluation, $SP = \sum b_i e_i$.

The subjective norm (SN) attitude was measured using four reference groups, neighbors, village head, spouse, and agricultural technician. Farmers were asked what each of the reference groups expected of them with regard to insecticide spraying

(nb_i). Responses were scored as (1) "Never spray," (2) "Spray rarely," (3) "Spray once every 2 years," (4) "Spray once a year at least," and (5) "Spray every season." Another assessment of the SN component was motivation to comply (mc_i) and this was determined by another five-point semantic differential scale going from "I don't care at all" to "What they think I should do is very important." The subjective norm attitude was computed as the sum of the product of normative beliefs (nb) and motivation to comply (mc), $SN = \sum nb_i mc_i$.

Statistical analyses

Cronbach's alpha available in SPSS version 11.5 (SPSS 2001) was used to assess the reliability of the two independent determinants of spray behavior, SP and SN. Categorical regression (CATREG) was used to analyze the relationship between the determinants of behavior and the dependent variable, insecticide spray behavior. Correlation analysis (two-tailed) was used to analyze between the subcomponents.

When a variable is generated from a set of questions, its reliability can be assessed by Cronbach's alpha, the index of reliability ranging from 0 to 1. The higher the alpha, the more reliable the generated scale is. As a general guide, alpha > 0.7 is commonly an acceptable reliability coefficient (Nunnaly 1978, Santos 1999). The use of categorical regression is appropriate for predicting a categorical dependent variable from a set of categorical independent variables. The spray behavior of farmers was grouped into four categories: 1 = none, 2 = 1 spray, 3 = 2 sprays, and 4 = > 3 sprays, representing farmers whose sprays are none, low, medium, and high.

Results

Reliability analyses

The spray attitude scale with all six belief subcomponents was computed and subjected to reliability analysis. The initial Cronbach's alpha was 0.43 and, after removing three of the subcomponents, the scale reliability index increased to 0.73. Subsequent analyses were conducted using the spray attitude scale with the three subcomponents, "All insects can cause loss in yields," "There is a need to kill all insects in the crop," and "Applying insecticides will increase yields." The subjective norm attitude scale using all four subcomponents had a reliability index of 0.90 and thus all four subcomponents were used.

Regression analyses

The theory of reasoned action describes farmers' spray behavior based on the two predictor components. Since the data are nonparametric, categorical regression analysis was used to evaluate the contributions of the predictors to spray behavior. The intercorrelation among the two predictors was extremely low (Spearman's rho = 0.08), implying that the regression was reliable. Farmers' spray behavior was directly correlated with subjective norm attitudes. The ANOVA of the regression was significant ($F = 57.6$, $P < 0.001$) but yielded a coefficient of determination (R^2) of 0.374, indicating that only 37.4% of the variance was explained by the regression. Table 1 shows the

Table 1. Regression coefficients of spray categories as dependent variable and subjective norm and spray behavior attitudes as independent variables.

Item	Standardized coefficients		Correlations		Importance
	Beta	Std. error	Zero-order	Partial	
Subjective norm (SN)	0.63	0.06	0.583	0.611	0.982
Spray behavior (SP)	–0.19	0.06	–0.035	–0.228	0.018

Table 2. Mean scores of subcomponents in subjective norm (SN) attitudes in the different spray behavior categories.[a]

Spray behavior category	Referent groups			
	Neighbors	Village heads	Spouses	Technicians
Did not spray at all	6.63 a	6.05 a	6.71 a	9.37 a
Sprayed once a season	11.02 ab	13.18 b	14.06 b	15.33 b
Sprayed twice a season	13.65 bc	13.12 b	13.53 b	16.06 b
Sprayed more than three times	16.08 c	16.46 b	10.43 b	17.38 b
F	15.04	21.47	19.06	16.13
P	<0.001	<0.001	<0.001	<0.001

[a]Scores vary from 5 to 25, with high scores indicating strong attitudes. The letters after the means indicate groups of homogeneous subsets from Tukey's honestly significant difference.

standardized regression coefficients. The subjective norm attitude was higher (0.63) than spray attitudes (–0.19). The subjective norm attitude is an important component determining decision-making. Besides seeking to satisfy personal beliefs, objectives, and gains, most people are also influenced by their perceptions of what referent groups (such as peers, neighbors, friends, village officials, and relatives) would think of them. The high subjective norm implies that the influence of referent groups on farmers' spray behavior is stronger than beliefs. This is relevant to designing change interventions. Since influence from beliefs is small, increased farmer training might not result in behavioral change. A better strategy might be to implement change at the communal level.

Since spray attitudes played only a small role in predicting farmers' spray behavior, a further investigation was made of the relationships of the subcomponents in subjective norm and spray behavior. Table 2 shows the mean scores of the subcomponents of farmers in different spray behavior categories. The scores of farmers who did not spray in all four subcomponents were significantly lower than for those who did. The intercorrelations among the subcomponents were high (Table 3). The regression with each subcomponent as independent variables was highly significant ($F = 35.1$, $P < 0.001$, d.f. 4, 84) and R^2 was 0.424. The regression coefficients are presented in

Table 3. Correlations (Spearman's rho) between spray categories and subcomponents of subjective norm (SN) attitudes.

Item	Subcomponents				
	1	2	3	4	5
1. Spray behavior category	–				
2. Neighbor subcomponent	0.45**	–			
3. Village head subcomponent	0.72**	–			
4. Spouse subcomponent	0.45**	0.67**	0.86**	–	
5. Technician subcomponent	0.39**	0.51**	0.67**	0.75**	–

**Indicates correlation significant at $P = 0.01$ (2-tailed).

Table 4. Regression coefficients of spray categories as dependent variable and subcomponents of subjective norm (SN) attitudes.

Group	Standardized coefficients		Correlations		Importance
	Beta	Std. error	Zero-order	Partial	
Neighbors	0.23	0.07	0.458	0.246	0.252
Village heads	0.54	0.09	0.506	0.411	0.643
Spouses	–0.45	0.08	0.185	–0.375	–0.196
Technicians	0.28	0.07	0.451	0.281	0.301

Table 4. Spouses seemed to have a negative influence over spray behavior, whereas village heads, neighbors, and technicians had a positive influence. Among these, the groups most influential on farmers' spray behavior in order of importance were village heads (importance = 0.643), technicians (0.301), neighbors (0.252), and spouses (negative 0.196).

Discussion

Many insecticide sprays that rice farmers in Asia apply are unnecessary, targeting leaf-feeding insects in the early crop stages (Heong and Escalada 1997). In Laos, 30% of the sprays are done at these stages and another 37% in late stages targeting the rice bug (Heong et al 2002). The rice bug is another one of those pests that are highly visible but that cause negligible loss (Van Den Berg and Soehardi 2000). Spray decisions can subject farmers to pesticide health hazards (Rola and Pingali 1993) and compromise a vital ecosystem service, natural biological control, and this can lead to the development of secondary pests (Way and Heong 1994, Heong and Schoenly 1998). Despite the negative effects, pesticide use tends to increase because farmers are often "locked" into continuing such unsustainable practices (Wilson and Tisdell

2001). Some of these factors are ignorance, lack of information about side effects, aggressive advertising and promotion by chemical companies, and loss aversion attitudes of farmers. Research and extension will need to go beyond developing technologies and focus on ensuring that the technologies are implemented to help farmers improve their practices.

The TRA provided a useful framework to explore farmers' spray decisions. Understanding the primary reasons why farmers spray is important in order to develop strategies to overcome misuse problems. In many cases, farmers' spray decisions are influenced by noneconomic factors such as perceptions and social factors. Subjective norm (or peer pressure) attitudes seem to have a big influence over Lao farmers' spray behavior. Since village heads and technicians are the two most influential referent groups in farmers' spray decisions, a strategy to train village heads and technicians on principles of integrated pest management (IPM) might pay more dividend than just training farmers. In addition, once village heads and technicians have acquired IPM knowledge, they can also provide *in situ* training to farmers besides functioning as influence groups. Establishing local village-level IPM clubs to initiate local participation and discussions about pest management and pesticides might also be useful.

In the Philippines, extension technicians were also found to play significant roles in onion farmers' pesticide misuse (Tjornhom et al 1997). In this case, the technicians were the main source for pesticide information and were also motivated to promote pesticide use. In countries such as China, where the government promotes a pesticide-first policy, overuse had been a direct consequence (Widawsky et al 1998). Extension technicians often supplement their incomes from pesticide sales, thus increasing their influence over farmers' spray decisions. Where extension plays both advisory and marketing roles in pest management, pesticide overuse often results (Norton et al 1991). Similarly, in Thailand, weak government policies had promoted pesticide misuse (Jungbluth 1996, Oudejans 1999).

There is a high potential for Lao farmers to become pesticide-dependent as several of its neighboring countries produce pesticides. Many old pesticides such as methyl parathion, monocrotophos, and metamidophos, banned in many developed countries, are still actively sold in local markets. Our brief visits to local general stores in villages revealed large quantities of pesticides from neighboring countries, with foreign language labels, sold among other household products. The availability of spray equipment can be another limiting factor, but, with the abundance of inexpensive plastic sprayers, this is likely to diminish. However, these sprayers are often poorly manufactured, have poor spray delivery, and often leak, posing a big health hazard to the operators. The poor pump and nozzle systems of sprayers provide delivery of pesticide active ingredients in large droplets, which results in contaminating soil and water systems and killing more natural enemies than pests. Besides pesticide control, agricultural authorities will need to develop mechanisms to control the quality of spray equipment manufactured locally or imported, to ensure that it adheres to minimum standards established by the FAO.

For Laos, the strong influence of village heads and technicians may in fact be used for improving farmers' decisions since current insecticide use is still low. Much of the insecticide misuse in rice production today has been attributed to the "unwelcome harvest" of the Green Revolution (Conway and Pretty 1991). The lessons learned from the implementation of the Green Revolution in the Philippines, Indonesia, and Vietnam could come to bear in initiating the "Doubly Green Revolution" (Conway 1997). A re-engineering of local village leaders and research and extension officials' knowledge and attitudes focusing on the new paradigms in IPM that place emphasis on ecological principles and enhancing naturally occurring biodiversity of biological control (Heong 1999) is urgently needed in Laos. In addition, pesticide policies need to be revisited and modified in order to control the import and sale of pesticide to avoid abuse. Programs such as the implementation of farmer training, such as the farmer field schools (Matteson 2000), the use of media to communicate (Escalada et al 1999), and entertainment education (EE) through radio and television (Singhal and Rogers 1999), will be useful in initiating social change in pesticide use.

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Notes

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CHAPTER 19

Rodents in the rice environments of Laos

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Laos has a diverse rodent fauna, with 53 described species and several others known but not yet scientifically named (Francis 1999, Aplin, unpublished data). As for much of Southeast Asia, there is a need to balance the management of a few pest species with the conservation of many harmless or even beneficial species (Aplin and Singleton 2003). The role that rodents play in ecosystems is not well recognized. They are important prey species for many native snakes, birds of prey, and carnivorous mammals. In turn, rodents can limit the growth of invertebrate populations, some of which are important pests in agricultural systems (Joshi et al 2004). Rodents also provide important ecosystem services as ecological engineers through influencing water infiltration and the flow of nutrients (Dickman 2003) and through their role as seed dispersers (Lu and Zhang 2004).

In Laos, the importance of balancing pest management and conservation is particularly acute. Of the 53 species of rodents found in the country, only 14 appear to have any effect on agricultural production, with only four to eight causing significant damage. From a conservation perspective, four rodent species found in Laos have been listed by the International Union for the Conservation of Nature (IUCN) as being at risk of extinction, while the biology and distribution of some 14 other species of rodent are so poorly known that IUCN has not been able to determine their conservation status.

The upland farming systems of Laos are changing rapidly in response to a range of factors, including the rapid increase in human population, government pressure to restrict shifting cultivation, and new economic opportunities. The population of Laos is approximately 5 million, and is increasing at a rate of 2.5% per annum, one of the highest growth rates in Southeast Asia. More than 80% of the population is living in agricultural households, and about 40% of the population is fully or partially involved in shifting cultivation in the upland environment. Sixty-five percent of these families depend on shifting agriculture for their livelihoods. With mounting pressure on the agricultural systems of Laos, it is likely that the effects of pests, weeds, and diseases will increase in the future.

Few rigorous estimates exist of the impact of rodent pests in rice-based agroecosystems in Asia, and estimates of a 5–10% loss to production preharvest are probably conservative (Singleton 2003). In many areas, losses have risen dramatically over the last decade, most noticeably in places where cropping frequency has increased from one to two or three crops per year (Singleton 1997). However, even a conservative estimate of an annual loss of 5% of rice production in Asia equates to approximately 30 million t, enough rice to feed 180 million people for 12 months. Postharvest losses are probably of a similar magnitude as preharvest losses, but there are less quantitative data on which to base any estimates of postharvest losses.

In Laos, farmers commonly report chronic annual grain losses caused by rodents in the upland environment of up to 30%. In addition, many areas have episodic outbreaks of rodent populations that can lead to losses by individual farmers of 50% to 100% (Schiller et al 1999, Douangboupha et al 2003). Because of these impacts, Lao farmers generally have a good knowledge of their local rodent communities and often distinguish ten or more different kinds of rodents with which they are familiar. This familiarity often extends to forest rodent species, which are actively hunted and trapped for consumption or sale. Table 1 gives a list of Lao "rat" names along with the equivalent scientific name or names (some names are applied to several species). Unless otherwise indicated, these names were obtained from farmers in Luang Prabang Province in the north of the country.

Collaborative research on rodent biology and management between scientists from Australia and Laos began in 1999. The research focus has been in the upland rainfed environment, with the aim of quantifying the impacts of rodents on agricultural production, identifying the key pest species, recognizing those that need to be conserved, and developing strategies of ecologically based rodent management (EBRM) (Singleton et al 1999). This chapter reports on some of the findings from these studies.

Rodent communities of rice-growing environments in Laos

The major pest species and their distribution

The small mammal fauna of Laos is perhaps the least known of the entire Asian region. This is particularly true of the rodents, which are generally understudied relative to other groups of mammals. Francis (1999) listed a total of 34 rats and mice (Muridae), three bamboo rats (Rhizomyidae), 12 ground squirrels (Sciuridae), and eight flying squirrels (Pteromyidae) as either known or likely to occur in Laos. Khamphoukeo et al (2003) tabulated the murid and rhizomyid species under four categories according to their pest status and degree of scarcity. Their listing is updated in Table 2, with the addition of two recently discovered species and some reattribution of particular species based on new information. This chapter focuses on the species listed as definite or probable agricultural pests. The major pest species belong to three genera, *Rattus, Bandicota*, and *Mus*. Another three genera include minor or more localized pests (*Berylmys*, *Cannomys*, and *Rhizomys*).

Members of the *Rattus rattus* complex are the dominant agricultural and village pests in almost all parts of Laos (Khamphoukeo et al 2003). This group of rodents is taxonomically complex (Aplin et al 2003a, 2004), with as many as 6–7 distinct

Table 1. Lao rodent names collected during fieldwork in 1999-2005, with equivalent scientific names.[a]

Lao name	Scientific name	Comments
Dtun	*Cannomys* and *Rhizomys* species	
Nuu american	*Bandicota indica*	Literally, "American rat" (so named on account of its large size), also called *nuu puk* in Sayabouly Province in the west of Laos
Nuu ban	*Rattus rattus group*	Literally, "house" rat
Nuu ghi	*Mus cookii?*	Identified as a small mouse of upland fields and forest
Nuu khii	"Rat of bamboo flower"	See text for discussion of this name
Nuu mon	*Berylmys* species	
Nuu na	*Rattus rattus* group	Literally, "field" rat
Nuu ta-suat	*Rattus exulans*	Literally, "big-eyed field rat"
Nuu na thong-khaw	*Rattus rattus* group	Literally, "white-bellied field rat"
Nuu noi	*Mus* species (probably *M. caroli*)	Literally, "small mouse" (identified as a long-tailed rice field mouse
Nuu puk	*Bandicota* species	Used for *B. indica* in Sayabouly Province but probably for *B. savilei* in Luang Namtha Province in the northwest of Laos
Nuu si	*Mus* species (probably *M. cervicolor*)	Identified as a short-tailed rice field mouse
Nuu sing	*Crocidura* spp.	Not rodents; small long-nosed shrews found in upland fields and forest
Nuu thammadaa	*Rattus rattus* group	Literally, "ordinary mouse," an alternative name for *nuu ban* (house rat), used in Luang Prabang
Nuu waay	*Leopoldamys* species	Literally, "rattan rat"

[a]Most of the names were recorded in Luang Prabang Province and verified using live or freshly killed specimens. Although most are in widespread use in other provinces, a few names appear to be used only on a local basis.

species involved across the wider Asian region. Because the correct scientific names for several of these species is not yet certain, they are identified by common names, pending completion of taxonomic studies. Within Laos, three members of the group have been recorded, each being found in a different geographic area. In the northern and northeastern provinces, and at least as far south as Vientiane Municipality in the central agricultural region, the local form is the North Asian house rat. The same species occurs broadly across Asia, from Japan in the east to Bangladesh (and probably eastern India) in the west. In general appearance, this species has a reddish brown back and its belly is variably pure white or buff to gray. The tail is usually longer than the body, sometimes much longer. In Sekong Province in the south of Laos, there is a similar looking but genetically distinct species known as the Mekong house rat;

Table 2. Summary of the murid and rhizomyid rodents of Laos, divided into four categories according to probable pest and conservation status.[a]

Definite or probable pests	Possible pests	Nonpests but thought to be common	Nonpests and thought to be rare
Murinae	**Murinae**	**Murinae**	**Murinae**
Bandicota indica	*Leopoldamys edwardsi*	*Berylmys bowersi*	*Berylmys mackenziei**
*B. savilei**	*L. sabanus*	*Chiropodomys gliroides*	*Chiromyscus chiropus*
Berylmys berdmorei	*Rattus nitidus*	*Maxomys surifer*	*Dacnomys millardi* (V)
Mus caroli		*Mus pahari*	*Hapalomys delacouri**
M. cervicolor		*M. shortridgei*	*Maxomys moi*
M. cookii		*Niviventer confuscianus**	*Maxomys* sp.
M. fragilicauda		*Niviventer fulvescens*	*Niviventer* sp. cf. *N. tenaster*
Rattus argentiventer		*N. langbianis*	
R. exulans		*Rattus sikkimensis*	**Arvicolinae**
R. "rattus" (short-tailed rat)		*Vandeleuria oleracea*	*Eothenomys melanogaster**
R. "rattus" (north Asian house rat)			*E. miletus**
R. "rattus" (Mekong house rat)		**Rhizomyidae**	
		Rhizomys sumatrensis	**Placanthomyinae**
Rhizomyidae			*Typhlomys cinereus**
Cannomys badius			
Rhizomys pruinosus			

[a]Information on the degree of scarcity are "guesstimates" based on the number of records and studies in surrounding countries. Species marked with an asterisk are recorded only provisionally from Laos. The two taxa listed as sp. in column 4 were mentioned as possible new species by Francis (1999). Species listed as possible pests or nonpests might qualify as temporary pest species during *nuu khii* outbreaks where these originate in forest habitats.

this species is also found in Cambodia and southern Vietnam. The distribution of this species in Laos is not well known. The North Asian and Mekong house rats are both ecological generalists and occur in villages, upland and valley-floor cropping areas, and around forest margins.

The third member of the *Rattus rattus* complex found in Laos was previously listed under the name *Rattus losea* (Khamphoukeo et al 2003), this classification being based on its similarity to Chinese and Vietnamese populations of this species (Marshall 1977). However, genetic studies have now shown that the Laotian (and most Thai) *R. losea* populations do not belong to this species, but represent a distinctive member of the *Rattus rattus* complex. In Laos, this species is currently recorded from localities in Vientiane Municipality and the provinces of Vientiane and Sekong. It is probably restricted to the lowland habitat bordering the Mekong River and its major tributaries. Unlike the other members of this group, it appears to be strictly a field rat. The correct scientific name for this species is still uncertain; until further clarification, it is called the "short-tailed rat." It is smaller than the other members of the *Rattus rattus* complex and, as its name suggests, it has a proportionally shorter tail. The belly fur is always a grayish color, never pure white.

The rice-field rat, *R. argentiventer*, is the major field pest in lowland rice-growing areas of Cambodia, Vietnam, Malaysia, and Indonesia (Aplin et al 2003c). In Laos, it has been recorded only from Khammouane Province (Francis 1999) in the central agricultural region. Further geographic sampling is needed to map the current range of *R. argentiventer* in Laos to provide a baseline against which to chart any future range expansion by this potentially significant pest species.

Two other *Rattus* species are probably minor pests of rice in Laos. The Pacific rat, *R. exulans*, has been collected in several localities on the Vientiane Plain. However, it does not seem to be present in any provinces with significant areas of upland agriculture although it extends to high elevations in other parts of its range and is perfectly at home in both village and garden habitats. The Himalayan rat, *Rattus nitidus*, is an important agricultural pest in parts of southern China (Aplin et al 2003c). In northeastern India and Thailand, it seems to be more closely associated with upland village habitats (Marshall 1977, Aplin, personal observations) but in Laos it seems to be absent or rare in villages—the few specimens collected in the provinces of Luang Prabang and Houaphanh came from trapping activities in rice fields adjacent to forest and in heavily disturbed forest remnants. It is possible that both *R. exulans* and *R. nitidus* have been excluded from upland village habitats in Laos by the spread of the two larger-bodied members of the *R. rattus* complex.

Two *Bandicota* species are listed as potential pest species (Table 2). The giant bandicoot, *Bandicota indica*, has been trapped on a regular basis in the provinces of Luang Prabang in the north and Sekong in the south of Laos. It does not appear to be particularly abundant anywhere in the country and may not be responsible for much damage to crops. In contrast, in parts of Cambodia and Myanmar, *B. indica* is a significant pest of lowland rice-cropping systems. The lesser bandicoot, *B. savilei*, is recorded only from photographs taken in Savannaket Province in central Laos (Aplin et al 2003b). The closest confirmed record is from the Ubon Ratchathani region of northeast Thailand, immediately west of Champassak Province in southern Laos (Musser and Brothers 1994).

The role of mice (*Mus* species) in damaging rice and other crops is almost always underestimated. This is probably because they are difficult to observe in the field and require special trapping methods for scientific study. In addition, they may cause a different kind of damage than other rodents, being able to climb the rice plant to feed directly on the panicle rather than cutting through the tillers. Farmers in Sayabouly Province in the west of Laos claim that mice in the fields mainly clean up any cut tillers and panicles left behind by *R. rattus*. However, in other parts of Laos, such as Luang Namtha Province in the northwest, farmers believe that mice cause substantial damage to lowland rice crops; this is supported by very high numbers of mouse burrows around the margins of fields in this area (Aplin, personal observations).

At least four species of mice are found in and around rice crops in Laos. The two most widespread species are *Mus caroli* and *M. cervicolor.* Both species dig their burrows in narrow bunds around paddy rice fields. A third species, *M. fragilicauda,* was described only recently from northeastern Thailand (Auffray et al 2003); the only other known occurrence is in paddy field areas in Sekong Province in southern Laos. A fourth species, *M. cookii*, appears to be restricted to upland rice fields; few specimens have been collected and little is known about its habit.

Various other species of rats are occasionally trapped in rice-cropping areas, especially where these abut areas of remnant forest. These captures may reflect low-level crop damage by these species; however, they might equally reflect foraging in fields for insects or other prey. The long-tailed arboreal rats *Berylmys bowersi* and *Leopoldamys* spp. account for most of these "occasional" captures, with fewer examples of the terrestrial rats *Maxomys surifer* and *Niviventer* spp. The rarely collected arboreal rat, *Chiromyscus chiropus,* has also been trapped in this situation. Only one of these species, *Berylmys berdmorei*, might sometimes achieve true "pest" status. This species appears to be uncommon across most of its geographic range (Marshall 1977), but in Luang Prabang Province it can be locally abundant, living in deep burrows excavated in steep banks around the margins of rice fields. One individual of this species was observed making extensive nightly movements of several hundred meters across valley-floor rice fields, while other individuals were trapped inside flooded rice fields (Aplin, unpublished data). Luang Prabang farmers hold this species responsible for damage to vegetable crops, especially sweet potato and other root crops. In Thailand, *B. berdmorei* is said to inhabit "swampy forests and marshy grass" (Marshall 1977) and this might explain its willingness to use the paddy field habitat.

Bamboo rats (members of the family Rhizomyidae) are most often associated with extensive stands of bamboo, where they feed mainly on the rhizomes and young shoots. All members of the group dig extensive burrow systems with numerous mounded exits and complexly branching tunnels many meters in length. Elsewhere in Southeast Asia, bamboo rats are reported to cause damage to tapioca, sugarcane, and rubber trees (Marshall 1977, Aplin, personal observations). In Luang Prabang, burrows of *Cannomys badius*, the smallest of the bamboo rat species, are often found in and around active upland rice fields. Several kinds of crop damage have been observed, including consumption of entire rice plants that are pulled downward by the roots into a tunnel. Vine fruits that rest on the ground, such as cucumbers and melons, are sometimes also eaten out from underneath. In Houaphanh Province in northeastern Laos, the same kind of damage is caused by a slightly larger species of bamboo rat, *Rhizomys pruinosus* (Mouan Muang Seum, personal communication).

Seasonal patterns in habitat use and abundance of upland rodents

Recent knowledge of rodent ecology in Laos comes from regular systematic trapping activities conducted in various habitats in four provinces (Luang Prabang, Oudomxay, and Houaphanh in northern Laos and Sekong in the south) between 1999 and 2002 (Khamphoukeo et al 2003), combined with extensive farmer interviews, excavation of burrow systems, observations made while participating in "rat hunts," and a limited

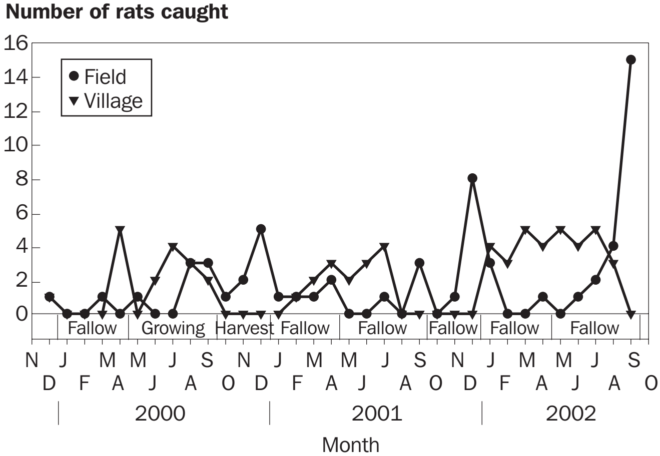

Fig. 1. Trapping results for a 3-year period at Hatsua village in Luang Prabang Province. The graph shows the number of rats caught in each of field and village habitats. With the exception of October 2003, the same number of traps were set each month. Village captures are high during the periods when grain stores are full (January to August/September) but low at other times. Field captures increase during the growing and harvest periods of each year.

study of rodent movement in Luang Prabang, using the techniques of radiotracking and line-spooling (see Aplin et al 2003c for an explanation of these methods).

The house rat is the most abundant rodent in all habitats within the upland agricultural landscape of Laos. In the village habitat, it is probably the only resident rodent, with other species (e.g., *B. indica*) encountered only as occasional visitors. In field areas, the house rat is likewise dominant, although in these habitats it occurs alongside several other resident species. In lowland rice fields, along valley floors, house rats are found together with *B. indica*, *B. berdmorei*, and two or more species of *Mus*. In upland fields, whether under crop or weedy fallow vegetation, house rats occur together with resident populations of *B. berdmorei* (mainly in moister gully habitats), *M. cookii*, and *C. badius*. House rats also occur in forest habitats but they appear to be less abundant in such contexts. Other resident species in forests include *R. nitidus*, *R. sikkimensis*, *B. berdmorei, B. bowersi*, *C. chiropus*, *Leopoldamys* spp., *Maxomys surifer*, *Mus pahari, Niviventer* spp., and the bamboo rats *C. badius* and *Rhizomys pruinosus*. How far the house rat penetrates away from the forest edge into progressively less disturbed habitats is not yet known. However, it is clear that it becomes less abundant away from field habitats.

The results of three years of trapping in and around Hatsua village in Pak Ou District of Luang Prabang are summarized in Figure 1. The results are simplified into two categories: village captures and field captures, with the latter combining results from shifting cultivation fields and a small rainfed lowland rice area within a valley.

Virtually all of the captures have been of a single species—the north Asian house rat, known locally as *nuu ban* or *nuu thammadaa*. Each year, the number of rats captured in the village habitat went through a dramatic increase, starting in December after harvest and refilling of village rice stores. Captures remained high until August or September, by which time all of the stored rice has been eaten (by people and rats). From then through until after the next harvest, few rats were captured in the village habitat.

The increase in rat numbers from December onward is probably due to a combination of migration from fields and intensive breeding in the village habitat. Farmers claim that many rats move from fields to the village following harvest and removal of their food resource. In support of this view, there is one record of the capture in a grain store in January 2003 of an adult rat that was radio-collared the previous November in an upland field, several kilometers away. There is also strong evidence of breeding within the village. Six out of seven adult female rats (84.5%) captured in Hatsua village in January to April were pregnant. This fell to 43.2% (16 pregnant out of 37 adult females) for May to September, but many of the nonpregnant females showed signs of recent breeding. Large numbers of small, recently weaned young were also captured at this time.

From August to December, when the rice stores are empty, rats are difficult to catch inside the village. Radiotracking of a small number of rats caught in August 2003 in a near-empty grain store showed that they were spending the days inside clumps of giant bamboo growing close to the village. On some nights they entered the village but on other nights they moved into nearby fields or riverside forest patches. Only 3 of 14 adult females caught over this period were pregnant (21.4%).

The number of rats captured in field habitats shows a pattern opposite to that of the village. Very few rats were captured in the fields from January to July of each year. These months include the fallow period and the early months of the growing season, times when there is little or no food available for rats in fields. Starting around July to August each year, the number of field captures increased to a maximum in December at the end of the harvest. Only 25% of the adult females captured during this period were pregnant but there was a high proportion of juveniles and young adults. This suggests that the majority of the new residents in upland fields are immigrants, with animals perhaps drawn from both the forest and village habitats. However, local breeding activity clearly also contributes to the population increase in field habitats. Harvesting presumably causes extensive disruption among the resident rats. Radiotracking of house rats during the harvest period found evidence of extensive, seemingly erratic nightly movements, often covering many hundreds of meters. Many rats spent the days sheltering inside piles of rice straw and Job's tear stalks, while others were using burrows in dense bamboo and weedy vegetation in gullies. Although many young rats are present at this time, survival of these late-season young rats is probably not very high as little food remains in fields and most likely a surfeit of adults already occupy patches of forest and fallow vegetation, including many individuals that have fled field areas. As suggested above, at least some of these refugees from the fields presumably make their way down to the village to continue the cycle of breeding and movement.

Impact of rodents in rice ecosystems in Laos

Lao farmers living in the upland environment generally draw a clear distinction between rodent damage suffered each and every year (chronic damage) and that suffered during rodent outbreaks. The damage suffered during outbreaks is sometimes so severe as to entail the rapid and complete destruction of all standing crops.

Chronic preharvest impact

In the upland environment, rodents are considered the most important pest of rice and many other crops (Schiller et al 1999). Upland rice farmers generally rate rodents as being second only to weeds as the overall most important constraint to upland rice cultivation. However, while farmers are able to control weeds through regular weeding, they currently lack any effective means of controlling rodents. As such, rodents are the production constraint over which farmers have least control (Schiller et al 1999).

Preharvest grain losses have not been properly quantified, but have been estimated to be 15% of the rice harvest annually (Schiller et al 1999). Since there is a chronic shortage of rice for upland farmers, this loss can further impair the livelihood of the chronically poor.

In a study of rodent damage in six villages in Luang Prabang Province, Harman (2003) reported that rodent damage to crops occurred mainly at planting and at harvest (Table 3) but with some differences between villages. Such information can be used to refine the timing of rodent management strategies so that control is conducted before damage occurs. Farmers reported that stored rice was the commodity most damaged by rodents, but rodent damage to upland rice was considered the biggest problem in some villages. In terms of highest losses, upland rice, maize, and stored rice were identified, whereas other stored crops, including sesame, suffered less damage (Harman 2003).

Rodents are generally not considered a major problem in the rainfed lowland rice agroecosystem or in the lowland irrigated environment. A survey of lowland farmers in 1993 from nine districts of seven provinces in the Mekong River Valley indicated that, in most districts, rodents were not regarded as a significant production constraint (Khotsimauang et al 1995, Schiller et al 1999). Another survey of farmers in areas of lowland cultivation in Vientiane Municipality and the provinces of Savannakhet and Champassak conducted in 1994 showed that rodents were a significant problem in only one area, where 30% of farmers reported that rodents were pests. Most farmers claimed that they could manage the rodent problems encountered (Rapusas et al 1997).

In contrast, areas of lowland rice adjacent to upland areas (referred to as montane paddy rice by Linquist et al in Chapter 3) can receive very high losses from rodents. These areas are generally adjacent to areas of degraded forest, fallow regrowth, and areas of upland cropping, all of which can harbor large populations of rodents. Early-

Table 3. Summary of the timing of maximum rodent damage to various crops in each of six villages in Luang Prabang Province (from Harman 2003), based on the results of farmer group meetings.

Crop type	Village					
	Houay Khot	Houay Kha	Ladthahae	Hatsua	Houay Leuang	Mok Mouang
Dry-season lowland	Sowing (December)		Harvest (May)			
Wet-season lowland	Harvest (November)	Harvest (October)	Harvest (October)	Harvest (October)	Flowering (October)	
Upland rice	Harvest (October)	Sowing (May)	Harvest (October)	Sowing (May)	Planting (June)	Threshing (October)
Maize	Harvest (August)	Harvest (August)				Harvest (August)
Job's tears	Harvest (November)		Harvest (October)	Planting (May)	Planting (May)	
Seasame		Harvest (September)	Harvest (July)		Harvest (August)	
Melon				Flowering (August)		
Cassava						Harvest (February)

maturing rice crops in this environment are particularly vulnerable. In some villages in Luang Prabang, farmers plant only one lowland crop per year because of the potential for high rodent damage in a second crop. This "forgone loss" is not normally quantified when examining estimates of rodent damage.

Bamboo flowering and *nuu khii* outbeaks

Episodic but irregular rodent irruptions occur in many parts of Laos. These are sometimes responsible for extreme crop losses, occasionally leading to localized or widespread famine (Douangboupha et al 2003). In some situations, up to 100% of crops can be damaged through localized outbreaks of rodents (Singleton and Petch 1994). Farmers typically associate these outbreaks with the gregarious flowering and seeding ("masting") of certain bamboo species and commonly refer to them as *nuu khii* events (*nuu khii* literally means "rat of bamboo flower").

The link between bamboo masting and rodent outbreaks is made across many other parts of South and Southeast Asia, wherever there are extensive tracts of bamboo (Chauhan and Saxena 1985, Nag 1999). Similar phenomena are also reported in South America, where severe rodent outbreaks occur (Jaksic and Lima 2003), and in Madagascar. Although the ecological link between bamboo seeding and rodent outbreaks has not been documented in full anywhere in the world, it is ecologically plausible that the production over one or two years of large quantities of highly nutritious bamboo seed could trigger an explosive increase in rodent populations within the bamboo forest

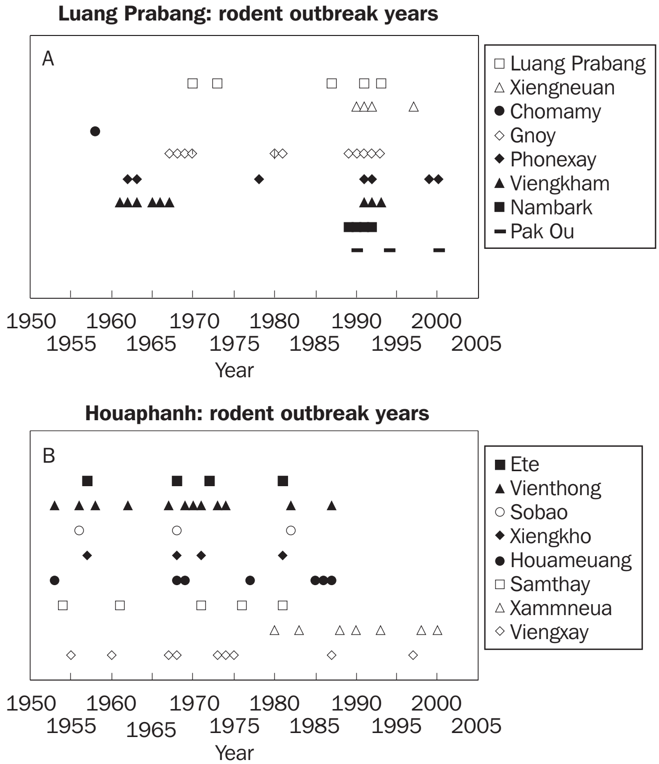

Fig. 2. Historical pattern of rodent outbreaks in various districts of two provinces of Laos (from Douangboupha et al 2003): (A) Luang Prabang in the north of Laos and (B) Houaphanh in the northeast.

habitat. Mass emigration of rodents into adjacent agricultural habitats following the depletion of the seed resource also seems plausible, given what is known of general rodent biology.

The frequency and duration of rodent outbreaks vary markedly from one province to another in Laos (Fig. 2). In Luang Prabang, the outbreaks seem to occur infrequently but tend to last 2–4 years. In Houaphanh, in the northeast of the country, they tend to be more frequent but typically fall within a single year. Although these historical records suggest that many outbreaks are localized to a particular district, there is also evidence of more widespread outbreaks, such as in 1989-93, when an outbreak affected most districts of Luang Prabang and neighboring Oudomxay in northern Laos (Douangboupha et al 2003). Because there are many species of bamboo in Laos, each with a patchy distribution in the landscape and each with a different flowering interval, irregular and localized outbreaks of the kind observed are consistent with the bamboo flowering hypothesis. In contrast, widespread and prolonged outbreaks are more likely caused by some wider environmental factors. One possible alternative cause is the El

Niño Southern Oscillation (ENSO) that has a strong influence on the climate of Laos (Holmgren et al 2001).

The species of rat or rats responsible for *nuu khii* outbreaks remains in doubt. Douangboupha et al (2003) listed six different ethnotaxa (Lao species) reported to be involved in historical *nuu khii* outbreaks: *nuu khii*, *nuu ban, nuu american, nuu na*, *nuu mon*, and *nuu tongkao* (refer to Table 1 for classifications). The following species were collected during an outbreak in Houaphanh in northern Laos in 2001: *Mus cervicolor* (identified as *nuu khii*), *Rattus rattus* (several specimens, variously identified as *nuu khii*, *nuu ban*, *nuu mon*, and *nuu tongkao*), *Berylmys berdmorei* (identified as *nuu mon* and *nuu way*), and *Bandicota indica* (identified as *nuu american* and *nuu na*). Most rodent species are quite adaptable and willing to change their diet as different food resources become available. Accordingly, many different species could probably use the temporary bamboo seed resource and then participate in *nuu khii* outbreaks. Some forest-dwelling nonpest species therefore might become temporary agricultural pests during an outbreak period.

Chronic postharvest impact

There is little information on the losses caused by rodents to stored grain in Laos (Singleton and Petch 1994). Nevertheless, farmers generally recognize this as being a significant problem and rate the damage to stored grain as equal to or greater than the field losses (Harman 2003; Table 4).

In all four upland villages (spread across four provinces, as noted above) where systematic trapping was conducted (Khamphoukeo et al 2003), members of the "house rat" group were consistently trapped in and around traditional grain stores. These species are excellent climbers and are difficult to exclude from such facilities, especially where there are overhanging trees or other vegetation. Mice (*Mus* spp.) were never trapped in these contexts and do not seem to be responsible for any postharvest damage or loss. However, this situation could change rapidly if the house mouse (*Mus musculus*) became established in rural villages in Laos (as it has done in parts of Myanmar). Farmers use several traditional methods to control rat damage to stored grain, but with limited success.

Rodent-borne diseases

Commensal rodents (rats and mice) are known reservoirs of many zoonotic diseases (Gratz 1994, Mills 1999). Rodent-borne diseases of major concern in agrarian and urban communities of Southeast Asia are leptospirosis, plague, hanta and arena viruses, lymphocytic chorio-meningitis virus (LCMV), typhus, and lungworm. Chronic high rodent numbers in places where livestock are housed, and in rice-cropping and village habitats, represent a key factor in the disease nexus (Perry et al 2002, Begon 2003).

Very little is known about the status of rodent-borne diseases in rural communities in Laos. One small study examined 48 animals (8 rat species) in the upland environment of Luang Prabang and Oudomxay provinces in northern Laos but found no individuals sero-positive for leptospirosis, LCMV, or hanta virus (Singleton et al 2003). However, in the border region between Laos and northeast Thailand, leptospirosis has had a major

Table 4. Farmers' perceptions of the most- and least-damaged field crop or stored commodity in each of six villages in Luang Prabang Province, based on two different methods. For the "seed method," farmers were asked to place seeds on an annual cropping calendar to quantify the timing and severity of damage caused by rodents. For the second method, farmers were asked to estimate the overall yield loss caused by rodents in each crop. The fact that the two methods gave different results is not unexpected given the complex relationship between rodent damage and yield loss (Aplin et al 2003c).

Damage type	Village					
	Houay Khot	Houay Kha	Ladthahae	Hatsua	Houay Leuang	Mok Mouang
Most-damaged crop (seed method)	Stored rice	Stored rice	Upland rice	Wet-season lowland rice	Upland rice	Stored rice
Crop with highest yield loss (%)	Maize and stored rice	Upland rice and maize	Stored rice	Stored rice	Stored rice	Upland rice and stored maize
Least-damaged crop (seed method)	Other stored crops	Stored sesame	Stored sesame	Stored melon	Stored sesame	Upland rice and cassava
Crop with lowest yield loss (%)	Other stored crops	Stored sesame	Stored sesame	Stored melon	Stored sesame	Cassava

impact on rural as well as urban communities (Tangkanakul et al 2001). From 1995 to 2003, the reported incidence of leptospirosis in humans showed a marked increase in this region. In 1996, 398 cases were reported, with a peak in 2000 of 14,285 cases and 362 deaths. The number of cases remained high through 2001 to 2003, with 171 deaths in 2001 and 95 in 2002. Most of the reported cases each year (ranging from 72% to 94% of those reported) occurred among rice farmers (Phulsuksombati et al 2001, Tangkanakul et al 2005). In northern Thailand in 2000, 3,914 cases of scrub typhus were reported, with most cases being male farmers (in northeast Thailand in 2000, the morbidity rate was 8.7 per 100,000 people) (Tangkanakul, personal communication). A 10-year study in northern Thailand identified 9 murid rodents as carriers of scrub typhus, with the main carriers being *R. rattus* (23%, 419 of 1,855), *R. argentiventer* (22%, 5 of 23), *B. berdmorei* (22%, 2 of 9), *R. losea* (13%, 82 of 638), and *B. indica* (9%, 52 of 564). *Rattus exulans* was a poor host for typhus, with only 2 of 146 animals infected (Coleman et al 2003). Information on leptospirosis and typhus from other Asian countries is extremely limited. Information on zoonotic viral diseases is even less available. However, some recent work in Thailand suggests that hanta viruses are quite prevalent in rodent populations in the region and thus may pose a significant risk to human health (Nitatapattana et al 2002),

Management of rodent pests in Laos

Traditional methods

Lao farmers use a variety of locally made traps and snares for rodent control, sometimes in combination with drift fences made of sticks or bamboo. These are used throughout the year, with an increase in activity as the upland rice crop matures and after harvest. Captured animals are often eaten or the meat smoked and sold in local markets.

Intensive hunting for rats is often carried out by men and children after harvest. A common target is the piles of rice straw and Job's tear stalks that are stacked around upland fields. Hunters generally place fishing nets along one side of the pile and then either disturb the pile or light a fire on the opposite side. Rats also are hunted at night with the use of air guns, crossbows, or slingshots.

Protection of stored grain

The Lao-style storage facilities in and around villages can be simply described as hut-like storage structures; these are sometimes built at ground level but more often they are raised on stilts. The roof is typically made of straw and the entrance is usually a single small window-like opening with a latch door or a standard-sized opening with a large door. The walls can be made of woven bamboo, wood, or bamboo cut into strips and tightly woven together. A mixture of buffalo dung and soil is sometimes plastered onto the walls and this helps to block any holes that rodents might use. Additional rodent deterrents include metal guards wrapped around the stilts of the structure and wire mesh nailed across the top of the storage compartment. The use of metal guards is regarded as one of the most effective methods for protecting grain stores against rodent damage (Harman 2003) but, to be effective, the store also needs to be constructed away from other buildings and overhanging tree cover. Grain stores protected by these measures usually show little or no evidence of damage or contamination by rodents. In contrast, unprotected stores in the same villages typically show much damage to the storage structure itself and heavy damage and contamination of the grain.

Rodenticide use

Until the mid-1990s, there was little use of rodenticides for controlling rodents in Laos. However, in the last decade, rodenticides have become more widely available and their use has increased, in some areas to a chronic level. The most widely used poison is a clear liquid of Chinese origin, supplied in ampoules with little if any labeling. Analysis of three ampoules found a compound similar to 1080 (sodium monoflouro-acetate) in two, and no obvious active ingredient in the third (Herwig Leirs, personal communication). Anticoagulants such as coumatetralyl and zinc phosphide of Russian and Japanese origin also are widely available. Rodenticides are applied in the field only when rodent numbers are high and heavy crop damage is observed. Poison use around villages is regarded as dangerous and is generally avoided.

When mixed with paddy grain and applied in fields, the "Chinese poison" has an immediate and visible impact on rodents, with many carcasses lying around the following day. Unfortunately, the baits are also highly effective against various non-target animals, including domestic cats, dogs, pigs, and fowl, either through direct consumption of the bait or from scavenging of carcasses. In many parts of Laos, regular rodenticide use has drastically reduced the numbers of domestic animals in villages. Farmers are painfully aware of this fact but claim to have little alternative other than to continue using these highly toxic baits. Native wildlife presumably also suffers nontarget mortality but nothing is known of the long-term impact on any species. The Lao government has a policy to discourage the use of rodenticides; however, they can still be purchased in local markets in many areas. The ecological understanding recently obtained of the major rodent pest species has the potential to provide a platform for ecologically based rodent management in Laos. In Indonesia, in lowland irrigated rice crops, such an approach has led to significant increases in yield and a greater than 50% reduction in rodenticide use (Singleton et al 2005).

Conclusions

The upland environment of Laos supports a rich array of rodent species, the great majority of which do little or no damage to crops. In developing rodent management practices, it is important to develop strategies that do not harm those species that are important members of the natural forest community and provide important ecosystem services. Important steps toward developing ecologically based and ecologically sensitive rodent management for Laos include (1) minimizing the use of indiscriminate poisoning with rodenticides, (2) focusing rodent management efforts on the manipulation of habitats and the selective culling of pest species at key times in their population cycles, and (3) encouraging farmers to work together at critical times to carry out effective control actions. Management techniques almost always need to be adapted to suit particular cropping systems and pest species (Leirs 2003), and as such are likely to differ for the different regions and rice-growing environments in Laos.

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CHAPTER 20

Weed ecology in the rice environments of Laos

W. Roder

The direct loss in rice production because of weeds in farmers' fields in Asia is reported to amount to about 20% (www.riceweb.org: Pests, diseases). In addition to this, weed control is a major component of production costs. In Laos, weeds are especially troublesome for upland rice farmers, resulting in much labor required for weeding (Table 1). Because of this, weed ecology and weed management have received high importance in research projects focusing on upland rice-growing environments (Roder 2001). In most Lao lowland rice-growing environments, weeds, although present, are less problematic.

Weed ecology and management in lowland systems

Publications by Khotsimuang et al (1995) and Inamura et al (2003) provide information on weed species, distribution, and management practices. A study by Khotsimuang et al (1995) included 141 villages in Vientiane Municipality, and Vientiane, Kham-

Table 1. Production costs for rice systems.

Parameter	Lao rice producer		United States
	Lowland	Upland	
Rice yield (t ha^{-1})	2	1.5	8.5
Value of production (US$ ha^{-1})	300	225	1,020
Labor input (days ha^{-1})	200	294	<2
Labor for weed control (days ha^{-1})	7	159	<0.5
Labor % weed control	3.5	54	–
Cost of weed control (US$ ha^{-1})	7	159	90
Weed control cost as % of production	2.3	71	9
Labor productivity in rice (kg day^{-1})	10	5.1	>4,000
References	Estimated based on Khotsimuang et al (1995) and Leacock et al (1993)	Roder (2001)	Livezey and Foreman (2004)

mouane, Savannakhet, Saravane, Champassak, and Sayabouly provinces, representing the most important lowland rice areas of the Lao PDR. A study by Inamura et al (2003) included 41 sites in Vientiane Municipality (Saythany and Nasaithong districts) and Luang Prabang (Xiang Ngeun, Nambak, and Luang Prabang districts), Oudomxay (Beng and Xay districts), and Luang Namtha (Namtha District) provinces.

Weeds as a production constraint

When ranking constraints to rice production, Lao lowland rice farmers generally ranked weeds third or fourth after drought and insect pests (Khotsimuang et al 1995, Schiller et al 2001). Because of low soil fertility in much of the lowland rice-growing area, weed growth is poor and the labor required for weeding is generally less than 10% of the total labor input (Inamura et al 2003, Table 1). The tall, traditional Lao rice cultivars with droopy leaves are more effective in suppressing weeds than the short, high-yielding varieties (Nantasomsaran and Moody 1995). With the introduction of high-yielding varieties, higher fertilizer applications, and increased cropping intensity in response to expanded irrigation facilities, weed competition may become more of a problem. In spite of their poor growth, weeds compete with rice for the limited nutrient and reduce rice yield. Inamura et al (2003) have shown that removing weed competition resulted in increased nitrogen-use efficiency and better harvest index.

Weed species

Weed species reported are similar across a wide range of the lowland rice-growing areas of Laos (Khotsimuang et al 1995, Inamura et al 2003, Table 2). From Luang Namtha Province in the north to Champassak Province in the south, *Ludwigia octovalvis* and *Fimbristylis littoralis* have been cited as the most important weed species (Table 2). *Ludwigia octovalvis* is listed among the seven most important broadleaf weeds of rice in Asia (IRRI 2003).

Weed management strategies

Lao lowland rice farmers are familiar with common weed management strategies. They use a combination of land preparation, water management, and manual weed control. However, weed management is hampered because of poor water control (Nantasomsaran and Moody 1995). Lack of water or water management was mentioned consistently as the main factor associated with weed problems by the farmers interviewed by Khotsimuang et al (1995) and years with lower than average rainfall were associated with increased weed competition.

Weeding in the lowland rice environments is done manually. Most farmers weed about 40 days after rice planting (Khotsimuang et al 1995, Inamura et al 2003). Weeding requirements vary substantially. Inamura et al (2003) reported the ratio of paddy fields weeded to total paddy for Vientiane Municipality, Luang Prabang, Oudomxay, and Luang Namtha provinces as 34%, 92%, 63%, and 33%, respectively. In some areas, especially in Vientiane Municipality and Luang Namtha Province, weeding was not necessary at all. In the survey by Khotsimuang et al (1995), the labor required ranged

Table 2. Weed species reported in Lao lowland rice environments.

Species[a]	Sites[b] where species reported			
	Khotsimuang et al		Inamura et al	
	(no.)	(%)	(no.)	(%)
Ludwigia octovalvis	6	86	8	100
Fimbristylis littoralis	5	71	8	100
Xyris indica	6	86	6	75
Marsilea crenata (minuta)	7	100	3	38
Ischaemum rugosum	2	29	2	25
Echinochloa colona	1	14	3	38
Cyperus difformis	1	14	1	13
Scirpus supinus	3	43	–	–
Paspalum distichum	–	–	5	63
Rottboellia exaltata	4	57	–	–

[a]Additional species recorded at 2–3 sites: (1) Khotsimuang et al (1995): *Monochoria vaginalis, Mimosa pudica, Scirpus grossus, Cyperus rotundus,* and *Eleocharis dulcis;* and (2) Inamura et al (2003): *Axonopus compressus, Ageratum conyzoides, Ludwigia hyssopifolia,* and *Sagittaria trifolia.* [b]Sites were seven provinces for Khotsimuang et al (1995) and eight districts for Inamura et al (2003).

from 2.2 to 11.5 days per ha (averaged at the village level). As recently as 2003, commercial herbicides were rarely being used for weed control in lowland situations.

Weed ecology and management in upland rice systems

Upland rice production systems in Laos have evolved from the traditional slash-and-burn agricultural systems, which were typical for the subtropical regions of Southeast Asia. Before the 1990s, little information was available on land-use systems, particularly on weed species, ecology, and management.

Weeds, the most important production constraint

In household surveys carried out in the three northern provinces of Luang Prabang, Oudomxay, and Bokeo during the early 1990s, 80–90% of the upland farmers rated weeds as their most important constraint to rice production (Table 3, Roder et al, 1997a). This rating by farmers did not refer to direct yield loss, but to the labor requirements for weeding. Some of the other important constraints frequently listed, such as land availability and labor, can be directly related to weeding requirements/problems.

Table 3. Farmers' rating of major constraints to upland rice production based on household surveys in three northern provinces of Laos.

Constraint	Respondents listing constraint (%)		
	Oudomxay (n = 32)[a]	Luang Prabang (n = 97)	Bokeo (n = 57)
Weeds	81	86	93
Rodents	12	72	61
Insufficient rainfall	47	50	2
Insect pests	69	30	2
Land availability	47	31	–
Domestic animals	16	17	23
Soil fertility	31	22	2

[a]n = number of farmer respondents.
Source: Roder et al (1997a).

Table 4. Labor requirement for upland rice production.

Activity	Days ha^{-1}
Slashing	33 (12–61)[a]
Burning	2 (1–3)
Fencing	2 (0–10)
Second burning	14 (5–30)
Weeding before planting	13 (0–40)
Planting	29 (16–44)
Weeding	146 (45–455)
Harvesting/threshing	33 (20–71)
Transportation	22 (7–47)

[a]Numbers in parentheses indicate range.
Source: Roder et al (1997a).

Farmers customarily provide adequate weed control, with 3–4 weedings per season resulting in labor inputs of 45–455 days ha^{-1} (Table 4). The most critical period for weed competition is 30–50 days after planting (Phengchangh 1998). As the fallow biomass is burned in March, about 2 months before rice planting, a first weeding is often undertaken. Weed control is by far the most labor-consuming task in upland rice production, accounting for 40–50% of total crop labor input (Table 4). Other tasks requiring appreciable labor inputs are slashing of the fallow vegetation and harvesting.

Table 5. Cover and frequency of major weeds in upland rice fields of northern Laos.

Weed species	Oudomxay Province		Luang Prabang Province: Viengkham District[a]		Luang Prabang Province: Pakseng District		Luang Prabang Province: Xiengngeun District	
	F[b]	C[c]	F	C	F	C	F	C
Chromolaena odorata	68	9.7	32	6.5	36	1.9	64	4.4
Ageratum conyzoides	31	6.6	23	5.5	11	0.7	60	3.4
Commelina spp.	18	2.6	8	1.3	22	1.2	58	3.4
Lygodium flexuosum	13	1.8	13	1.6	28	1.8	34	1.6
Panicum trichoides	5	0.5	3	0.4	6	0.3	32	1.5
Corchorus sp.	3	0.3	8	1.5	8	0.6	10	0.4
Pueraria thomsonic			7	1.3	5	0.2	12	0.7
Panicum cambogiense			4	0.5			8	0.5
Imperata cylindrica			1	<0.1	4	0.2	4	0.2
Dioscorea sp.			4	0.4	2	0.1	<1	<0.1
Crassocephalum crepidioides	<1	<0.1	1	0.1			2	0.1
Total cover (cm m^{-1})		22		19		7		16

[a]Additional species of importance in Viengkham District were *Cyperus trialatus* and *Pteridium* sp., with frequencies of 26% and 13% and cover of 4.5 and 3.3 cm m^{-1}, respectively. [b]F = frequency (%) in transect segments of 1 m. [c]C = cover in cm m^{-1}.
Source: Roder et al (1997a).

Weed species

With a few exceptions, *Chromolaena odorata,* introduced to Laos in the 1930s, is the most important weed found in upland rice throughout the country (Photo 20.1, Roder et al 1995b, 1997a). Following field measurements over a wide area in Luang Prabang and Oudomxay provinces, *C. odorata* contributed almost 40% of the total weed cover during the rice crop (Table 5). *Ageratum conyzoides, Lygodium flexuosum,* and *Commelina* spp. (mostly *C. benghalensis* L.) were abundant in all regions surveyed. The latter is difficult to control because it can root easily from nodes of small stem segments left in contact with moist soil. *Imperata cylindrica* and *Mimosa invisa* were present but were not regarded as being significant problems, except in relatively localized areas (Photo 20.2). In some upland areas, such as in parts of Houaphanh Province, small areas of *I. cylindrica* are deliberately maintained by farming households to provide a source of material for roofing thatch. The major weed species appear to be adaptable to a wide range of environmental conditions. Correlation analysis between elevation, fallow period, selected soil fertility parameters, and frequency of weed occurrence showed no or little relationship (Roder et al 1995a,b).

Phengchanh (1998) evaluated competition and allelopathic effects of *C. odorata* and *A. conyzoides* on traditional upland rice varieties. His studies showed that the critical time for removing the competition ended at 30 days for *A. conyzoides* and at 45

Table 6. *Ageratum conyzoides, Chromolaena odorata,* and *M. graminicola* density for fallow categories (years of fallow) observed in the weed survey (1993).

Fallow (no. of years)	*A. conyzoides* (number m^{-2})	*C. odorata* (number m^{-2})	*M. graminicola* (number g^{-1} root)
2–3	15 ± 4[a]	8 ± 2	156 ± 82
4–5	11 ± 2	8 ± 1	72 ± 28
6–8	9 ± 3	10 ± 1	41 ± 17
>8	5 ± 3	8 ± 3	32 ± 31

[a]Mean and standard error.
Source: Roder et al (1998a).

days after planting for *C. odorata.* Root exudates of both species showed stimulatory and inhibitory effects and varied with rice variety. Allelopathic effects by *C. odorata* have also been demonstrated by Nakamura and Nemoto (1994).

Shift in weed species

Within a short time after its introduction in the 1930s, *C. odorata* had become the most abundant weed and fallow species (Roder et al, 1995b, 1997a). In interviews conducted during the early 1990s, elderly upland farmers could not recollect the dominant weed species prior to the introduction of *C. odorata*. The invasion by *C. odorata* had apparently not resulted in a major displacement of other species. With a coincident reduction in the fallow period, the spread of *C. odorata* may have largely replaced tree species coppicing from old plants or growing from seeds.

With repeated cycles of short fallow periods, a shift from *C. odorata* to *A. conyzoides* (Roder et al 1998a) or to grass species (Fahrney 1999) had become apparent in the 1990s. These trends toward weed species that are more difficult to manage is likely to continue. Changes in weed composition are likely to have strong effects on the fallow vegetation and soil fertility. Studies in the 1990s documented effects of cropping intensity on the prevalence of *A. conyzoides* (Photo 20.3). The same studies also showed some association between rice yield and the prevalence of *A. conyzoides* and the root-knot nematode (Roder et al 1998a, Table 6). Farmers in most areas recognize *A. conyzoides* as their most serious weed problem (Fahrney 1999). The shift from tall-growing species or coppicing trees to weed species such as *A. conyzoides* or grasses also leads to increasing intensity and frequency of weeding with hand hoes (Photo 20.5), thereby increasing the potential for soil loss substantially (De Rouw et al 2005).

Fallow length, weeding requirement, and labor productivity

Many authors have made reference to the relationship between weed problems and the length of the fallow period (SUAN 1990, Roder 2001), but quantitative data are limited. Traditional land-use systems were influenced by factors such as climate, land availability, land tenure, population pressure, food preferences, political events, and ethnicity, yet all farmers use fallow length and fire as the most important weed management strategies (Roder 2001, Moody 1975, De Rouw 1991, Warner 1991). Fallow species composition, species characteristics, biomass produced, and biomass quality all have a direct effect on soil conditions, ease of slashing, burning temperature, weed dynamics during cultivation, and ultimately crop yield and farmers' return on labor invested. The primary functions of the fallow period are to restore soil fertility and reduce weed pressure. Long fallow periods with tree cover eliminate most of the annual weed species. Furthermore, high fallow vegetation biomass increases temperatures at the time of burning, thus decreasing viability of weed seeds, which may have been present in the topsoil. To maintain long fallow periods, large land resources and consequently low population densities are required.

Little information is available on the upland production system prevalent in Laos in the 19th century and before, but we can assume that the traditional systems evolved under low population densities. Reports by Thorel (1875), Boudene (1913), and Gourou (1942) indicate that fallow periods of 20 years and more were the norm during the time of their observations. Thorel's remarks also suggest that weeding was not necessary during the 19th century. Observations made in the 1950s mention weeding, but not to the extent that it is required today. Izikowitz (1951) gave a detailed description of slash-and-burn cultivation by Lamet farmers in northern Laos in the 1940s. He considered cutting of the fallow vegetation as the most important labor input, and reported fallow periods of 12–15 years and weeding inputs in June and July. With weeding limited to a period of 2 months only, the weeding intensity may have varied from 1 to 2 weedings per season. Halpern (1961) indicated that weed control in upland rice (slash-and-burn systems) was less labor-consuming than for lowland rice.

Based on investigations carried out in the districts of Xiengngeun and Viengkham of Luang Prabang Province, the average fallow period reported decreased from 38 years during the 1950s to 5 years in 1992, whereas the weeding requirement increased from an average of 1.9 weedings per season in the 1950s to 3.9 weedings in the 1990s (Roder et al 1997a, Table 7); this change represents a remarkable increase in the labor input for weed control. With stagnant yields, upland farmers' returns to labor inputs have therefore declined substantially (Table 7). In another study carried out in Luang Prabang, Leacock et al (1993) reported labor inputs of 268, 205, and 194 days ha^{-1} or returns to labor of 4.3 kg of grain day^{-1} for upland rice, 8.6 for lowland rice, and 13.3 for maize production. Because of the unsatisfactory returns to labor and increased expectations, Lao hill farmers are under great pressure to change their land-use practices. However, a combination of a lack of markets for alternative potential cash crops, a lack of access to credit facilities, and poor alternative employment opportunities have left them little choice but to continue producing upland rice for their own consumption.

Several authors have used remote-sensing techniques to estimate the length of the fallow period (Sandewall et al 2000). When comparing estimates of the fallow period made by remote-sensing methods with those reported in interviews, the lat-

Table 7. Trend in fallow length, weeding requirement, labor input, population density, and wage equivalent in rice.

Parameter	1950s	1970s	1990s
Fallow period (y)	38	20	5
Weeding requirement (no.)	1.9	2.3	3.9
Total labor requirement for upland rice (d ha^{-1})	226	239	294
Rice yield (t)	1.7	1.6	1.5
Population (millions)	1.8	3.0	4.2
Population density (nationally, persons km^{-2})	7.6	12.5	17.6
Labor productivity in rice (kg day^{-1})	7.5	6.7	5.1
Rice equivalent of labor wage for construction (kg d^{-1})	8.4	n.a.	5
Rice equivalent of labor wage for farm work (kg d^{-1})	6 + meal	6 + meal	4 + meal

Source: Roder (1997).

ter have often suggested comparatively shorter fallow periods. Several factors may contribute to this discrepancy, the most important being (1) remote-sensing methods integrate events over a timeframe of more than 10 years, while the interview system may only ask the farmer, "What was the fallow period for the rice field used in the year of the interview?; (2) remote-sensing methods may also include areas that, for various reasons, cannot be used further for cultivation.

Weeds for fallow improvement

Plant species regarded as weeds during the period of the rice crop may potentially become useful fallow species after the rice harvest. The composition of fallow plant species and their characteristics are important factors influencing soil fertility parameters, weed dynamics, and grain yield of the next rice crop. In most environments, *C. odorata* provides the bulk of biomass in the initial years after the rice harvest. At sites monitored by Roder et al (1997b) in northern Laos, the average aboveground biomass was 1.4 t ha^{-1} at the rice harvest, increasing to 9.8 t ha^{-1} and 15.5 t ha^{-1}, respectively, after 1 and 2 years of fallow (Photo 20.5). At rice harvest, tree and bamboo species contributed 61% to the total biomass (Table 8). Their development, however, is too slow to fill the gap left after the rice harvest and, after the first year of fallow, tree and bamboo species contributed only 37% of the biomass, whereas *C. odorata* contributed 49%. Similarly, *C. odorata* was the dominant fallow species in the initial year in slash-and-burn fields in southern Laos (Chansina et al 1991). As the duration of the fallow period increases, woody bamboo and tree species gradually replace *C. odorata* (Roder et al 1995b, 1997b). The contribution of grass species to the weed and fallow biomass is generally small, and, in contrast with some other slash-and-burn systems in Asia, *Imperata cylindrica,* although present, is rarely dominant in upland production systems of Laos.

Chromolaena odorata regrowth from rootstock after burning can seriously compete with young rice plants but, because of its growth habit (relatively few but

Table 8. Average aboveground biomass in four slash-and-burn fields in northern Laos after the rice crop (1991) and two subsequent years of fallow (1992-93).

Species	Plant biomass (t ha^{-1})		
	At rice harvest	One-year fallow	Two-year fallow
Chromolaena odorata	0.23 ± 0.07[a]	4.8 ± 0.7	4.5 ± 1.4
Lygodium flexuosum	0.14 ± 0.03	0.6 ± 0.4	0.1 ± 0.05
Other broadleaf species	0.17 ± 0.03	0.5 ± 0.3	1.3 ± 0.9
Grasses	0.03 ± 0.02	0.1 ± 0.1	0.2 ± 0.1
Bamboo	0.24 ± 0.15	2.1 ± 1.7	4.0 ± 2.0
Tree species	0.51 ± 0.11	1.5 ± 0.9	5.3 ± 1.4
Total[b]	1.4 ± 0.13	9.8 ± 1.1	15.5 ± 1.9

[a]Mean + standard error. [b]Rice grain harvested and rice stems were 1.1 and 1.2 t ha^{-1}.
Source: Roder et al (1997b).

large plants, and no rooting from aboveground plant parts), it is much easier to control by hand weeding than species such as *Commelina* or *Lygodium flexuosum*. Plants growing from seeds have a comparatively slow initial growth phase and are less of a problem in the initial growth stage of the rice plant. The potential of *C. odorata* to expand rapidly and provide a protective cover in the early part of the fallow period is probably the single most important property making it a good fallow plant for the sloping fields prevailing in Laos. This fast expansion is made possible by the abundance of seed produced and its mobility. The seeds are dispersed by wind during April and May, and germination starts about the same time as the planting of the upland rice crop.

Although *C. odorata* is the most abundant weed species in upland fields in Laos, farmers regard it as a desirable fallow plant. When asked to list "good fallow plants" (or plants they like to have in their fallow fields), farmers widely favored *C. odorata* over any other species present (Roder et al 1995b, 2005). None of the respondents considered it as a bad fallow species. Farmers give various explanations for their preference of *C. odorata*, including its dominance under good soil conditions, the absence of negative effects on rice yield, it is relatively easy to control by hand weeding in the rice crop, and it has fast growth and large biomass production. Some of the plants listed as bad fallow plants, especially *Cratoxylon prunifolium* and *A. conyzoides,* are generally associated with poor rice yields. Farmers interviewed in Savannakhet Province in central Laos suggested that soil structure is better where *C. odorata* is dominant when compared with fields where bamboo is the dominant species (Keovilayvong et al 1991).

Weed and residue management strategies

Traditional upland field preparation involves burning of the slashed aboveground biomass, consisting of 4–20 t of dry matter per ha depending on the duration of the fallow period (Roder et al 1997b, 1998a). Increasing numbers of farmers have, of re-

Table 9. Effect of residue treatment on fresh weed biomass over the rice growing season (on-farm and on-station experiments, 1993-95).

Residue treatment	Weed biomass (fresh, g m^{-2})			
	1993 (on-farm)	1994 (on-farm)	1994 (on-station)	1995 (on-station)
Residue burned	430	830	220	491
Residue mulched	740	990	440	663

Source: Roder et al (1998a).

cent times, been planting a second or third rice crop before allowing the field to revert to fallow. Fields that have been cropped to rice in the previous year have relatively low aboveground biomass (approximately 1–3 t ha^{-1}), and field preparation without burning the residue is theoretically feasible. Retaining the residue as a mulch might be expected to improve soil moisture conservation and slow organic matter losses (Roder et al 1998a). With these expectations, several studies have been made to assess the effects of residue management, especially burning. These studies, undertaken over a range of environments and years, consistently showed that, compared with burning, residue mulching increased weed biomass and often reduced rice yields (Roder et al 1998a, Table 9). These studies confirmed that burning of residues not only makes land preparation easier for farmers but also offers a cheap method of weed control.

Other studies have shown that mulching with *C. odorata* or pigeon pea (*Cajanus cajan*) plant material up to amounts of 4 t of dry matter per ha did not reduce weed biomass (Roder 2001). *Arachis pintoi*, when used as a live mulch, had only a limited effect on weed biomass but strongly affected rice yield. In spite of the negative results from these various studies, it is expected that mulching may become an important strategy in evolving permanent rice production systems in the upland environment of Laos (Roder et al 1998b).

Improved fallow as a weed management strategy

Replacement of the fallow vegetation by fast-growing species, preferably nitrogen-fixing legumes, is a widely recommended technique for maintaining crop yields and suppressing weeds in slash-and-burn systems under reduced fallow periods (Roder 2001, Garrity 1993). Improved fallow systems have often been recommended as a strategy to reduce the impact of shorter fallow cycles on soil fertility, and to manage weeds (Roder 2001).

The potential of legumes to improve fallow vegetation under Lao conditions was recognized decades ago. Goubeaux (1930) listed 46 legume species tested for green manure. The presence of *Mimosa invisa*, a serious weed in some isolated upland areas, is an unpleasant testimony of those activities (Poilane 1952). Similarly, Chevalier (1952) and Poilane (1952) recommended *C. odorata* for fallow improvement in Lao PDR. The main species promoted by development agencies for fallow improvement over the past two decades have been *Leucaena leucocephala, Gliricidia sepium,* pigeon pea, and *Calliandra calothyrsus.* Little or no adoption of these species by farmers has been observed, probably because the technologies recommended were not appropriate or economical (Roder 1997).

In more recent research, increased attention has been given to the evaluation of species that have some fodder value to capitalize on the potential for increased livestock production by replacing fallow vegetation with fodder species (Phimphachanhvongsod et al 2005). The initial phase of the fallow period is currently used for grazing ruminants, but little forage is available because of the overwhelming dominance of unpalatable species such as *C. odorata.* Besides increasing the quantity of fodder, replacing the fallow vegetation with more palatable species may result in improved weed suppression through the interaction of fallow species and grazing animals. Furthermore, the activities of grazing animals should accelerate nutrient cycling and reduce the residue load (Roder 2001). Although grazing rotation systems may have high potential, only system components have been evaluated, such as species introduction and species establishment (Roder and Maniphone 1995), rather than the systems themselves.

Out of a wide range of fast-growing legumes tested in the 1990s (Roder 2001, Roder and Maniphone 1995), pigeon pea received special attention with activities focusing on collection and testing of local and introduced cultivars, establishment methods, rotation effects, residue management, and weed suppression (Roder et al 1998b). Of the legume species tested, only *Gliricidia sepium* (Photo 20.6) had a higher production of fallen litter and higher total biomass than *C. odorata* (Roder and Maniphone 1998).

The adoption of fallow management strategies and fallow species will depend largely on the farming systems currently evolving in the uplands of Laos. Pigeon pea, for example, is a very promising species but only if the seeds have a market or if the plant is used in a cut-and-carry system for ruminant or pig production. *L. leucocephala* has potential in a system where firewood has a market value. It can be expected that the improved fallow systems most likely to succeed will be systems that include grazing and that optimize nutrient and moisture management. The most promising species for such systems are *Stylosanthes guianensis, L. leucocephala,* and *Brachiaria* species. Caution needs to be exercised to avoid introducing species that have the potential to become new weed species for Laos and neighboring countries, as happened following the introduction of *Mimosa invisa.*

Other weed management strategies

Weed management strategies that have been tested in addition to residue management/mulching and improved fallow include the use of herbicides, various methods of cropping management, and tillage (Table 10). Herbicides tested had no effect on *L. flexuosum,* tree species, and woody perennials. Furthermore, chemicals with relatively good effect on *C. odorata* and other broadleaf species (2,4-D and propanil) were less effective than hand weeding (Roder et al 1995a). The application of glyphosate at 2.5 kg a.i. ha^{-1} eliminated the need for weeding before planting and reduced the weed biomass during the rice growing season. If planting can be done just before or im-

Table 10. Weed management strategies tested.

Strategy	Effect[a,b] W	L	E	RY	Adoption[b]	Limitations	References[c]
Residue management—mulching							
Residue burning	√√	√√	×	√√	√√√	C loss, not possible in systems with perennials	1, 2
Mulching residues	×××	×××	√	××		Lower rice yield	1, 2, 3, 4, 5
Mulching pigeon pea	×	×	√	√√		Market for pigeon pea	1, 4
Arachis live mulch	√	×	√	û		Lower rice yield	1
Improved fallow							
Manipulating species	√	×		√		No economic benefit	1, 3, 6
Grazed fallow	√			√	√	Requires livestock	1, 7
Cropping management							
Planting density of rice	√√	××	√	√×		Labor, reduces yield	1
Intercropping	√√	××	√	√×	√	Market, increased labor	1
Crop rotation	√	√×	√×	√	√	Market	1
Tillage	√	√×	××	√×		Erosion	3, 8
Rice varieties	√	√	√	√×		Yield, acceptance	3
Herbicides							
Per-plant glyphosate	√√	√√	×	√√		Cost, policies	1
Brachiaria and glyphosate	√√	√√	√√	√		Policies	5
Postemergence	√√	√√	√	√		Cost, policies	1

[a]W = reduce (√) or increase (×) weed biomass, L = reduce (√) or increase (×) labor input, E = reduce (√) or increase (×) soil loss by erosion, RY = increase (√) or reduce (×) rice yield. [b]Trend: one symbol (√ or ×) is some trend increasing; number of symbols is increasing trend. [c]1 = Roder (1995c), 2 = Roder et al (1998a), 3 = Fahrney (1999), 4 = Roder et al (1998b), 5 = Tivet et al (2004), 6 = Roder and Maniphone (1998), 7 = Roder (2001), 8 = De Rouw et al (2005).

mediately after glyphosate application, the first weeding after planting can be delayed substantially (Roder et al 1995c), thus reducing the labor requirement for weeding by 40–80 days ha^{-1} and reducing potential soil erosion losses. Similar reductions in labor inputs were reported by Tivet et al (2004) when testing glyphosate for the control of *Brachiaria ruziziensis* cover without slashing or burning.

Cropping strategies increasing the competitiveness of the rice crop, or combinations including other competitive crops, have the potential for reducing labor for weeding without the need for expensive chemicals that might also have potential to damage the environment. Various strategies have shown some effect on weeds, but they have several limitations, including the following:

- Hand weeding becomes more difficult (closer planting density, intercropping).
- Risk of lower rice yield or quality (planting density).
- Insufficient market for the product (pigeon pea, soybean, maize).

Invasive weed species

Changes in land use or other events and interventions, such as road construction leading to changes in the vegetation cover, often lead to colonization by invasive weed species. Laos has introduced appropriate legislation governing the movement (both import and export) of plant materials (Nhoyboukong and Khamphoukeo 2002). Yet, considering the long borders with neighboring countries, these regulations cannot prevent the movement of weed species across borders. Furthermore, a number of invasive plant species are already in the country. The most problematic introduced invasive weed species listed by Nhoyboukong and Khamphoukeo (2002) are *Mimosa invisa* and *M. pigra* in upland environments and *Echinochloa colona* and *E. crus-galli* in lowland environments. These latter two grass species are also listed among the eight most important grass weeds of rice in Asia (IRRI 2003).

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CHAPTER 21

The history of lowland rice variety improvement in Laos

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As recently as 1990, almost 98% of the area under rice cultivation in Laos, and about 97% of production, was from cropping activities associated with the annual wet season. The lowland environment accounted for about 72% of total production and the upland environment a further 25%. In 1990, only 12,000 ha were cropped to rice under irrigated conditions in the dry season. The Green Revolution of the 1970s and 1980s that brought about significant changes in the way rice was produced in most parts of Asia had little impact on rice production practices in Laos. In 1990, about 95% of the lowland wet-season crop was based on the use of traditional varieties, whereas, in the upland environment, 100% of production was based on the use of traditional varieties. It was not until after 1993, following the release of a small number of improved Lao glutinous varieties in the lowlands, that production practices started to change, initially with the replacement of many of the traditional varieties, and then more recently with increased inputs (mainly inorganic fertilizer) and increased mechanization of production (mainly land preparation and threshing).

The great diversity of the traditional rice germplasm base that existed in Laos until the mid-1990s is reflected in the results of germplasm-collecting missions that were undertaken from 1995 to 2000, in which more than 13,000 samples of rice were collected for conservation and use (Appa Rao et al 2002). Although without associated DNA analysis it is difficult to ascertain the number of distinct varieties in the collection, it is believed to number at least 3,000, making Laos second only to India in the number of varieties that are currently stored in the International Rice Germplasm Bank at the International Rice Research Institute in the Philippines.

Following the release of several improved Lao glutinous varieties in 1993, and their introduction to farmers throughout much of the main lowland rice-growing area in the Mekong River Valley, replacement of much of the traditional germplasm in this region of Laos was rapid. The basis for the adoption of these improved varieties by farmers was a combination of their greater yield potential relative to the traditional varieties, even under conditions of minimum inputs, and their greater responsiveness to fertilizer when it was applied. By the early 2000s, from 70% to 80% of the wet-season lowland rice area in many provinces in the Mekong River Valley was being planted to improved varieties. The adoption of improved varieties in the wet-season lowland areas in the north of the country was less rapid, as the varieties released during the 1990s were less well adapted to the specific growing conditions of northern Laos, where lower temperatures prevail, particularly near the end of the wet season as well as during the dry season. In the rainfed upland environment, by the early 2000s little had changed, with almost 100% of production still being based on the planting of traditional upland varieties. Most upland variety evaluation work has focused on identifying superior varieties within the traditional germplasm base.

Although changes from traditional cultivation practices in Laos have occurred only relatively recently, including the adoption of improved varieties in the lowland environment, there were some past attempts to develop improved rice varieties for use in the country. This chapter provides a history of the work that has been undertaken for developing improved rice varieties for the lowland environment of Laos.

The early history of lowland rice variety improvement

Before 1975

Agricultural research in Laos in a conventional context began in 1913 with the establishment of two small research stations by the French administrators of that time. One of these early stations was at km 42 on the road between the provincial capital of Pakse and Paksong District on the Bolevens Plateau in Champassak Province in southern Laos. This southern station was used primarily for early research on tree fruit and coffee for the Bolevens Plateau area, an elevated area of very rich volcanic soil that subsequently developed a reputation for the quality of the coffee it continues to produce. The second research station was established in the northeastern province of Xieng Khouang; its research focus was tree fruit and tea. Despite the importance of rice to the people of Laos at that time, there was almost no research interest in the crop. The first recorded instance of an attempt to introduce alternative varieties of rice was by a member of the Luang Prabang–based royal family of Laos, Prince Maha Oupalath Phetsarath, who, in the late 1940s, introduced a number of rice varieties from Vietnam for evaluation on a small research farm under the patronage of the royal family, on the outskirts of Luang Prabang. However, it is acknowledged that, at that time, there would have been regular cross-border germplasm exchange among farmers in provinces in the areas of Laos bordering Vietnam, China, and Thailand. Evidence of this is seen in the popular aromatic variety *Khao kai noi* (small chicken rice), which is currently grown in the provinces of Houaphanh and Xieng Khouang. This variety is believed to have originated from the nearby Vietnamese province of Sou-la, from where it was introduced to the Lao province of Houaphanh, immediately adjacent to Vietnam; later it was also introduced to Xieng Khouang, farther to the south. Vietnamese traders currently purchase this variety from these provinces of Laos.

The first research station to be established in Laos with a focus on rice was the Salakham Rice Research Station (SRRS), which was established in Hatsaiphong District of Vientiane Municipality in 1955. In 1972, the British government provided financial support for the construction of research laboratories for soil, entomology, and plant pathology research, together with training and administrative facilities, at this station. The focus of almost all the early research work coordinated through this station was on variety improvement. During the mid- to late 1960s, Israel provided some assistance through the Mekong Committee Secretariat for the improvement of rice varieties grown in Laos, with the introduction of several lowland varieties. In this early period, until the change of government in 1975, small amounts of assistance for rice-related research were also provided by France, the United States, and Japan. The early variety improvement activities focused mainly on germplasm collection, and the introduction and evaluation of promising lines and recommended varieties from the International Rice Research Institute (IRRI) in the Philippines and the national rice research programs of Thailand and the Philippines. The research activities of the SRRS were supported by some on-station and on-farm research (primarily on variety evaluation) in the north (Sayabouly and Luang Prabang provinces), the central region (Vientiane and Savannakhet provinces), and the south (Champassak Province). In 1964, the first high-yielding variety (HYV), the nonglutinous variety IR8 from IRRI in the Philippines, was introduced to several of these provinces; IR8 was then followed by IR253-100 (glutinous) and IR848-120 (glutinous), also from IRRI; C4-63-1 (nonglutinous) from the Philippines; and Niaw Sanpatong (glutinous) from Thailand. One aromatic variety, *Do-nang-nuan* (early-maturing, soft lady), was selected from the traditional germplasm collection, multiplied, and distributed to farmers. Some of these early introductions were distributed through USAID-sponsored agricultural development projects, as well as through other bilateral development projects. Recent collection missions have revealed that some of these early introductions are still being used on a limited scale in different parts of Laos, with the varieties often being identified by names that relate to the programs that initially introduced them, for example, *Khao Chao America* (American nonglutinous rice) and *Khao Philippines* (Philippines rice). Some varieties from these early introductions, which were adopted by farmers, carried names that reflected their country, including *Khao Cheen* (Chinese rice), *Khao Viet* (Vietnamese rice), *Khao Kampuchia* (Cambodian rice), *Khao hom phama* (aromatic Myanmar rice), and *Khao Hom Thai* (aromatic Thai rice).

The majority of the early variety introductions to Laos had nonglutinous endosperm. On account of the national preference for the consumption of glutinous rice, most of these introductions, if grown at all, were grown only on a very limited scale. Some seed multiplication of selected glutinous varieties started in 1964. Three traditional varieties, *Do-nang-nuan*, *Do-lay*, and *Keaw-lay*, were the first varieties distributed in the lowlands through the seed multiplication program. Of these, *Do-nang-nuan*, an aromatic photoperiod-sensitive variety, was the most popular. In 1971, *Khao Sanpatong*, a photoperiod-sensitive traditional variety from Thailand; IR253-100, an IRRI improved variety, both of which were introduced under a program of assistance from Israel in 1967; together with the Lao traditional variety *Khao do-hom* (early maturing, aromatic) were also included in the multiplication and distribution program near Vientiane. However, relatively few farmers actually started growing these varieties.

1975-90

In the late 1970s and 1980s, several other glutinous varieties were introduced to the country and, after evaluation, were adopted and grown on a reasonably large scale in lowland areas in the Mekong River Valley. Among these were three from IRRI in the Philippines, IR848-120, IR253-100, and IR789-98, and three from Thailand, RD6, RD8, and RD10. Variety RD10 was first introduced unofficially to a village (Sithan) in Hatsaiphong District of Vientiane Municipality and was then grown through one of the agricultural cooperatives that were established in this area in the early 1980s (Nong Khamsene Cooperative). It was subsequently distributed and promoted elsewhere in the Mekong River Valley through the Salakham Rice Research Center. In some parts of the country, RD10 became known as RD16; it is believed that the RD16 designation probably originated from indistinct labeling in its early distribution. There was later further official introduction of RD10 from Thailand, but the RD16 identity was retained by farmers in many areas. In the late 1990s, IRRI variety IR253-100 and the three Thai varieties (RD6, RD8, and RD10) were still being grown in some provinces. In 2005, these three Thai varieties were still being included among variety recommendations for the lowland environment in the Mekong River Valley; RD6 was being recommended for the rainfed environment in the central and southern agricultural regions, RD8 for the rainfed environment in the upper central region, and RD10 nationwide for both the irrigated and rainfed environments. The popularity of RD6 has been on account of its aromatic character and excellent eating quality (RD6 is based on selection within a radiation-induced glutinous mutation of the very popular nonglutinous jasmine rice *Khao dok mali* of Thailand). RD8 is sometimes grown on lower terraces under rainfed conditions (it is later maturing than RD6). It has a sturdy plant type that is not susceptible to lodging, it is large seeded, and it has good eating quality. RD10 is highly regarded on account of its good eating quality and wide adaptability (it is suited to the irrigated environment, is slightly earlier maturing than RD6, and does not need high levels of inputs to achieve reasonable yield). Between 1979 and 1989, several Vietnamese improved nonglutinous varieties were also introduced for evaluation, the most notable of which were the aromatic japonica varieties VN72 and OM80. However, once again they were grown only on a limited scale because of the national preference for the consumption of glutinous rice. Another Vietnamese nonglutinous variety introduced in the late 1970s, which was grown in parts of the Vientiane Plain, was CR203 (a variety based on the IRRI line IR8423-132-6-2-2). CR203 was noted for its high yield potential. By the late 1980s and early 1990s, CR203 had declined in popularity because of its poor eating quality. However, in the mid-1990s it regained some degree of popularity, particularly in the Vientiane Plain, because of demand for its specialized use in the production of noodles and beer.

From 1975 to 1990, considerable attention was also paid to the evaluation of Lao traditional varieties. Some of the more popular traditional varieties grown in the lowland environment are listed in Table 1. Using some of these popular traditional varieties, several crosses and selections were made at the Salakham Rice Research Center near Vientiane, with their ultimate release as named improved varieties. The first crosses were between the Thai traditional variety Sanpatong and IRRI variety IR848-

Table 1. Popular traditional rice varieties in the lowland environment of Laos during the late 1970s and 1980s.

Province	Variety name[a]	Plant type[b]	Endosperm type	Flowering date	Variety characteristics
Vientiane Province	Khitom hang nak	T	G	Mid-Oct	–
	Hom thong	T	G	End Sept-early Oct	Slightly aromatic
Vientiane Municipality	Dok tiou	I	G	End Sept-early Oct	Slightly aromatic, suited to soils of low fertility, susceptible to leaf blast
	Khao dok mai	T	G	End Oct	Slightly aromatic, good eating and grain quality
	Do deng	T	G	End Sept-early Oct	Strong culms, good eating and grain quality
	Chao deng	T	NG	Early Oct	Broad adaptability, good processing quality
	Chao peuk deng	T	NG	Late Oct	Good processing quality
Khammouane	Mak yom	T	G	Mid-Oct	Good eating quality
	Phouang malai	T	G	Mid-Oct	Sturdy culms
	Hang hee	T	G	Early Oct	–
	Sanpatong do	I	G	End Sept	Adapted to poor soils
	E-ang	T	G	End Sept	Adapted to poor soils
Savannakhet	Pakheng khao	T	G	Mid-Oct	Heavy grain, susceptible to leaf blast
	Hom-nang-nouane	T	G	Mid-Oct	Slightly aromatic, susceptible to leaf blast
	Ee phone	T	G	Early Oct	Wide adaptability, susceptible to leaf blast
	Nang ang	T	G	Mid-Sept	Wide adaptability, salinity tolerant
	Nang nee	T	G	Early Oct	Salinity tolerant
Saravane	Intob hom	T	G	Early Oct	–
Champassak	Mak Fai	T	G	Early Oct	Submergence tolerant
	Mak hing	T	G	Mid-Oct	Drought tolerant
	Mak kham do	T	G	Mid-Oct	Adapted to poor soils
	Ee khao ngan	T	G	End Oct	Sturdy culms
	Dovieng	T	G	Early Oct	Wide adaptability

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Table 1 continued.

Province	Variety name[a]	Plant type[b]	Endosperm type	Flowering date	Variety characteristics
Phongsaly	Kon kam	T	G	Early Oct	–
	Lai	T	G	Early Oct	–
Houaphanh	Kai noi	I	G	End Sept-early Oct	Aromatic, popular in northern provinces
Xieng Khouang	Khao la	T	G	Early Sept	Slightly aromatic
	Chao na	T	NG	Early Sept	Good processing quality
Oudomxay	Meuang nga	T	G	Mid-Oct	Blast and gall midge resistant
	Takiet	T	G	End Sept	Blast resistant
	Chao meuang sing	T	NG	End Sept	Good processing quality
Luang Namtha	Meuy (Hok)	T	G	End Oct	–
	Pheuang leuang	T	G	End Oct	–
Luang Prabang	Mae to	T	G	End Oct	Resistant to gall midge
	Do lai	T	G	End Oct	–
	Leua gnia	T	G	End Oct	Big panicles and sturdy culms
Sayabouly	Vang thong noi	T	G	End Oct	–
	Mae hang tob euak	T	G	Mid-Oct	Susceptible to blast

[a]Most names of traditional varieties commence with the word Khao (= rice). [b]I = intermediate plant type, T = tall plant type, G = glutinous, NG = nonglutinous.

Table 2. Varieties introduced in 1975 to 1985 that were recommended for seed multiplication and release.

Country/source	Variety/line	Endosperm type	Year released
IRRI	IR22	Nonglutinous	1978
	IR24	Nonglutinous	1978
	IR29	Glutinous	1977
	IR253-100	Glutinous	1977
	IR36	Nonglutinous	1977
	IR38	Nonglutinous	1977
	IR2823-103	Nonglutinous	1964
	IR789-98	Glutinous	1979
Vietnam	NN75-1	Nonglutinous	1984
	U9	Nonglutinous	1984
	CR203	Nonglutinous	1984
Thailand[a]	RD6	Glutinous	Before 1975
	RD10 (RD16)[b]	Glutinous	1980
	RD8	Glutinous	1984
Indonesia	B1014bpN18-1-4	Nonglutinous	1981

[a]These varieties had widespread adoption in the central and southern regions of Laos. [b]RD10 became known as RD16 in some areas.
Source: Hatsadong (personal communication).

120; the objective of these crosses was to produce varieties with the yield potential of IR848-120, while having the grain quality of Sanpatong. Several Salakham lines were established but only one, *Salakahm 1* (SLK1), demonstrated a yield potential comparable with that of IR848-120. A second set of crosses was based on parental lines of *Mae-hang* (a traditional variety with large panicles) and IR2823-103 (a nonglutinous line introduced from IRRI). The crosses aimed at producing high-yielding glutinous lines with a desired plant type and resistance to brown planthopper. Many promising glutinous fixed lines were established by 1988; however, most of these lines did not have the yield potential of IR2823-103. A third series of crosses was based on the parental lines *Ea-khao* ("white lady"—a traditional glutinous variety) and IR2823-103; however, no fixed lines were established from the progeny of these crosses.

From among the introduced varieties that were evaluated by the SRRS during 1975-85, several of them were recommended as promising lines and varieties (Table 2). From 1975 to 1990, about 1,000 t of seed of recommended varieties was produced by the Salakham Rice Research Station (Table 3). The characteristics of the promising varieties released by the SRRS before 1975, and then subsequently during 1975 to 1985, are summarized in Table 4.

Apart from the selections from among the introduced material, and promising lines from selected crosses, several Lao traditional varieties were identified as being well suited to different parts of Laos. These varieties and the areas for which they were recommended are summarized in Table 5. All were photoperiod-sensitive and therefore recommended only for wet-season lowland cropping.

Table 3. Quantity of seed of recommended varieties released by the Salakham Rice Research Station in 1975-90.

Designation	Source	Year released	Endosperm type	Quantity of seed (kg)
Sanpatong	Thailand	1964	Glutinous	46,615
Do nang nouane	Laos	1964	Glutinous	5,530
Deng home	Laos	1978	Glutinous	8,700
IR848-120	IRRI	1964	Glutinous	35,940
IR253-100	IRRI	1964	Glutinous	121,410
IR789-98	IRRI	1979	Glutinous	32,830
IR29	IRRI	1977	Glutinous	1,000
RD16(RD10)	Thailand	1980	Glutinous	162,000
RD8	IRRI	1984	Glutinous	9,200
SLK1-27	Laos	1984	Glutinous	520
SLK1-11	Laos	1984	Glutinous	450
SLK1-3-2	Laos	1984	Glutinous	1,535
SLK1-7-2	Laos	1984	Glutinous	3,740
KDML105	Thailand	1977	Nonglutinous	2,000
IR8	IRRI	1964	Nonglutinous	5,300
IR22	IRRI	1978	Nonglutinous	2,830
C4-63-1	Philippines	1964	Nonglutinous	44,080
IR36 and IR38	IRRI	1977	Nonglutinous	400,000
IR2823-103	IRRI	1964	Nonglutinous	12,080
B1014-bpN18-1-4	Indonesia	1981	Nonglutinous	7,840
NN75-1	Vietnam	1984	Nonglutinous	1,740
IR42	IRRI	1985	Nonglutinous	90,000
Total				995,340

Source: Hatsadong (1986).

Expansion of the seed multiplication and rice research network

In 1985, a new agricultural research center was established near the village of Naphok in Saythany District of Vientiane Municipality. This center was later (after 1990) to become the key center for the coordination of most research relating to the rice environments of Laos. Three other smaller stations were established with European Commission support through the Mekong Secretariat in the 1980s as rice seed multiplication and processing stations: Hat Dok Keo Station about 15 km south of the capital Vientiane, Thasano Station in Khanthabouly District of Savannakhet, and Phone Ngam Station in Pakse District of Champassak. Seed-processing facilities were established at all three stations. In the 1990s, the latter two stations also became important regional rice research centers while also continuing their rice seed multiplication roles, whereas the focus of activities of the Hat Dok Keo Station moved to horticultural research.

Table 4. Characteristics of varieties released by the Salakham Rice Research Station before 1986.

Variety designation	Endosperm type	Growth duration (d)	Yield (t ha^{-1})	Characteristics[a]
IR253-100	G	130–150	3–6	Sturdy culms, big grain, drought tolerance, wide adaptability, acceptable eating quality, low threshing ability Susceptible to bacterial leaf blight (BLB), narrow brown leafspot (NBLS), false smut, stem borer (STB), brown planthopper (BPH)
IR848-120	G	130–140	3–7	Sturdy culms, soft rice, wide adaptability, high threshing ability, low milling quality Susceptible to low temperature, BLB, NBLS, STB, BPH
IR789-98	G	130–140	3–6	Long grain and slender, good milling quality, narrow adaptability, delayed flowering Susceptible to NBLS, bakanae, and yellow-orange leaf diseases, BPH, and STB
IR848-44	G	130–140	3–5	Long grain and slender, intermediate response to fertilizer, wide adaptability, good eating quality Susceptible to NBLS and rice bug, susceptible to drought
RD6	G	22–25 October	3–4	Photoperiod sensitive, tall plant type, aromatic, good eating and milling qualities, moderate resistance to blast and brown leafspot, suitable for direct seeding, suited to middle terraces of central and southern agricultural regions Susceptible to BLB, BPH, GLH; tendency to lodge

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Table 4 continued.

Variety designation	Endosperm type	Growth duration (d)	Yield (t ha^{-1})	Characteristics[a]
RD8	G	24–26 October	3–4	Photoperiod sensitive, tall plant type, large seeded, good milling and eating qualities, moderate resistance to blast and brown leafspot, suited to middle terraces of central and southern agricultural regions, suitable for direct seeding Susceptible to BLB, BPH, GLH, GM; tendency to lodge
RD10 (RD16)	G	130–135	4–5	Relatively high yielding, long grain and slender grain, good milling and eating qualities, broad adaptability and can be grown in both wet and dry seasons, intermediate response to fertilizer, susceptible to flooding Susceptible to BLB, leaf blast, BPH, stem borer, and GM
KDML 105	NG	17–20 October	2–3	Photoperiod sensitive, tall plant type, aromatic, good eating and milling qualities, tolerant of saline and acid soils, resistant to root-knot nematode, suited to central and southern agricultural regions; suitable for direct seeding Susceptible to leaf blast, neck blast, BLB, orange leaf virus, grassy stunt virus, BPH, GLH, and stem borer
CR203	NG	125–130	4–6	Photoperiod nonsensitive and high yielding, suited to noodle and beer production, broad adaptability and can be grown in both wet season and dry season, suited to direct seeding, resistant to BPH, leaf blast, BLB Moderate milling and eating quality

Continued on next page

Table 4 continued.

Variety designation	Endosperm type	Growth duration (d)	Yield (t ha^{-1})	Characteristics[a]
SLK1-7-2	G	135–140	3–5	Good milling and eating quality, wide adaptability, resistance to BLB Susceptible to drought and BPH
IR8	NG	135–145	3–6	Wide adaptability, high response to fertilizer, poor eating quality Susceptible to BLB, BPH, and STB
IR22	NG	130–140	3–5	Uniform plant, good eating quality, wide adaptability Susceptible to brown leafspot, green leaf hopper, gall midge, and drought
IR24	NG	130–140	3–6	Sturdy culms, short growth maturity, good eating quality, tolerance of drought, wide adaptability, good performance under late transplanting Susceptible to yellow-orange leaf disease and stem borer
C4-63-1	NG	130–135	3–6	Intermediate plant type, good milling and eating quality, susceptible to low temperature, wide adaptability Susceptible to NBLS
IR2823-103	NG	125–130	3.5–7	Sturdy culms, erect leaves, short growth duration, wide adaptability, resistance to BPH Susceptible to adverse soil, susceptible to BLB and stem borer
IR36	NG	120–125	3–5	Wide adaptability, short growth duration, good milling quality, resistant to BPH Susceptible to drought
IR42	NG	135–145	3–5	Wide adaptability, resistance to major pests and diseases, high response to fertilizer Poor milling quality
B1014-bpN-18-1-4	NG	130–135	3–5	Wide adaptability, resistance to BPH and stem borer Poor milling quality

[a]G = glutinous, NG = nonglutinous, BPH = brown planthopper, STB = stem borer, NBLS = narrow brown leafspot, GLH = green leafhopper, GM = gall midge.
Source: Hatsadong (1986).

Table 5. Traditional varieties recommended for the wet-season lowland environment during the 1980s.

Region/province	Varieties recommended	Variety characteristics
Central region(Vientiane Municipality and Vientiane Province)	*Chao deng* (nonglutinous, red rice)	Nonglutinous, broad adaptability, and easy processing
	Chao louk pa (nonglutinous, fish fingerling rice)	Nonglutinous, suitable for swampy areas, good for noodle processing
	Khao dok mai (white flower)	Glutinous, slightly aromatic, good grain and eating quality
Southern region(Champassak Province)	*Ee khao ngan* (young lady, late-maturing rice)	Glutinous, sturdy culms
	Ee loup (young lady, drooping flag-leaf rice)	Glutinous, suited to middle and lower terraces, good grain and eating quality
	Mak phai khao (white sour berry rice)	Glutinous, suited to middle and lower terraces, submergence tolerant
	Chao lep nok (nonglutinous, bird claw rice)	Nonglutinous, adapted to acidic soils and drought-prone areas, good for noodle processing
Northern region(provinces of Luang Prabang and Sayabouly)	*Khao mae* to (mother of "To" rice)	Glutinous, gall midge resistant
	Khao Nang dom (Miss Dom rice)	Glutinous, good eating quality
		Glutinous, blast resistant, good eating quality
Northeastern region (provinces of Xieng Khouang and Houaphanh)	*Khao khai* (hairy rice)	Glutinous, aromatic
	Khao kai noi (small chicken rice)	

Adoption of improved rice varieties in lowland rice-growing areas in the late 1980s

Despite the work that had been done on variety improvement for the lowland environment from the mid-1960s through the 1980s, and the establishment of a rice seed multiplication program in the mid-1980s with EEC support, in 1990 the majority of the lowland rice-growing area of Laos was still being planted to traditional rice varieties. There were several reasons for this.

1. The lack of a developed extension service meant that seed of varieties identified as being suitable for the lowlands of Laos could not be obtained by the majority of Lao farmers. Farmers were more likely to change varieties based on farmer-to-farmer seed exchange. Hence, in areas of central and southern Laos, seed of the Thai varieties being used was often obtained by seed exchange across the Mekong River, rather than through the extension service. There was similar farmer-to-farmer seed exchange for lowland varieties involving China and Vietnam in the north of the country. The overall level of adoption of varieties introduced in this manner in the north of the country was generally much less than in the central and southern regions.

2. With glutinous rice being preferred for consumption by the majority of the Lao population, there was relatively little interest in the nonglutinous varieties that were introduced. An exception to this was the Vietnamese nonglutinous variety CR203, which, in addition to giving a high yield, was suited to noodle production, and it continued to be cultivated through the 1990s mainly for this use.
3. Rice production until the early 1990s continued to be based on a system of minimum inputs apart from family labor. In an environment where soil nutrient deficiencies were widespread and often acute (Schiller et al 1998, Linquist et al 1999) and where there was very little fertilizer use, the traditional varieties were often better adapted to Lao growing conditions.
4. Most of the improved varieties were recommended for lowland areas in the Mekong River Valley. Often, these varieties did not perform well when grown in more northern areas of the country, where lower temperatures generally prevail, particularly at the end of the wet season and during the dry season.

In the early 1990s, less than 10% of the main wet-season lowland rice-growing area in the Mekong River Valley was being planted to introduced or improved varieties. The main improved varieties being grown were RD6, RD10, and to a lesser extent RD6, all from Thailand (there were also small areas planted to improved glutinous varieties that had originated from IRRI but that were being grown under names that no longer reflected their source). The Vietnamese nonglutinous variety CR203 was still being grown on a limited scale for use in beer and noodle production. In the northern agricultural region, almost 100% of the wet-season lowland area was being planted to traditional varieties.

Recent developments in the lowland variety improvement program

1991-2004

In collaboration with IRRI, and with the support of funding provided by the government of Switzerland, in 1991 a program started to revitalize the rice research activities and capability of Laos. Coordination of the rice research program was moved from the Salakham Rice Research Station (which then served as a focus of extension-related activities) to the National Agricultural Research Center (NARC) in Saythany District of Vientiane Municipality. Infrastructure (laboratories and administrative facilities) at NARC was initially provided by FAO from 1979 to 1983. Additional training and administrative and research facilities were provided with Swiss support through the 1990s. Between 1992 and 1995, several other research stations were upgraded to become important regional research centers within a national rice research network. These key regional centers were Phone Ngam Station in Pakse District of Champassak, Thasano Station in Khanthabouly District of Savannakhet, 30 Ha Station in Phiang District of Sayabouly, Luang Namtha Research Station in Luang Namthat District of Luang Namtha, and Houay Khot Research Station in Xieng Nguen District of Luang Prabang. Smaller facilities were also established in several other provinces. All these regional centers, with the exception of the Houay Khot Station in Luang Prabang (where the research focus was mainly on the upland rice environment), played an important role in the national rice research program through the 1990s and early 2000s. Rice research also became a national priority in an effort to achieve rice self-sufficiency for the country (in 1990, the annual rice deficit was probably about 10% of the national requirement, although with significant regional differences in the level of the deficit). A major focus of the research initiatives at that time was the development of improved glutinous varieties for both the rainfed lowland and irrigated environments. However, the greatest emphasis and greatest impact have been in the rainfed lowland environment. Concurrent research programs also started on other aspects of production. The major components of the varietal improvement program that started in the early 1990s were the

- Selection and evaluation of lines based on crosses obtained from the IRRI, Thai-IRRI, and Thai breeding programs, and full participation in the IRRI shuttle breeding program.
- Introduction and evaluation of varieties and promising lines from other national rice research programs.
- Introduction and evaluation of INGER (International Network for Genetic Evaluation of Rice) material.
- Crossing of breeding lines within Laos, and selection of progeny for adaptation to Lao growing conditions.
- Evaluation and selection from among traditional varieties collected within Laos.

Apart from the broad breeding and variety improvement objectives of yield improvement and resistance to specific pests and diseases, other specific objectives within the variety improvement program have been the

- Identification of varieties suited to the drought-prone areas of central and southern Laos.
- Identification of varieties suitable for direct seeding in the rainfed lowland environment.
- Identification of varieties with low-temperature adaptation in the wet-season lowland and dry-season irrigated environments of northern Laos.
- Development of a database for the overall breeding program for Laos and the digitization of data for genetic analysis of breeding experiments.
- Introduction of multilocation trials for efficient selection of varieties with broad adaptability, as well as location-specific varieties.

These last five objectives have been given increased focus since 2000 in collaborative research programs supported by the Australian Center for International Agricultural Research (ACIAR) and The Rockefeller Foundation.

Lowland varieties released from 1990 to 2005

The variety improvement program of the early 1990s focused on the development of improved varieties for the main lowland rice-growing area in the Mekong River Valley. Further, the main initial interest was on the development of varieties for the wet-season rainfed lowland environment, rather than the dry-season irrigated environment. However, as the majority of the varieties released were photoperiod nonsensitive, many were also suited to cropping in the dry-season irrigated environment. In addition, as the primary objective of the early rice research program was the achievement of rice self-sufficiency for the country, and as the majority of the population preferred glutinous rice for consumption, the variety improvement program of the 1990s focused on developing improved glutinous varieties.

Naming of varieties

As with the naming of varieties used in the 1970s and 1980s, in which Salakham (SLK) was the prefix used to designate a new variety, the system of naming of varieties developed in the 1990s and later was one that reflected the name of the research station where the breeding lines were identified and developed. The names used were

Thadokkham (TDK)—the location of the main research center responsible for coordinating the activities of the national rice research program (Naphok Agricultural Research Center), in Thadokkham village in Saythany District of Vientiane Municipality.

Phone Ngam (PNG)—the name of the southernmost lowland rice research and seed multiplication center in Pakse District of Champassak.

Thasano (TSN)—the name of the lowland rice research and seed multiplication center in Khanthabouly District of Savannakhet in the lower central region of Laos.

Namthane (NTN)—the location of the 30-ha Rice Research and Seed Multiplication Center in Phiang District of Sayabouly in the lower northern region of Laos.

Varieties released

A total of 17 improved glutinous varieties were released in 1993 to 2005: 7 TDK varieties, 5 PNG varieties, 4 TSN varieties, and 1 NTN variety. Table 6 summarizes the distribution of the releases. The main characteristics of each of the varieties, together with the background of their parentage, are summarized in Table 7. All were glutinous varieties, and all but two (PNG2 and TDK4) are photoperiod nonsensitive, and hence potentially suitable for evaluation for the dry-season cropping regime as well as the wet season.

Some of these varieties released after 1993 are no longer being recommended. For example, following release, PNG2 was found to be susceptible to neck blast (and also leaf blast, brown planthopper, and green leafhopper) and is no longer being recommended or distributed to farmers. Variety TDK7, which was released in 2003, was also subsequently found to be very susceptible to neck blast and is also no longer being recommended to farmers. Another early release, variety PNG1, although also

Table 6. Release of new improved glutinous varieties from 1993 to 2005.

Year	Varieties released	Total released
1993	TDK1, TDK2, PNG1	3
1995	PNG2	1
1997	TDK3	1
1998	TDK4, TSN1, NTN1	3
2000	TDK5	1
2003	TDK6, TDK7	2
2004	TSN2, TSN3, TSN4	3
2005	PNG3, PNG5, PNG6	3
Total		17

susceptible to the same disease, is still widely accepted by farmers on account of its adaptability to poor soils and relatively short maturity.

Traditional varieties recommended during the 1990s and early 2000s

From 1970 to 1990, collecting missions supported by USAID, Russia, Japan, and other agencies collected more than 3,000 samples of cultivated traditional rice (Inthapanya et al 1995). Most of the samples in these collections were glutinous varieties. However, on account of a lack of appropriate storage facilities in the country, most of this germplasm collection was lost. From 1991 to 1994, a further 1,000 samples were collected, mainly from the northern provinces of the country, in a joint collecting program of IRRI and the Lao Ministry of Agriculture and Forestry (MAF). Unfortunately, the passport data for much of the collection were inadequate to allow the collection to be used. A much more comprehensive collection was made in 1995 to 2000. In a collaborative program between IRRI and MAF, supported by the Swiss government, 13,192 samples of cultivated rice and 237 samples of six wild rice species were collected. Much of the germplasm in this collection is unique to Laos and represents a range of diversity. Although these collections have undergone only preliminary evaluation, some varieties have already been identified as having unique genetic traits and are being recommended in some lowland areas (Table 8). Some are also starting to be used as parental material in the ongoing variety improvement program. The component of this collection that came from the upland environment (about 56%) is being evaluated to identify varieties with broad adaptability to that environment for wide distribution.

Future emphasis of the variety improvement program

By 2005, the variety improvement program had developed specific variety recommendations for the main lowland rice-growing areas (both rainfed and irrigated) of Laos, the Mekong River Valley. There had been a high level of farmer acceptance and adoption of the improved varieties developed and distributed during the 1990s,

Table 7. Improved rice varieties released between 1993 and 2005 for the lowland environment.

Year released	Variety name	Origin	Endosperm type	Growth duration (days)	Characteristics[a]
1993	Thadokkham 1 (TDK1)	Thai-IRRI cross	G	135–140	High-yielding variety (HYV), photoperiod nonsensitive (PNS), can be grown in both wet and dry season, resistance to BPH, moderate resistance to Bl and BLB, high response to nitrogen, wide adaptability Susceptible to neck blast, bakanae disease, and GLH; poor milling quality in dry season
1993	Thadokkham 2 (TDK2)	Thai cross	G	135–140	HYV and PNS can be grown in both wet and dry season, good eating quality, moderate resistance to Bl and BLB Susceptible to BPH and GLH
1993	Phone Ngam 1 (PNG1)	Thai-IRRI cross	G	125–130	HYV and PNS, suitable to wet and dry season, good eating and milling quality; good adaptability to drought-prone areas of central Lao; resistance to GLH and Bl; moderate resistance to BLB Susceptible to neck blast and BPH
1995	Phone Ngam 2 (PNG2)	Thai-IRRI cross	G	Mid-October flowering	Photoperiod-sensitive variety, tall plant type, good milling and eating quality, good adaptability to drought-prone areas of central and southern regions Susceptible to neck blast, leaf blast, BPH, and GLH

Continued on next page

Table 7 continued.

Year released	Variety name	Origin	Endosperm type	Growth duration (days)	Characteristics[a]
1997	Thadokkham 3 (TDK3)	Vietnam	G	130–135	HYV and PNS can be grown in both wet and dry season, good eating quality, moderate resistance to Bl, good resistance to BLB, good milling quality in dry season Susceptible to BPH, gall midge, and bakanae disease
1998	Thadokkham 4 (TDK4)	Thai-IRRI cross	G	Mid-October flowering	Photoperiod-sensitive variety, intermediate plant type, good milling and eating quality, resistance to BL and BLB, moderate resistance to BPH, suitable for fertile soils Susceptible to acidic soils, GLH, and gall midge
1998	Thasano 1 (TSN1)	Thai-IRRI cross	G	140–145	HYV and PNS, suitable for wet season, good eating and quality milling quality, moderate resistance to Bl and BLB, tolerance of acidic soils Moderately susceptible to BPH, GLH, and GM; not suitable for dry season
1998	Namtane 1 (NTN1)	Thai-IRRI cross	G	130–135	HYV and PNS, can be grown in both wet and dry season, good eating quality, good milling quality in the dry season, moderate resistance to Bl, good adaptability in drought-prone areas of central and southern regions Moderately susceptible to BLB, BPH, and GLH

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Table 7 continued.

Year released	Variety name	Origin	Endosperm type	Growth duration (days)	Characteristics[a]
2000	Thadokkham 5 (TDK5)	Lao cross	G	125–130	HYV and PNS, short growth duration, can be grown in both wet and dry season, good eating quality, good milling quality in dry season, moderate resistance to Bl and BLB, good adaptability to high elevation in northern Laos Moderately susceptible to BPH and GLH, easy to shatter
2003	Thadokkham 6 (TDK6)	IRRI cross	G	135–140	HYV and PNS, suitable for wet and dry season, good eating quality, good milling quality in dry season, moderate resistance to Bl and BLB, good adaptability to high elevation in northern Laos Moderately susceptible to neck blast, BPH, GLH, and GM
2003	(Thadokkham 7 (TDK7)	IRRI cross	G	135–140	HYV and PNS, suitable for wet and dry season, good eating quality, good milling quality in dry season, moderate resistance to Bl and BLB, tolerance of acidic soils Very susceptible to neck blast, moderate susceptibility to BPH, GLH, and GM
2004	Thasano 2 (TSN2)	Lao cross	G	130–135	HYV and PNS, suitable for wet season, good eating and milling quality, moderate resistance to Bl and BLB, tolerance of drought Susceptible to BPH, GLH, and GM

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Table 7 continued.

Year released	Variety name	Origin	Endosperm type	Growth duration (days)	Characteristics[a]
2004	Thasano 3 (TSN3)	Lao cross	G	135–140	HYV and PNS, suitable for wet and dry season, good eating and milling quality, resistance to BLB Susceptible to Bl, BPH, GLH, and GM
2004	Thasano 4 (TSN4)	Lao cross	G	125–130	HYV and PNS, suitable for wet and dry season, good eating and milling quality, drought tolerance Susceptible to Bl, BLB, BPH, GLH, and GM
2005	Phone Ngam 3 (PNG3)	IRRI cross	G	130–135	HYV and PNS, suitable for wet season, good eating and milling quality, moderate resistance to Bl, tolerance of acidic soils, suitable for drought-prone areas of central and southern regions Susceptible to BLB, BPH, GLH, and GM; susceptible to low temperature; not suitable for dry season
2005	Phone Ngam 5 (PNG5)	IRRI cross	G	125–130	HYV and PNS, suitable for wet and dry seasons, good eating and milling quality, moderate resistance to BLB, tolerance of acidic soils, suitable for drought-prone areas of central and southern regions, suitable for direct seeding Susceptible to Bl, BPH, GLH, and GM
2005	Phone Ngam 6 (PNG6)	IRRI cross	G	130–135	HYV and PNS, suitable for wet season, good eating and milling quality, moderate resistance to BLB, suitable for drought-prone areas of central and southern regions Susceptible to Bl, BPH, GLH, and GM; susceptible to low temperature; not suitable for dry season

[a]BPH = brown planthopper, Bl = blast, BLB = bacterial leaf blight, GLH = green leafhopper, GM = gall midge.

Table 8. Characteristics of Lao traditional varieties recommended for the lowland environment in the early 2000s.

Variety name[a]	Origin	Endosperm type	Flowering date	Variety characteristics	Areas recommended
Nang nouane (soft lady)	Savannakhet	G	5-10 Oct	Large grains, good eating quality, and broad adaptability Susceptible to lodging, gall midge (GM), blast (Bl), bacterial leaf blight (BLB), brown planthopper (BPH), and green leafhopper (GLH)	Upper and middle terraces in provinces of central and southern regions; small plains in northern provinces of Sayabouly, Luang Namtha, Oudomxay, and Houaphanh
Hom nang nouane (fragrant soft lady)	Savannakhet	G	15-20 Oct	Big grain, aromatic with excellent eating quality, good vegetative vigor, and strong culms Susceptible to lodging under fertile conditions; susceptible to GM and BPH, moderate susceptibility to Bl and BLB	Main plains in central and southern regions
Meuang nga	Oudomxay	G	10-15 Oct	Good eating quality, resistance to Bl and GM, wide adaptability Susceptible to lodging, BPH, GLH, and BLB	Central and southern regions and lowland areas of northern provinces of Luang Namtha, Bokeo, Luang Prabang, and Sayabouly
Ta khiet (frog's eye)	Oudomxay	G	5-10 Oct	Big grain, good eating quality, resistance to Bl, suitable for rice-growing areas of some northern provinces—Oudomxay, Luang Namtha, Luang Prabang, Sayabouly, Xieng Khouang Susceptible to lodging, BPH, GLH, and BLB	Central and southern regions, and lowland areas of northern provinces of Luang Namtha, Oudomxay, Xieng Khouang, and Luang Prabang
Mark hing (hing fruit)	Champassack	G	10-15 Oct	Tolerance of late drought Susceptible to Bl, BLB, and GM	Drought-prone areas (late drought) in central and southern agricultural regions

Continued on next page

Table 8 continued.

Variety name[a]	Origin	Endosperm type	Flowering date	Variety characteristics	Areas recommended
Dok mai (flower)	Vientiane Municipality	G	10-15 Oct	Big grain, good eating quality, good adaptability to low soil fertility Susceptible to BLB, BPH, and GLH	Upper and middle terraces in central and southern regions
Lai keo (clear lined)	Luang Prabang	G	15-20 Oct	Good eating quality Susceptible to BPH, GLH, and BLB; only moderate susceptibility to gall midge	Central and southern regions, and northern provinces of Oudomxay, Luang Namtha, Bokeo, Luang Prabang, and Sayabouly
Dok tiou (tiou flower)	Vientiane	G	Late Sept-early Oct	Tolerance of late wet-season drought and poor soil fertility Susceptible to Bl, BLB, BPH, GLH, and GM	Drought-prone areas of central and southern regions
Kai noi (small chicken rice)	Houaphanh	G	Late Sept	Bold grain, good milling and eating quality, performs well in northern provinces and can grow in upper terraces of main plains of central and southern regions Weak stem, susceptible to BLB, BL, BPH, and GLH	Northern provinces, upper terraces of main plains in central and southern regions

[a]Most names are preceded by the prefix *Khao,* which means rice.

Table 9. Projections for population growth and rice consumption requirements.

Year	Population[a]	Milled rice consumption requirement (000 t)[b]	Total paddy production requirement (000 t)[c]
2000	5,100,000	918	1,866
2005	5,800,000	1,044	2,122
2010	6,400,000	1,152	2,341
2015	7,100,000	1,278	2,597
2020	7,700,000	1,386	2,817

[a]Source: National Statistical Center. [b]Based on a requirement of 180 kg milled rice/person/year (WFP/FAO). [c]Assumes seed, distilling use, and postharvest losses of 18% before milling, and a milling conversion of 60% of the remainder (MAF 2000).

with more than 70% of wet-season rice cultivation in the Mekong River Valley being based on improved varieties, and 100% of the dry-season irrigated environment. Between 1990 and 2000, official rice production statistics indicated an approximate 48% increase in rice production from about 1.5 million tons to 2.2 million tons. Most of this increased production came from cropping activities in the wet-season lowland environment. The country was also officially reported to have achieved rice self-sufficiency in 1999 (although it is acknowledged that significant areas were still suffering from significant chronic rice deficits, particularly those still largely dependent on upland rainfed crop production, and the yields being reported are also regarded as inflated and actual rice production is probably below that reported).

Population growth projections for Laos predict a population of about 7.7 million by 2020; this represents an approximate 33% increase in the population from 2005 (Table 9). The projected paddy rice requirement to meet the rice consumption needs of the 2020 population is about 2.8 million tons. This compares with about 2.5 million tons officially reported as being produced in 2004. With official government policy for the upland environment focusing on a move from the growing of annual crops to more sustainable forms of agriculture in that environment, combined with a greater use of the dry-season irrigation potential for nonrice crops, the wet-season lowland environment (both rainfed and irrigated) will become increasingly important in meeting national rice production needs (in 2004, official statistics indicated that the upland environment accounted for about 200,000 t of rice, while the dry-season irrigated environment accounted for about 340,000 t). Rice research relating to the wet-season lowland environment will need to focus on a combination of reducing year-to-year production variability in this environment and raising the yield potential. In terms of the impact this is likely to have on the future variety improvement program, the following areas of focus are likely:

- Improved drought tolerance of varieties grown under rainfed conditions in the Mekong River Valley.
- Development of varieties well suited to direct seeding rather than transplanting.

- Development of varieties better adapted to the specific growing environment of the montane lowlands (lowland areas at higher altitudes).
- Incorporation of improved resistance to gall midge for varieties in areas prone to gall midge infestation.
- Incorporation of improved disease resistance into varieties, particularly for leaf and neck blast, whose problems appear to have been increasing in recent years.
- Development of improved nonglutinous varieties to meet an expected increase in consumption of nonglutinous rice in the main population centers.
- Development of specialty or "boutique" rice for a limited export market.

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CHAPTER 22

Advances in agronomic research in the lowland rice environments of Laos

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Rice cultivation accounts for more than 80% of the land in agricultural production in Laos. The most important rice production system is the wet-season lowland, which in 2004 accounted for about 75% (575,500 ha) of the total rice area and 78% (1,970,000 tons) of total production. Although during the 1990s there was a significant expansion in the area being serviced by irrigation (mainly to allow second cropping in the dry season—78,000 ha were cropped in the 2003-04 dry season—but also to provide an expansion of the wet-season irrigated area), the majority of the production from the wet-season lowland environment remains rainfed-based. In both the medium and longer term, it can be expected that the wet-season lowland environment will remain the most important rice-producing environment within Laos, with the majority of production continuing to come from rainfed-based cropping, subject to weather vagaries. The significance of the potential effects of weather on production is reflected in the fact that, in the 37-year period from 1966 to 2002, in almost every year, at least part of the country was affected by either drought or floods, or a combination of both (Schiller et al 2001). The drought problem in the main wet-season lowland rice-growing area, the Mekong River Valley, is aggravated by the permeable nature of the sandy soils that prevail in much of the area. Farmers throughout the central and southern regions rank drought as one of their most serious production constraints (Schiller et al 2001).

Systematic agronomic research targeting improved productivity in the different rice production systems of Laos began in 1990. The impact of the research output has been significant, particularly through the development and adoption of improved varieties in the wet-season lowland and dry-season irrigated production systems. Since 1990, the adoption of improved varieties in the wet-season lowlands of the main lowland rice-producing area in the Mekong River Valley has resulted in their replacement of traditional varieties in most of the cropping area (Schiller et al 2000, and Chapter 21, this volume). Most of these new varieties have been Lao improved glutinous varieties. The ongoing agronomic research program has tackled a range of other production constraints in each of the lowland rice-producing environments, both the wet-season rainfed lowland environment and the dry-season irrigated environment, resulting in the formulation of a range of technical recommendations capable of reducing the impact of the periodic wet-season droughts, as well as helping raise the yield potential of crops grown in these environments. This chapter summarizes the contribution of the agronomic research to yield improvement in the lowland environment since the early 1990s.

Agronomic practices in the wet-season rainfed lowland environment

The rainfall pattern throughout most of Laos is weakly bimodal, with a minor peak in May and early June, and a major peak in August and September. About 75% of the annual rainfall is received between May and October. In most provinces of the Mekong River Valley, total annual rainfall ranges from 1,500 to 2,200 mm. In some of the more northern provinces (Sayabouly and Luang Prabang), the total drops to 1,200 to 1,300 mm. The pattern of distribution can vary from year to year, causing large fluctuations in rice production. Early wet-season drought is a common occurrence from mid-June to mid-July, corresponding to the period when the monsoons change from southeast to southwest. The effects of this drought can be reduced by appropriate cropping practices, including matching crop phenology with water availability (Fukai 1999, Fukai et al 1999). Late wet-season drought occurs if the regular monsoon rains end early (in most areas, some rain continues to be received until early to mid-October). Fukai and Cooper (1995) have demonstrated that late-season drought alone can reduce grain yields by an average of 30%. The potential impact of different management practices on minimizing the impact of both early and late wet-season drought in the rainfed lowland environment is outlined in the following sections.

Effects of sowing dates on the performance of local and improved cultivars

At the beginning of the wet season, seedbed sowing usually takes place in early May to early June, depending on the timing of the onset of the early wet-season rains. Delaying sowing beyond this period increases the risk of exposing the crop to late wet-season drought, particularly when photoperiod-insensitive and mildly sensitive varieties are grown. When strongly photoperiod-sensitive varieties are sown late in July and August, the crop often flowers when the plants are still small, with a resulting significant decline in yield. This is the case whether the crop is direct-seeded or transplanted (Figs. 1A and 1B). Under normal conditions, a yield decline of 40% to 50% can result when seedbed sowing is delayed until late July. Early sowing (early June) is not appropriate for all situations, however, with notable exceptions being (1) under conditions of high soil fertility, when excessive growth during a long vegetative phase may lead to lodging, particularly for photoperiod-sensitive varieties; (2) under weedy conditions when an extended period of land preparation is required to provide good weed control before transplanting; (3) when short-maturity varieties are being grown, early sowing can mean that flowering of such varieties takes place during the period of peak rainfall (in August and September), resulting in poor fertilization and low grain yield (variety SK12 in Fig. 1C) (Sipaseuth et al 2001a,b).

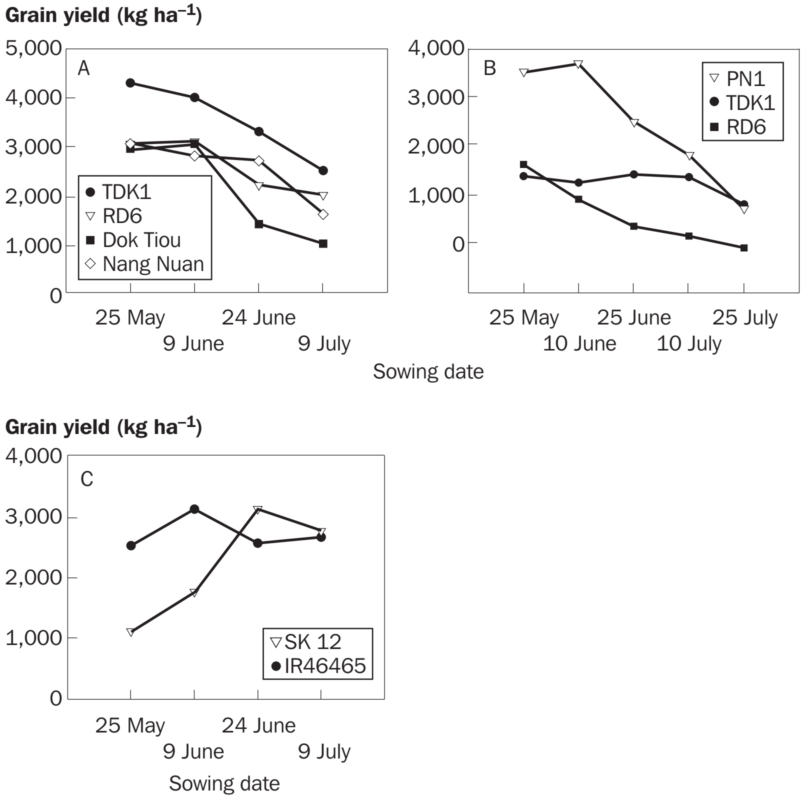

Fig. 1. Effect of sowing date on grain yield of popular cultivars grown in (A) Vientiane Municipality (transplanted in 1994), (B) Savannakhet Province (direct seeded in 1996), and (c) Champassak Province (transplanted in 1994).

Effects of seedling age at transplanting on crop grain yield

In addition to the importance of sowing date for maximizing wet-season grain yield, with the period late May to mid-June being the optimum period for transplanting, seedling age at transplanting can also be an important yield determinant (Fig. 2). In 1997 and 1998, studies were undertaken in Vientiane Municipality and Savannakhet Province on the relative impact on grain yield of the use of 25- and 45-day-old seedlings for several of the more popular improved Lao varieties. In addition to the studies further confirming the importance of early sowing and transplanting, the yield from the use of 25-day-old seedlings was, on average, 22% higher than that of 45-day-old seedlings, with the yield advantage of the younger seedlings being consistent across all sowing dates studied, from 25 May until 25 July (Sipaseuth et al 2001a,b). There are several agronomic advantages from the use of young seedlings for transplanting: the root system in young seedlings can recover qickly after pulling from the seedbed and subsequent transplanting, less damage occurs to the developing buds of secondary

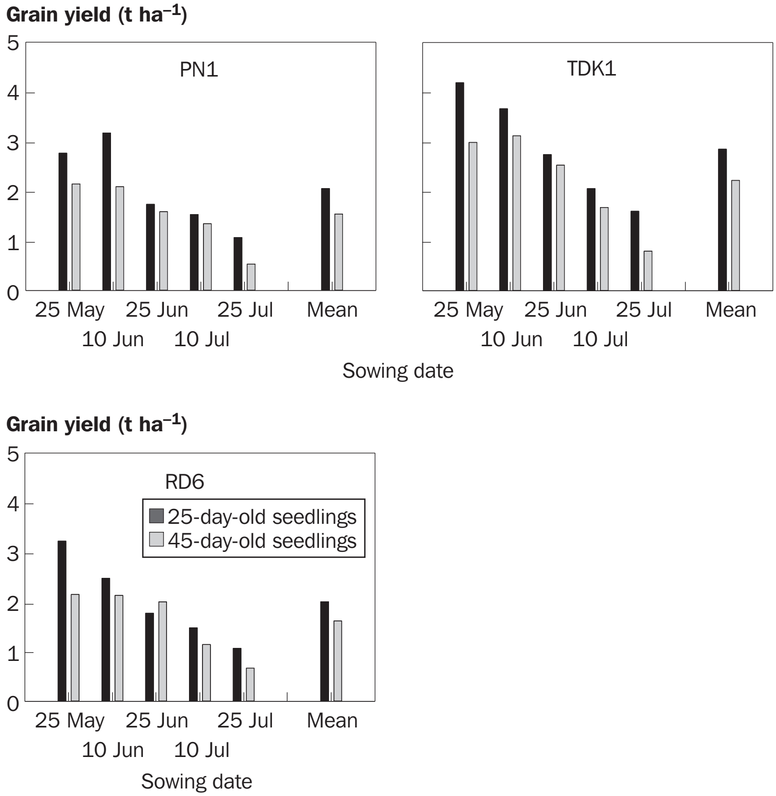

Fig. 2. Effects of time of sowing and seedling age at transplanting on wet-season grain yield in three popular Lao cultivars, PN1, TDK1, and RD6, in Vientiane Municipality.

tillers during transplanting of young seedlings, and younger seedlings are less exposed to leaf desiccation after transplanting than are older seedlings.

Effect of hill spacing and nitrogen application regime on grain yield

In some conditions, high plant densities increase grain yield independent of the need for increased fertilizer application. Under farming conditions in Vientiane Municipality, in the absence of fertilizer N, increasing the planting density from 16 to 44 hills m^{-2} was found to increase grain yield by an average of 63% for some of the popular improved Lao varieties (Fig. 3). When fertilizer N was applied, often the level of yield response was found to increase with increased planting density. For variety Namtane-1 (NTN1), at a planting density of 44 hills m^{-2}, the yield response to the application of 90 kg N ha^{-1} was as much as 75% (relative to zero), while at a planting density of 16 hills m^{-2} the response to the same level of N was less than 10%. High planting densities can also suppress early weed growth as well as reduce later weed competi-

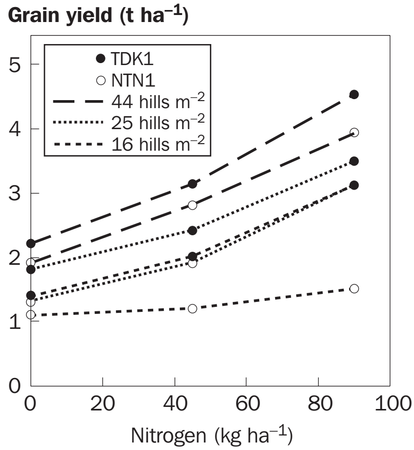

Fig. 3. Effects of hill spacing and nitrogen fertilizer application on grain yield of two popular rice varieties, TDK1 and NTN1, in Vientiane Municipality.

tion. Reduced tillering under high planting densities and low fertilizer inputs tends to reduce the proportion of unproductive tillers, resulting in a higher harvest index. This suggests that, at higher planting densities, the crop can better exploit nonfertilizer soil nutrients, including N. Further, any fertilizer N applied at higher planting densities is used more efficiently than at lower densities. When higher plant populations are achieved by increasing plant number per hill, from 3 to 6 (as distinct from an increase in the density of hill plantings), tillering decreased and the panicle/tiller ratio increased by an average of 8% (data not shown).

Establishment method for direct seeding

Direct seeding is becoming an increasingly popular establishment method in the rainfed lowland environment of Laos, particularly in areas where labor is becoming less available and/or labor costs are increasing. It can be expected that direct seeding in areas of the Mekong River Valley will become increasingly popular near the larger provincial towns, where alternative off-farm employment opportunities are becoming increasingly available. Direct seeding can be done either by broadcast wet seeding or row seeding using mechanical row-seeders (Fig. 4).

Comparative studies of broadcasting and row seeding in Vientiane Municipality and Savannakhet have demonstrated similar yields within a season (Fig. 5) (Sipaseuth et al 2000). Although there might be no yield difference between row seeding and broadcasting, the relatively recent availability of low-cost row-seeders is making their use an attractive option. Direct seeding of wet-season lowland crops is increasing in popularity in Savanakhet, which has the largest area of wet-season lowland rice of any single province in Laos (134,740 ha in 2004).

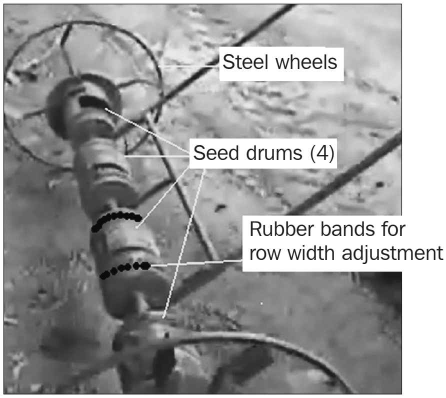

Fig. 4. Row-seeder (drum) for direct seeding (modified to allow adjustments in row spacing for different conditions).

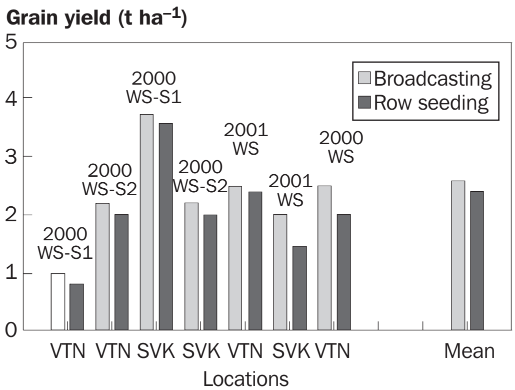

Fig. 5. Comparative yields between broadcast and row-seeded plots in wet-season (WS) rainfed lowland rice crops in Vientiane Municipality (VTN) and Savannakhet Province (SVK) in 2000-02 (S1 and S2 indicate two different sowing times).

Variety differences for weed competition in wet-season direct-seeded rice

The potential effects of weed competition on grain yield depend on weed density and on the ability of different rice varieties to tiller and effectively compete with weeds for available nutrients and water (Fukai 2002, Sipaseuth et al 2002). Cultivar differences for grain yield variation under different weed conditions are evident in the information summarized in Table 1. Weeding before tillering has been found to increase grain yield by about 37% in experiments conducted in Vientiane Municipaity and by as much as 45% in Champassak Province. Those genotypes that have the highest yield potential

Table 1. Yields (kg ha^{-1}) of 12 rice genotypes established under direct seeding and grown under weeded and unweeded conditions, 1998 wet season, Vientiane Municipality and Champassak Province.

Genotype	Vientiane		Champassak[a]	
	Weeded	Not weeded	Weeded	Not weeded
IR68102-TDK-B-B-33-1	2,470 a	1,821 a	1,456 de	1,019 bcd
IRUBN4-TDK-1-2-1	2,246 a	1,184 abc	1,973 a	899 bcd
TDK1	2,660 a	1,683 abc	1,959 a	809 d
IR57514-PMI-5-B-2-1	2,514 a	1,642 ab	1,914 ab	940 bcd
IRUBN8-TDK-1-1	2,217 a	978 bc	1,707 bc	917 bcd
Dokmay	2,621 a	1,200 abc	1,924 ab	1,082 b
RD6	2,227 a	1,198 abc	2,123 a	1,299 a
NSG 19	2,014 ab	975 bc	1,318 e	1,008 bcd
IR58821/IR58821/CA-7	1,313 b	639 c	1,629 cd	814 cd
Mahsuri	2,129 a	1,423 abc	2,007 a	1,062 b
IR49766-KKN-52-B-23	1,851 ab	1,060 abc	1,971 a	1,028 bcd
Hom Nang Nuan	1,858 ab	1,230 abc	1,478 de	1,054 bc

[a]In the Champassak study, yields in both weeded and nonweeded experiments were low on account of bird damage at maturity. Means with the same letters are not significantly different at the 5% significance level.

were also found to give the highest grain yield under unweeded conditions. Cultivars with good early establishment, medium plant height, good lodging resistance, and good root systems generally perform well when direct-seeded (e.g., varieties PNG5 and IR68102-TDK-B-B-33-1, which were released in 2005) (Fukai 2002).

Effect of seeding rate on yield of direct-seeded rice

Studies in two wet seasons (2001 and 2002) in Vientiane Municipality of the effects of increasing seeding rate on grain yield for direct-seeded rice revealed that there was no increase in yield for either broadcast or row-seeded crops when the seeding rate was increased above 75 kg ha^{-1} (as high as 200 kg ha^{-1}). This result is in contrast to the effects of increasing plant density in transplanted rice. However, in Savannakhet Province, in a 2001 wet-season study where the crop was affected by weed competition and yields were comparatively low relative to the Vientiane study, there was a positive response to the increased seeding rates. Grain yield increased by 26% and 29% in broadcast and row-seeded crops, respectively, when the seeding rate was increased from 50 to 200 kg ha^{-1} (Fig. 6A). The high seeding rates resulted in increased plant density in both the broadcast and row-seeded establishment methods (Fig. 6B). There was a significant increase in 1,000-grain weight as seeding rate decreased to 50 kg ha^{-1} when seed was broadcast (Fig. 6C). Increased seeding rates resulted in reduced weed weight at 30 DAS in both broadcast and row-seeded establishment methods (Fig. 6D). Overall, the higher seed rates and high rice plant densities resulted in a decline in weed competition, thereby contributing to higher grain yields (Fig. 7).

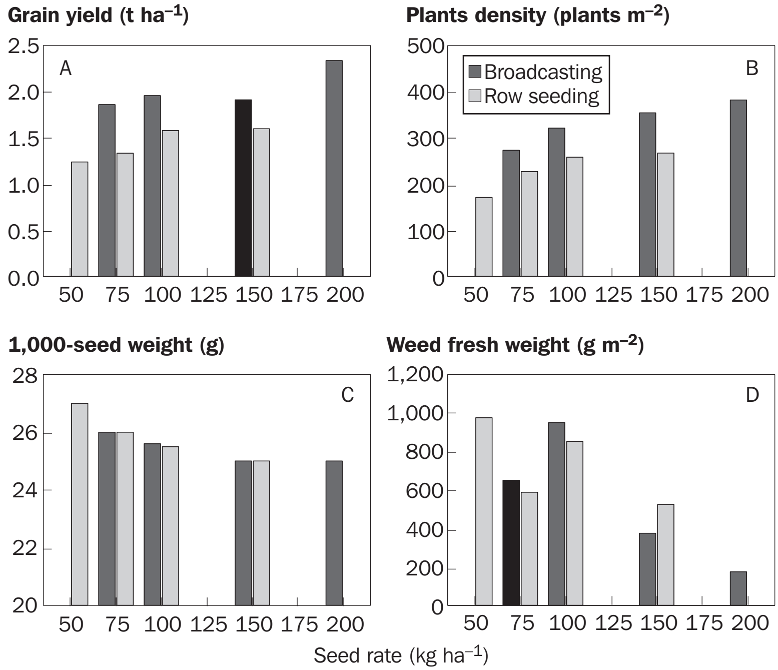

Fig. 6. Effect of seeding rates on (A) grain yield, (B) plant density, (C) 1,000-seed weight, and (D) weed weight at maturity for crops established using broadcasting and row seeding in Savannakhet Province in the 2001 wet season.

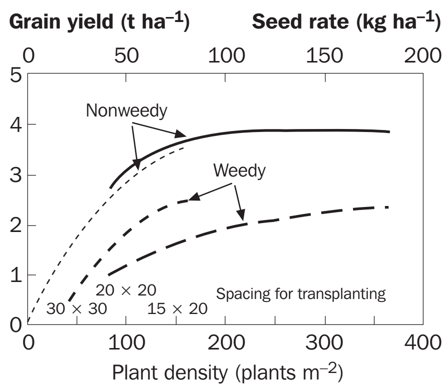

Fig. 7. Schematic diagram showing the relationship of yield variation in response to different population densities, for direct-seeded and transplanted rice crops, in the presence and absence of weeds (the thin lines represent transplanted crops and thick lines direct-seeded crops).

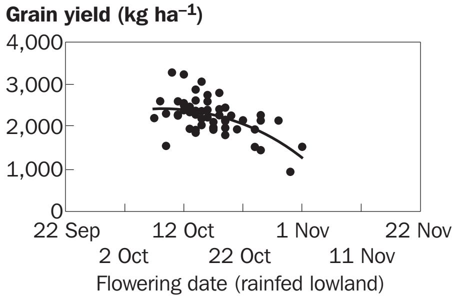

Fig. 8. Grain yield variation of cultivars of different maturity times when sown in mid-July 2001 under rainfed lowland conditions in Vientiane Municipality.

Maturity time of varieties appropriate for the rainfed lowlands

The maturity time requirement of photoperiod-insensitive cultivars for the wet-season plantings is determined by the time of sowing. Almost all Lao traditional cultivars are photoperiod-sensitive, while almost all the improved varieties released since 1993 are photoperiod-insensitive. The maturity time requirement of photoperiod-insensitive cultivars for the wet-season plantings is determined by the time of sowing. For normal rainfed lowland wet-season crops for which seedbed sowing is recommended to take place in early June, followed by transplanting in early to mid-July, most photoperiod-insensitive and -sensitive cultivars flower in late-September to early October. Apart from the risks associated with early sowing of there being a lack of standing water in the paddies at the time of transplanting, the other important yield determinant is water availability at the time of flowering (Inthapanya et al 2004). The potential effect of flowering dates on grain yield of varieties of differing maturity time is illustrated in Figure 8. The planting of photoperiod-sensitive varieties that flower as late as mid-October should be avoided in all areas where sandy soils with poor water-holding capacity can result in the absence of any standing water in the paddies at the time of flowering. This situation applies to most areas of lowland rice cultivation in the Mekong River Valley. Under such conditions, only varieties that flower in late September and very early October should be grown. For photoperiod-insensitive varieties for which flowering and maturity time are largely determined by time of sowing, the longer the maturity time of the variety, the earlier sowing needs to take place. However, in the absence of supplementary irrigation for seedbed sowing, flexibility in setting the sowing date outside the range determined by the onset of the wet-season rains is not always an option, and a delay in sowing due to the late onset of rains can result in greater potential exposure to late wet-season drought at flowering.

Drought and toposequence position

The rainfed lowland rice ecosystem is diverse and, in most areas of Laos (but particularly in rainfed lowland areas of the Mekong River Valley), three subecosystems

Fig. 9. The three subecosystems—upper, middle, and lower terraces—that are found in much of the rainfed lowland rice environment in Laos.

are usually distinguished in the toposequence—the upper terrace, the middle terrace, and the lower terrace (Fig. 9). Differences are large in rainwater availability at difference positions in the toposequence. Water availability at positions higher in the toposequence is not as great as in positions lower in the toposequence because of the downward movement of water through the soil profile, and also the lateral movement of water from high to low positions (Tsubo et al 2005).

It is also generally recognized that soils in the lower terraces have a higher clay content and become saturated earlier in the wet season, making them suitable for land preparation and planting earlier than in the upper and middle terrace areas. Further, at the end of the wet season, water remains available longer in the lower terraces than in the upper parts of the toposequence. The soils in the upper terraces, on account of their often higher sand content, are more drought prone as well as generally less fertile than the soils in the lower terraces. At the end of the wet season, they dry out more rapidly than the soils in the lower terraces. As water disappears, drought conditions can develop much earlier in the upper terraces, causing yield variation among cultivars within different maturity groups. Cultivar requirements for different parts of the toposequence can therefore be quite different (Basnayake et al 2004). This is clearly demonstrated in the results of a comparative evaluation of nine genotypes evaluated in Phonethong District of Champassak Province in the 2000-02 cropping seasons (Table 2). Genotypes best suited to planting in the upper terraces are those with a high yield ratio when planted in this environment. The planting of early-maturing cultivars in the upper terraces can reduce the potential effects on yield of drought because of the early end of the wet-season rains. This result also highlights the importance of careful selection of the terrace environment in which genotypes are evaluated for potential release as improved varieties, as well as the need for specific recommendations as to the most appropriate growing environment for individual varieties, after release.

Potential yield and farm income responses to technology adoption in the rainfed lowland environment

Between 1994 and 1998, studies were undertaken in villages in the rainfed lowland environment of Laos, one in the southern province of Champassak and the other in the central province of Vientiane, of the potential impact on rice production and related

Table 2. Grain yield at top and low positions and yield ratio of 9 high-yielding genotypes in Champassak Province.

Genotype	Yield (kg ha^{-1}) in upper terrace	Yield (kg ha^{-1}) in lower terrace	Yield ratio (upper/lower)
TDK94018-6-1-3	2,755	3,175	0.86
IR70825-47-12-5-TDK-2-3-B	2,742	2,479	1.10
IR70183-74-1-1-1	2,664	3,327	0.80
PNG1	2,558	2,654	0.96
IR70824-TDK-5-B-1	2,356	2,970	0.79
ILOUP	2,330	3,204	0.72
RD6	2,233	3,638	0.61
LR2427	2,245	3,416	0.65
IR70824-TDK-44-2-B-1-2	2,230	2,866	0.77

farm household welfare from the adoption of improved rice production technologies (Schiller et al 2000). Part of the technology packages related to improvements in agronomic practices, the main change being to get farmers to adopt higher plant populations through closer hill spacing (a reduction from 30 × 30 cm often used to a spacing of 20 × 20 cm) and an increased number of plants per hill (an increase from 2–3 to 4–5 seedlings). The technology package also included the adoption of the first of the improved glutinous varieties developed by the Lao national rice research program, Thadokkham-1 (TDK1) and Phonengam-1 (PNG1). In both villages, the equivalent of an application of 60-30-0 kg ha^{-1} of NPK fertilizer was also recommended in the form of the compound fertilizer 16-20-0 and urea (46-0-0). The compound fertilizer containing P was applied immediately before transplanting, in the last phase of land preparation (the soils in much of the Mekong River Valley of Laos are highly P deficient, Linquist and Sengxua 2001). Application of N was divided equally between transplanting and 35 and 55 DAT for the two medium-maturity varieties. The adoption and impact of the recommendations were monitored and measured over five wet seasons, 1994 to 1998. Farmers who adopted the combination of technical recommendations more than doubled their yields and net returns in both provinces, with average yields of 3.2 to 3.7 t ha^{-1} being readily achieved when all recommendations were adopted; these yields were also about 1.4 t ha^{-1} higher than when farmers adopted just improved varieties (Fig. 10). An economic analysis of the impact of the adoption of the technology packages showed that net returns closely reflected the changes in grain yield. Greater detail of the impact of the technology adoption can be found in Schiller et al (2000). The results of the study clearly indicated that to achieve the maximum potential benefits from improved technology adoption in the rainfed lowland environment, full technology packages should be recommended and they need to be adopted by farmers.

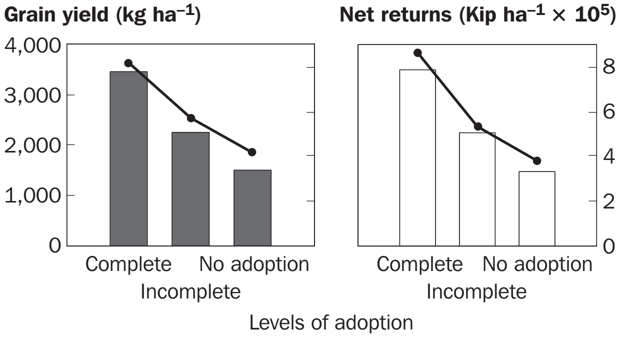

Fig. 10. Impact (grain yield and net returns) of technology adoption at the village level in Champassak and Vientiane provinces for improved lowland rice production (Schiller et al 2000). Bars indicate grain yield and the line shows the net income; complete = all recommendations adopted, incomplete = mainly the adoption of improved varieties.

Agronomic practices in dry-season irrigated lowland rice cultivation

From 1990 to 2001, dry-season irrigated rice area increased by 750% (from 12,000 ha in 1990 to 102,000 ha in 2001). Grain production from this environment also increased more than tenfold, from 41,000 t to 436,000 t. Most (95.5%) of this expansion has taken place in the central and southern agricultural regions. In 2001, there was still only about 6,500 ha developed for irrigation in the northern agricultural region. However, by 2004, not all the potential dry-season irrigable area was being used because of a combination of high pumping costs, poor water reticulation (and resulting poor water-use efficiency) in some irrigation scheme areas, and relatively low grain prices.

The normal cropping cycle for dry-season cropping in the main irrigation scheme areas in the Mekong River Valley involves seedbed sowing about mid-November and harvesting in March and April (two of the hottest months). Average rainfall in most areas during this period is less than 15% of the total, and any form of cropping is reliant on irrigation. The main production constraints faced in most dry-season rice cropping areas are the potential effects of low temperatures near the period of seedbed sowing and early seedling growth and the potential effects of high temperatures in some areas during March and April, about the time of flowering. The mean minimum temperature during the sowing period varies from 5 to 15 °C in the north and from 12 to 18 °C in provinces of the Mekong River Valley (Sihathep et al 2001). Maximum daytime temperatures in March and April in the Mekong River Valley can reach 36 °C, and can reach 35 °C in the north of the country.

Agronomic research relating to dry-season irrigation cropping has focused on nursery management, time of sowing and transplanting, seedling age at transplanting, and plant density. Studies have also been conducted on plant density effects on direct-seeded crops.

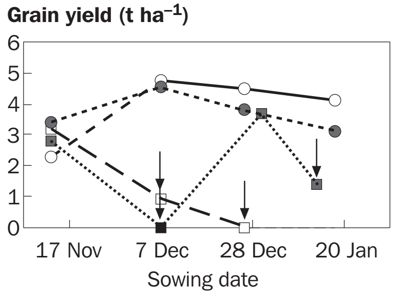

Fig. 11. Grain yield for dry-season irrigated rice at different sowing dates at four sites: Vientiane Municipality (●) and Champassak (○) (central and southern Laos, respectively) and Luang Namtha (□) and Xieng Khouang (□) (northern and northeastern Laos); (arrows indicate the severe effects of low temperature on the grain yield of varieties TDK1 and RD10).

Effects of sowing date on the performance of local and improved cultivars

Seed germination is poor and sometimes fails when the average minimum temperature at sowing falls below 12 °C. As noted, the mean minimum temperature during the sowing period (mid-November to early January) in the northern region varies from 5 to 15 °C (Fukai et al 2003). The potential effect of these temperatures on grain yield has been clearly demonstrated in studies undertaken in 2000 to 2002, in an examination of crop performance in the two northern provinces of Luang Namtha and Xieng Khouang relative to Vientiane Muncipality and Champassak in the central and southern regions, respectively (Basnayake et al 2003). The results (Fig. 11) clearly show the potential effect of low temperature when sowings take place in the northern region in the coldest months of December and January. In contrast, there was much less impact of sowing date on yield in Vientiane Municipality and Champassak Province, where mean temperatures were about 10 degrees higher than for the northern provinces, as well as being above the critical 12 °C required for seed germination (Sihathep et al 2001).

Seedbed management to reduce low-temperature impact in the northern region

In areas of northern Laos where average temperatures during December and January can fall below 12 °C, the level critical for germination and early seedling, two management options have been developed to raise the temperature in the seedbed (Fukai et al 2003). The first option is the use of plastic sheeting to cover the seedbed immediately after sowing, with the plastic being removed when the seedlings are about 5 cm tall. The second option is to cover the seedbed with a plastic dome until

Fig. 12. Farmers in Xieng Khouang Province pulling seedlings from a nursery protected by a plastic dome during the dry season (December).

Table 3. Mean grain yield (t ha^{-1}) when plastic covers and plastic domes were used during nursery establishment at different locations at higher elevations in northern Laos in the 2002-03 and 2003-04 dry seasons.

Province	Cropping season	Control (unprotected)	Plastic cover	Plastic dome	LSD ($P<0.05$)
Luang Prabang	2002-03	4.03	4.29	3.84	ns[a]
Sayabouly	2002-03	3.22	4.21	3.69	0.56
Xieng Khouang	2002-03	4.04	4.21	4.24	0.17
Luang Namtha	2002-03	3.48	3.62	3.56	ns
Xieng Khouang	2003-04	2.18	2.58	2.32	0.12
Luang Namtha	2003-04	3.60	3.72	3.68	ns

[a]ns = nonsignificant at the 5% level.

the seedlings are tall enough for transplanting (Fig. 12). Nighttime temperatures inside the plastic dome when such measures have been implemented have been found to be about 4 °C higher than the external ambient temperature, resulting in improved germination and seedling growth. The use of such domes or plastic covers in areas where low temperatures affect seedbed rice has been shown to increase yields by an average of over 0.5 t ha^{-1} (Table 3). An additional benefit of the use of the plastic covering that has been reported by farmers is that it helps protect the seedlings in the nursery from rodent damage.

Effects of seedling age at transplanting in the dry season

Although seedling age at transplanting can be an important determinant of yield for wet-season lowland rice crops, it is less important in dry-season irrigated crops in

Table 4. Grain yield (t ha^{-1}) of variety TDK5 from dry-season irrigated crops using transplanted 25-, 35-, and 45-day-old seedlings grown at four locations in northern Laos.

Province	Yield (t ha^{-1}) in relation to seedling age at transplanting (days)		
	25	35	45
Luang Namtha	3.62	3.60	3.44
Luang Prabang	4.03	3.60	4.14
Xieng Khouang	3.88	4.00	3.90
Sayabouly	3.67	3.68	3.63
Mean (nonsignificant)	3.80	3.72	3.78

areas affected by low temperatures, particularly in the north of the country (Table 4). The reason for the lack of a relationship between seedling age and final yield for dry-season crops in northern areas is that, under low-temperature conditions, plants require a longer vegetative period to achieve physiological maturity (often from 30 to 45 days longer than in the area of the Mekong River Valley). For most cultivars grown at low temperatures in the northern region, the growth duration for flowering is much longer than in the wet season. However, in the main dry-season rice-growing areas of the Mekong River Valley (MRV), the effect of seedling age on grain yield in the dry season is similar to that of wet-season cropping. The use of young seedlings (less than 30 days old) for transplanting in the dry season is important in the MRV, as the temperature is favorable most of the time for rapid vegetative growth.

Seedling number per hill and population effects on grain yield in dry-season irrigated rice

Studies were undertaken in 1995 and 1996 in Vientiane Municipality of planting density for transplanted dry-season irrigated rice, using the two popular varieties TDK1 and RD10. In both years, yield improved when planting density was increased from 16 to 44 hills m^{-2} (Fig. 13). In the 1995 study, average yield increased by about 16%, while in 1996 the improvement was about 54%. Variety RD10 also had yield improvement from increasing the number of seedlings per hill from 3 to 6, with average yield increasing by 9%, but TDK1 did not show the same yield response. The lack of a yield response for TDK1 to the higher seedling number per hill was probably because this variety has a high tillering capacity (with an average of about 10 tillers per plant) and there is less advantage from increasing seedling number per hill above three. The yield advantage from increased plant populations, whether through reduced hill spacing (i.e., increased density of hills) or increased plant number per hill, is likely to be manifest mainly with varieties with a low tillering capacity.

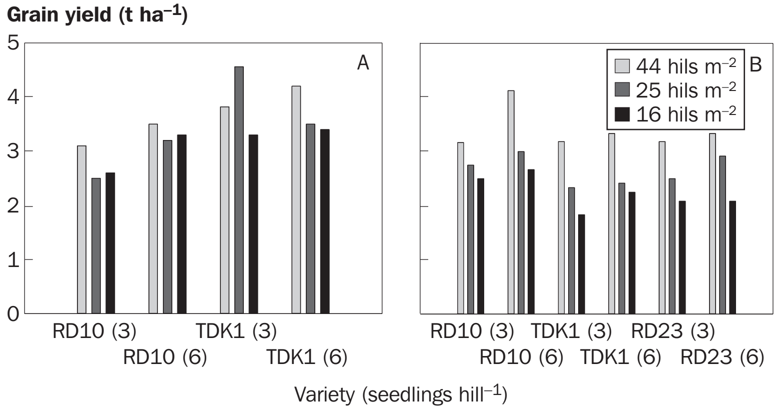

Fig. 13. Effects of hill spacing and number of seedlings transplanted per hill on grain yield of (A) two popular varieties in 1995 and (B) three varieties in 1996, in Vientiane Municipality (the number in parentheses next to the variety name is the number of seedlings per hill).

Population effects on the yield of direct-seeded dry-season rice

In studies undertaken in Vientiane Municipality in the 2001-02 and 2002-03 dry seasons, it was apparent that seeding rates higher than 75 kg ha^{-1} did not result in higher grain yields (Table 5). The yield advantage associated with high seeding rates with wet-season cropping (see Fig. 6) was largely associated with the effect of reducing weed competition. In the dry-season environment with direct seeding, better water management in the establishment phase of the crop generally allows better weed control, and so this potential advantage of high seeding rates is lost.

Double rice cropping in the irrigated environment

There are opportunities to grow two rice crops, one in the wet season and one in the dry season, in areas of Laos serviced by irrigation facilities. Wet-season cropping in such areas would require only supplementary irrigation (supplementary to rainfall) rather than having total reliance on irrigation scheme supplies. Dry-season rice cropping in northern areas where mean minimum temperatures are below 12 °C during the time of seeding and early seedling growth will continue to remain difficult. However, with early planting in November or the adoption of improved seedbed management practices such as those described earlier, it is possible to double-crop these areas and achieve yields the equivalent of those achieved in provinces in the central and southern agricultural regions along the Mekong River Valley (Table 6).

Double cropping in the northern areas of the country will require an ongoing program of varietal selection to develop varieties with a greater tolerance of low temperatures that is required in the main irrigated areas in the Mekong River Valley.

Information on the optimum sowing and maturity dates for the wet-season and dry-season crops allows estimates to be made of growth duration (transplanting to

Table 5. Effects of seeding rate (kg ha^{-1}) on grain yield (t ha^{-1}) for direct-seeded crops in Vientiane Municipality, in the 2001-02 and 2002-03 dry seasons.

Seeding rate (kg ha^{-1})	Yield (t ha^{-1}) 2001-02	Yield (t ha^{-1}) 2002-03	Mean yield (t ha^{-1})
75	4.43	3.57	4.00
100	4.68	3.25	3.97
150	4.58	3.63	4.11
200	4.73	3.42	4.08
Mean	4.61	3.47	4.04
LSD 5%	ns[a]	ns	ns

[a]ns = nonsignificant.

Table 6. Grain yield and optimum sowing date in the dry and wet season and total yield for five locations in Laos.

Province	Dry season		Wet season		Total yield (t ha^{-1})
	Yield (t ha^{-1})	Optimum[a] sowing	Yield (t ha^{-1})	Optimum[a] sowing	
Luang Namtha	4.06 (5)	Mid-Nov	4.16 (3)	Early June	8.22
Xieng Khouang	3.09 (5)	Mid-Nov	4.74 (3)	Early July	7.83
Luang Prabang	4.23 (2)	Late Dec	3.81 (2)	Early July	8.03
Sayabouly	3.58 (2)	Early Dec	5.13 (2)	Mid-June	8.71
Vientiane	3.73 (3)	Early Dec	2.44 (1)	Mid-June	6.17

[a]The grain yield for each season is for the optimum sowing date at each location (the numbers within parentheses represent the number of years of experimentation on which the yield estimates are based).

harvest) and between-crop interval (the period between harvesting of one crop and transplanting of the next). Growth duration for dry-season crops in the northern region (Luang Namtha, Xieng Khouang, and Luang Prabang) can be as much as 45 days longer than for provinces in the Mekong River Valley (Vientiane and Sayabouly) for the same variety because of the effects of low temperature in the northern region on extending the vegetative growth phase of photoperiod-insensitive varieties (Table 7).

For variety TDK5, the growth duration for dry-season cropping in Sayabouly and Vientiane was only about 112 days, whereas, when the same variety was grown in Xieng Khouang, growth duration reached 157 days. For wet-season cropping, crop growth duration in the northern provinces for the same variety was reduced (relative to dry-season crops) by between 22 days (Luang Prabang) and 61 days (Xieng Khouang). Crop duration is not only important from the context of the cropping calendar (thereby

Table 7. Growth duration (days) for the dry-season (DS) crop, duration from DS to wet season (WS), WS duration, and duration from WS to DS for the optimum sowing date at each location. The estimations are based on the transplanting and harvesting dates of variety TDK5.

Location	DS growth duration (d)	Duration from DS to WAS (d)	WS growth duration (d)	Duration from WS to DS (d)
Luang Namtha	138 (20 Dec-6 May)	64	102 (9 Jul-19 Oct)	62
Xieng Khouang	157 (16 Dec-21May)	70	96 (30 Jul-3 Nov)	43
Luang Prabang	120 (24 Jan-23 May)	68	98 (30 Jul-5 Nov)	80
Sayabouly	112 (5 Jan-26 Apr)	70	115 (5 Jul-28 Oct)	69
Vientiane	111 (5 Jan-25 Apr)	77	97 (11 Jul-16 Oct)	81

providing sufficient time for seedbed planting between succeeding crops), but also in being able to ensure that the critical stages of the physiological growth of the crop are not exposed to conditions that affect final yield potential. For dry-season crops in the northern region, this means avoiding the potential effects of high temperature when flowering occurs in April, when temperature can reach as high as 35 °C. For wet-season crops in drought-prone areas of the Mekong River Valley, the flowering of crops in early to mid-October needs to be avoided to reduce the potential impact of late wet-season drought. Crop duration will become an increasingly important consideration in areas where double cropping is combined with direct seeding, for which the interval between successive crops becomes more critical.

Conclusions

The agronomic studies undertaken in the lowland rice environment from the mid-1990s to 2004 clearly indicate a potential for some agronomic practices to have a significant impact on yield potential, as well as to minimize the impact of year-to-year variation in production caused by periodic droughts and, in the case of dry-season irrigated cropping in the northern region, the potential impact of low temperature. However, as was also clearly indicated in the results of studies presented on technology adoption by farmers in Vientiane and Champassak in the central and southern regions, the adoption of improved agronomic practices represents only one component of the overall technology package that farmers need to maximize production potential. Improved varieties and the implementation of appropriate soil fertility management practices are also integral components of packages that need to be adopted by farmers in both the rainfed and irrigated lowland environments.

The current low-temperature and growth duration constraints to both wet-season rainfed and dry-season irrigated rice crops in the northern agricultural region will probably be alleviated through the development of varieties better adapted than those currently available to the particular growing conditions experienced in this region. Improved drought tolerance might also be expected in varieties developed for the more drought-prone areas of the Mekong River Valley. When used in combination with the agronomic practices capable of alleviating some of the potential impact of drought, these varieties will further help reduce the year-to-year variability in production that is still a major constraint in wet-season crops that are outside potentially irrigable areas, and that can be expected to constitute the major source of rice production for Laos for the foreseeable future. The importance of these lowland areas will be further augmented, as the area under rainfed upland rice cultivation declines in line with government policy to adopt more sustainable agricultural practices in such areas. The focus of ongoing agronomic studies in the main lowland rice-growing area of the Mekong River Valley should include studies on improved water-use efficiency (including the continued evaluation of varieties for improved drought tolerance), together with the continued evaluation of direct-seeding practices. Proper land leveling and the development of improved drainage, both of which can be facilitated with an expected increase in the mechanization of production, might be expected to lead to the wider adoption of direct seeding and/or use of younger seedlings for transplanting. Further research attention also needs to focus on the use of supplementary irrigation to reduce the impact of drought on wet-season rice cultivation.

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CHAPTER 23

Soil fertility management in the lowland rice environments of Laos

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Agriculture is the main livelihood of approximately 95% of the rural households in Laos, and rice is the single most important crop. Rice provides about 70% of the total calorie supply and constitutes around 60% of total agricultural production (UNDP 1998). Given this situation, any increase in rice production contributes to a general improvement in the welfare of rural households (Schiller et al 2000). In addition, heavy demand for increased production comes from the fast population growth. The population of Laos is growing at 2.5% per annum and is expected to increase from 5.3 million in 2000 to about 7.7 million in 2020. Another factor contributing to growing rice demand is the expected increase in per capita consumption connected to the fast development process in Laos. The major share of the necessary production increase can come only from rice-based lowland systems, which currently supply 88% of the total rice production. Although varying from year to year, the majority of lowland rice is produced in rainfed systems (about 80%), whereas irrigated lowlands contribute about 20% of lowland rice production (MAF 2002, Chapter 3).

During the last 15 years, rice-based lowland systems in Laos underwent considerable changes, ranging from a much improved infrastructure, which increased the number of farmers with access to markets and income opportunities outside of agriculture, to the establishment of considerable irrigation capacity and the development of improved rice production technologies. Although, based on these developments, considerable productivity increases were achieved after 1990 (rice production increased from 1.5 million tons in 1990 to 2.3 million tons in 2001; FAO electronic data base), considerable scope remains for further improvement. Given the now widespread use of improved, input-responsive varieties in lowland environments (see Chapter 21), appropriate crop and natural resource management (CNRM) becomes an increasingly important concern. Farmers are often quick to adopt suitable improved germplasm, but the dissemination and adoption of adjusted CNRM technologies is a necessary second step and a much slower process that is vital to further improving productivity while maintaining system sustainability. Within this context, this chapter summarizes recent research results and developments related to integrated nutrient management of rice-based lowland systems in Laos and proposes some future challenges and opportunities.

General characteristics of rice-based lowlands in Laos

For the purpose of this chapter, two broad regions of lowland rice cultivation are distinguished (Fig. 1). In mountainous northern Laos, lowland rice cultivation is confined to valley areas with characteristic soil, climate, and ecological conditions (included in this region are the provinces of Xieng Khouang and Saysoumboun, which are more usually part of the central region for agricultural statistical purposes). In the central and southern agricultural regions of the country, where about 80% of the total lowland rice area is located, rice is grown mostly on the plains adjacent to the Mekong River (Vientiane Municipality and the provinces of Vientiane, Borikhamxay, Khammouane, Savannakhet, Saravane, and Champassak). Development of irrigation capacity increased significantly from 1995 onward, with the area of dry-season rice increasing from 13,000 ha in 1995 to 102,000 ha in 2001 (MAF 2002). Most of this expansion has been on the Vientiane Plain (Vientiane Municipality and Vientiane Province) and on the six main rice-growing plains in central and southern Laos, particularly in the provinces of Savannakhet and Champassak. Consequently, more then 90% of the irrigated lowlands are situated in central and southern Laos.

The agroclimatic characteristics of the rice production environments are described in detail in Chapter 4. We can generalize that total annual precipitation is higher in the central and southern regions (about 1,900 mm per year) than in the northern region (about 1,400 mm per year), that variability of monthly rainfall is high in both regions, causing regular occurrence of intermediate drought spells or flooding during the cropping season, and that minimum and maximum temperatures are mostly favorable for rice cultivation. Only in the northern region are low temperatures at the onset of the dry season a regular production constraint.

The soils of Laos have been characterized using the FAO/UNESCO soil classification criteria (FAO 1998). This shows that the predominant lowland rice soils in the central and southern regions are Acrisols. Acrisols are strongly weathered soils with a clay-enriched subsoil, they are dominated by low-activity clay minerals, they have a low base saturation (<50%), and the percentage of H and Al in the exchange complex is high. Thus, the soil pH is usually close to 5.5 or lower, and the soils have a low inherent fertility. The typical visual characteristics of lowland rice Acrisols are their mottled appearance due to red, iron-rich patches in a usually gray, bleached soil matrix, which reflects exposure to regular flooding and subsequent drying cycles (gleyic or stagnic properties). Associated soils also frequently used for lowland rice cultivation in central and southern Laos are Cambisols. They occur in areas with younger parent material than for the Acrisols, are less weathered, and are generally more fertile than neighboring Acrisols. Because of a similar soil water regime, they do have gleyic properties in common with many Acrisols. In northern Laos, the same soil types as in the southern and central regions are typical in the lowlands. Especially in the larger valleys, where no recent sedimentation of soil material occurred, Acrisols predominate. In narrow valleys, on the fringes of wider valleys, and in low-lying areas, where new soil material is deposited from further upslope or the river (colluvium or

Fig. 1. Map of Laos showing northern (shaded) and central/southern Laos as used in this chapter. The north is mountainous and most of the lowland rice is confined to valley areas, whereas most lowland rice in the central and southern region is grown on the plains adjacent to the Mekong River. About 80% of all lowland rice in Laos is grown in the provinces of Vientiane, Borikhamxay, Khammouane, Savannakhet, Saravane, and Champassak.

Table 1. Some topsoil characteristics (0–0.2 m) of paddy soils in central and southern Laos. Shown are average, minimum, and maximum values of 12 fields in representative lowlands of southern Laos.

	$pH_{H_2O\ 1:1}$ –	TOC[a] (mg kg^{-1})	TSN[a] (mg kg^{-1})	Available K[b] (cmol kg^{-1})	Olsen P (mg kg^{-1})	Clay	Sand (%)	Silt
Average	5.3	8.7	0.8	0.12	3.4	26	26	48
Minimum	4.2	3.2	0.2	0.06	2.3	4	1	25
Maximum	6.5	19.7	1.9	0.26	5.8	47	71	82
	CEC	Exch. Ca	Exch. Mg (cmol kg^{-1})	Exch. Na	Exch. K	Base sat. (%)	Exch. acidity	Exch. Al (cmol kg^{-1})
Average	8.1	2.8	1.2	0.15	0.08	49	0.7	0.5
Minimum	2.1	0.3	0.2	0.05	0.04	20	0.1	0.0
Maximum	12.6	5.3	2.7	0.30	0.19	72	3.3	2.8

[a]TOC = total organic carbon, TSN = total soil N. [b]Available K was determined by extraction with 1 M ammonium acetate.

alluvium), Cambisols are associated soils. But, as in central and southern Laos, gleyic or stagnic properties are common.

Analysis of lowland paddy soils (0–0.2 m) of Laos indicates that 80% of the soils in the central and southern region contain less than 2% organic matter (>1.2% soil organic C), 68% are coarse-textured (sandy, loamy sands, and sandy loams), and 87% have a pH (H_2O) of less than 5.5. In contrast, soils in the north are more fertile: 66% of these soils contain more than 2% organic matter, 80% are loams or clay loams, and 52% have a pH of more than 5.5. Some typical topsoil characteristics of central and southern lowlands and their range are given in Table 1. The soil data presented confirm the general trends described by Linquist et al (1998), but also show the large spatial variability of soil characteristics.

Until the early 1990s, only 2% of the total rice area in Laos was irrigated, and rainfed lowland rice production was based on traditional practices. Mostly traditional varieties were grown and mechanization of any aspect of production or postharvest processing was exceptional. No agrochemicals were used by the majority of farmers, and farm residues were the main source of nutrient inputs. Since the mid-1990s, there have been considerable changes in lowland rice production, reflecting a combination of advances in research and the efforts of government and development agencies. Improved varieties have been developed and were adopted by the majority of lowland farmers, particularly in the main rice-growing areas in the Mekong River Valley (Chapter 21; Table 2). Especially, improved modern-type varieties (TDK, PNG, and TSN varieties) provide important yield gains compared with traditional and improved traditional-type varieties (RD and KDML varieties from northeast Thailand). Possibly because of different sample sizes, locations, and methods used, average yields reported by official statistics are higher (2.8 t ha^{-1} in 1990, 3.0 t ha^{-1} in 1995, and 3.3 t ha^{-1} in

Table 2. Varieties, inorganic fertilizer use, and average yields in lowland systems, central and southern Lao PDR, from 1990 onward. Based on Pandey (2001) and Shrestha (2004).

Item	Year		
	1990	1996	2001
Planted area (%):			
Traditional varieties	95	79	25
Improved varieties, traditional-type	5	21[a]	46
Improved varieties, modern-type	0	–	29
Farmers using inorganic fertilizer (%)	–	60	93
Average yield (t ha^{-1}):			
Traditional varieties	–	1.3	1.4
Improved varieties, traditional-type	–	1.5[a]	1.9
Improved varieties, modern-type	–	–	2.3

[a]Average for improved traditional and modern-type varieties.

2001; MAF 2002) but show a trend similar to the survey data presented in Table 2. Many farmers also adopted improved crop management practices, including higher transplanting densities, the use of low rates of inorganic fertilizer, splitting fertilizer applications, and increased use of organic fertilizers (Shresta 2004). The same survey indicated that land preparation is becoming increasingly mechanized, as is postharvest processing, and that pesticide use remains low.

Recent changes in technology adoption have been most pronounced in irrigated areas, particularly in dry-season irrigated crop production. The potential of many irrigation schemes for providing supplementary irrigation during the wet season, even during periods of drought, has generally been underused. Dry-season irrigated rice cropping reached a peak of 102,000 ha in 2001, but by 2004 had dropped to 77,000 ha (see Chapter 3), the decline probably being the result of a combination of increasing costs of production and marketing problems. Diversification into nonrice crops on paddy fields is limited and mostly restricted to the irrigated dry season and relatively small areas. Only one (rice) crop per year is grown in purely rainfed areas.

Nutrient management and agroeconomic sustainability in the lowlands of Laos

Research efforts to increase the productivity of lowland rice in Lao PDR included a large number of researcher-managed field trials on various aspects of nutrient management, mostly farmer-managed field trials to assess the agroeconomic performance and sustainability of different nutrient management options, and socioeconomic surveys covering a range of nutrient management issues. The main objectives of the researcher-managed trials conducted from 1991 to 2001 were to determine the most limiting nutrients, identify appropriate fertilizer rates, evaluate different application strategies, and assess integrated nutrient management options (including the use of residues, inorganic fertilizer, and green manure). Most of the trials examining these issues were conducted in farmers' fields under the supervision of local researchers and had a randomized complete block design with usually four replications. The germplasm used was the regionally preferred improved modern-type variety, and the chosen sites represented all major lowland rice areas in Lao PDR (Linquist et al 1998, Linquist and Sengxua 2001, 2003).

To evaluate the agroeconomic performance of nutrient management options in farmers' fields and under their management, survey data and farmer-managed field studies can be used. The survey information reported in this chapter was collected in the 1996 wet season (700 farmers from 15 villages in the provinces of Champassak and Saravane; Pandey and Sanamongkoun 1998) and in the 2001-02 wet and dry seasons (240 households from 12 villages in Champassak and Savannakhet provinces, and Vientiane Municipality; Shrestha 2004). Another main source of information for the agroeconomic performance evaluation of different nutrient management options was on-farm trials conducted between 2003 and 2005. In these trials, four collaborating farmers were selected at each of six sites (two sites each in Vientiane, Savannakhet, and Champassak provinces). Participating farmers tested a set of nutrient management options over two seasons, using their preferred crop management practices.

Major nutrient deficiencies and toxicities

From 1992 to 1998, a total of 43 on-farm nutrient omission experiments were conducted throughout the country in the rainfed lowland environment during the wet season. Nitrogen was deficient at most sites (Fig. 2), but N deficiency was more prevalent in central and southern Laos. In some cases, a missing N response was attributed to recent land clearing, high soil organic matter content (i.e., high indigenous-N supply), and/or high residue applications. Phosphorus was the second most limiting nutrient, with 71% of the central and southern sites responding to P, and 37% in the north. At about 30% of the central and southern sites, the soils were so P deficient that there was no response to other nutrients unless P was applied. K was much less limiting than N and P (25% in the central and southern region, 11% in the north). Approximately 25% of the sites showed some response to the application of S, but responses were small and in most cases nonsignificant, although severe deficiencies were observed at some sites, for example, in Sekong Province.

Similar results were achieved for the irrigated dry season in 22 NPK omission trials undertaken from 1992 to 1999. With one exception, all sites showed a significant N response, 79% of the central and southern sites and 50% of the sites in the north responded to P application, and potassium was limiting at 29% of all central and southern sites and at 50% of the sites in the north. Dry-season yields without fertilizer were only 1.5 and 1.7 t ha^{-1} for the central and southern region and the north, respectively, whereas significantly higher average yields without fertilizer were recorded in the wet season (2.0 and 2.6 t ha^{-1} for the central and southern region and the north, respectively).

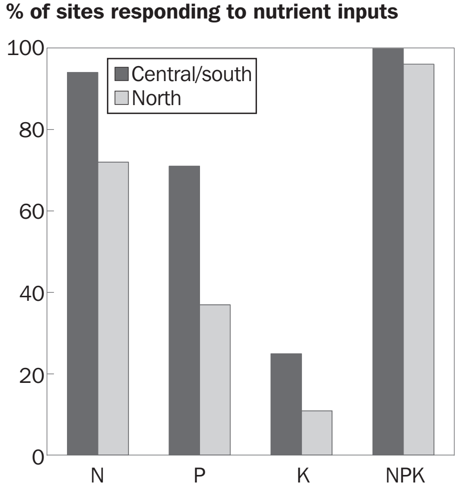

Fig. 2. The percentage of sites at which rainfed lowland rice responded to the addition of nitrogen, phosphorus, and potassium. Data represent means of 43 NPK omission trials (24 in the central and southern region and 19 in the north) conducted from 1992 to 1998 in the wet season.

No detailed analysis of toxicities and their importance is available for the rainfed lowlands in Laos, but Fe toxicity symptoms are regularly observed in farmers' fields, most often in paddies situated mid-slope, where iron-rich groundwater surfaces. Aluminum toxicities are also likely given the frequently very low soil pH and significant amounts of exchangeable Al (see Table 1); however, symptoms are rarely severe enough to be easily recognized in the field.

Effects and suitable rates of inorganic fertilizers

To evaluate the response of rice to N application, experiments were conducted at 20 sites (12 in central and southern Laos, 8 in northern Laos) from 1993 to 1998. The fertilizer-responsive, modern-type variety TDK1 was used in all trials. In all regions, there was a linear response to N applications up to 60 kg N ha^{-1}. Higher N doses did not increase yields in the north, but yield response remained linear up to 90 kg N ha^{-1} in the central and southern region (Fig. 3). Improved modern-type varieties (i.e., TDK1) usually showed higher yields and a better N response than traditional varieties in the central and southern region (Linquist and Sengxua 2001, Pandey, 2001).

Even though not all areas will show immediate benefits from the application of P, a general P application is advised because soil P levels are generally low and P deficiency is widespread, especially in central and southern Laos (see Table 1 and Fig. 2). Long-term strategies of P management with adjustments to reflect average yields are possible because P is highly immobile in the soil and seasonal fluctuations of crop

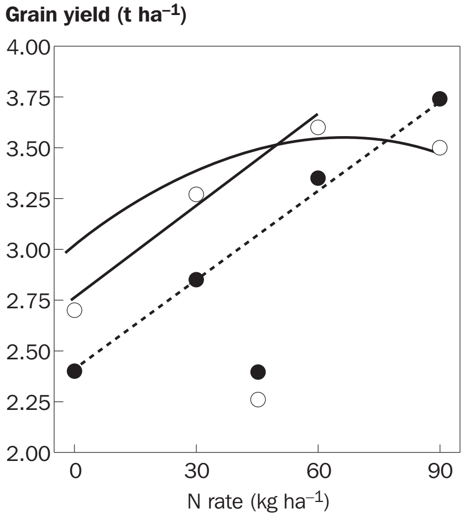

Fig. 3. The grain yield response of TDK1 to added N fertilizer in central/southern and northern Laos. The data represent means of 20 experiments (12 in the central and southern region and 8 in the north). The linear straight regression line for the northern points is added to illustrate that the response rate up to 60 kg N ha^{-1} is identical in both regions.

P needs can be buffered by the residual effects of applied P (data not shown). The P application rate can therefore be adjusted to reflect average yield levels (or target yields) based on crop P uptake. This approach also ensures that the P balance is near neutral, even if few crop residues are returned to the field. Table 3 shows the average N, P, and K uptake for improved modern-type varieties, indicating necessary P doses of 2.5 to 3.5 kg P (5.7 to 8.0 kg P_2O_5) per t grain yield if all crop residues are removed from the field and no organic fertilizers are used. However, responses to P application were quite variable across sites, which was attributed to the positive correlation of clay content and soil P-fixation capacity. Therefore, Linquist and Sengxua (2001) have proposed variable P doses for which first-time P application recommendations are 6–13 kg P ha^{-1} on sandy soils, 13–19 kg P ha^{-1} on loam soils, and 19–26 kg P ha^{-1} on clay loam and clay soils. Phosphorus applications for following seasons are adjusted to reflect target yields.

Potassium responses were observed on only a relatively small number of soils (Fig. 2). Where K deficiency occurred (e.g., Phiang District of Sayabouly Province), significant responses to K application and a strong correlation with the occurrence of the fungal disease brown spot were observed (data not shown). K deficiency is expected to increase in the future because of the increased use of fertilizers containing only N and P and the low soil-K supply of coarse-textured soils (Table 1), especially when

Table 3. Concentration and uptake of N, P, and K in rice straw and grain at harvest for improved modern-type varieties in rainfed lowlands of Laos. Based on Linquist and Sengxua (2001) (S1) and experimental data from the wet season 2003 (S2; n = 60).

Item	S1		S2		S1		S2		S1	S2
	Nutrient concentration				Nutrient per ton of grain yield[a]					
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Total	Total
	(%)				(kg t^{-1})				(kg t^{-1})	
N	0.79	0.32	0.88	0.37	7.9	4.8	8.8	5.5	12.7	14.3
P	0.19	0.04	0.24	0.07	1.9	0.6	2.4	1.1	2.5	3.5
K	0.28	0.79	0.32	1.09	2.8	11.9	3.2	16.4	14.7	19.6

[a]Assumes an average harvest index of 0.4 according to field data, i.e., if rice grain yield is 1 t ha^{-1}, straw yield would be 1.5 t ha^{-1}.

few crop residues are recycled. Rice straw at harvest contains about 80% of plant K (Table 3); therefore, straw management is critical for the K balance of the system. As Figure 4 shows, K deficiency can be induced quickly on many soils if the cropping intensity is high, fertilizers containing N and P only are used, and straw remaining on the field is burned or grazed (the dominant farmers' practices at the trial sites). Although these results were obtained in irrigation scheme areas, the same development can be expected in the rainfed lowland environment, albeit at a slower rate.

Limited data are available for a comparison of yield response to inorganic fertilizers in the wet (mostly rainfed) and dry (irrigated) seasons. As described above, the observed frequencies of N, P, and K deficiencies were similar in both seasons. Lower average temperatures in the dry season might influence indigenous nutrient availability and biological N fixation; however, the extent of such effects remains speculative, although average dry-season yields were lower in the unfertilized treatments of nutrient omission trials (Table 4). Higher dry-season solar radiation should increase the yield potential of crops grown during this time, but this does not influence the fertilizer response at low to medium fertilizer application rates. Comparisons of the full NPK treatment (60-13-17 kg N-P-K ha^{-1}) included in the nutrient omission trials (1992 to 1999: 43 wet-season trials, 22 dry-season trials) show that average yields were 3.4 t ha^{-1} (central and southern region) and 3.5 t ha^{-1} (north) in the wet season versus 2.7 t ha^{-1} (central and southern region) and 3.4 t ha^{-1} (north) in the dry season (Linquist and Sengxua 2001). However, these differences have to be interpreted with caution, as a much smaller number of sites was evaluated in the dry season. In the central and southern lowlands, lower average yields in the dry season were also observed in the participatory on-farm trials conducted between 2003 and 2005 (details below; Table 6). The highest-yielding nutrient management option tested resulted in a yield of 3.8 t ha^{-1} in the wet season and 3.2 t ha^{-1} in the dry season. In these trials, suboptimal irrigation by farmers might have contributed to a lower dry-season response.

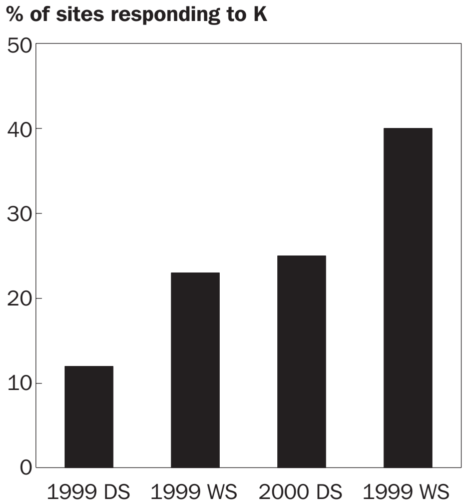

Fig. 4. Results of four seasons (DS and WS = dry and wet season, respectively) comparing the use of 16-20-0 NPK fertilizer and 15-15-15 NPK fertilizer as a basal fertilizer for rice. The graph shows the percentage of sites (total of 17 sites) at which use of 15-15-15 NPK fertilizer produced yields at least 0.4 t ha^{-1} greater than where 16-20-0 NPK fertilizer was used.

Integrated nutrient management solutions

The examples above show that, based on improved modern-type varieties, the use of inorganic fertilizers can effectively increase yields of rice-based lowland systems in Laos. But they also indicate that a balanced nutrient management strategy needs to be developed and adopted to avoid unsustainable nutrient management practices, and that improved crop residue management needs to be part of this strategy. Another important issue is the development of feasible application strategies especially adjusted to the variable water availability in rainfed systems.

Recycling residues has several potential advantages: the residues contain micronutrients not commonly found in inorganic fertilizers, they can contain substantial amounts of nutrients that would be expensive to apply as inorganic fertilizers (e.g., K in rice straw), and application of organic residues can maintain or even increase soil organic matter, which generally has a positive influence on soil fertility. Low costs are also often cited as an advantage of residues, but, as Pandey (1998) has pointed out, if input costs for their production and application (e.g., labor, land, and transportation) are included, nutrients from residues can often be more expensive than nutrients from inorganic fertilizers. Figure 5 shows some results from trials evaluating the effect of residues on yields and fertilizer-use efficiency. The application of inorganic fertilizer alone increased yields by 134% in Champassak Province and by 107% in Saravane Province, whereas residues alone increased yields by about 50% at both sites. In

Table 4. Agroeconomic indicators of different nutrient management options for lowland rice during 2003 to 2005 in Laos. On-farm results are presented separately for rainfed systems on coarse-textured soils, for irrigated systems in the dry season (DS), and for mostly rainfed rice in the wet season (WS). Improved modern-type varieties were used in all treatments.

Treat-ment	N-P-K applied	Org. material applied ($kg\ ha^{-1}$)	Com. organic fertilizer	Grain yield 14% MC ($t\ ha^{-1}$)	Yield gain over T2	AE[a] of applied N ($kg\ kg^{-1}$)	Costs[b] of fertilizer treatment ($US\$\ ha^{-1}$)	Gross value paddy	V/C ratio versus T2 –	V/C ratio versus T6 –	Benefit increase over T2 ($US\$\ ha^{-1}$)
Wet season 2004, rainfed rice, coarse texture (n = 11)[d]											
T2	0-0-0	0	–	1.57 c	–	–	0	204	–	–	–
T3	69-7-13	2,000	–	2.55 a	0.98 a	9	75	332	1.7	1.14	52
T4	33-4-8	2,000	–	2.36 ab	0.79 ab	13	51	307	2.0	1.20	51
T5	0-0-0	2,000	1,864	2.28 ab	0.71 ab	–	200	297	0.5	–	–108
T6	0-0-0	2,000	–	1.95 bc	0.37 b	–	6	253	7.9	–	42
Dry season 2003-04 and 2004-05, irrigated rice, medium texture (n = 16)[d]											
T2	1-0-0	563	–	2.04 c	–	–	3	224	–	–	–
T3	65-8-9	2,000	–	3.24 a	1.20 a	11	72	349	1.8	1.53	56
T4	34-4-5	2,000	–	2.83 b	0.79 b	8	42	305	2.1	1.56	42
T5	1-0-0	2,000	2,375	2.56 b	0.52 b	–	222	278	0.2	–	–165
T6	1-0-0	2,000	–	2.33 bc	0.29 b	–	7	250	6.1	–	22
Wet season 2003 and 2004, rainfed rice, medium texture (n = 20)[d]											
T2	4-1-0	250	–	2.32 d	–	–	4	282	–	–	–
T3	64-10-9	2,000	–	3.76 a	1.44 a	14	66	451	2.7	1.74	107
T4	35-6-6	2,000	–	3.34 ab	1.02 b	13	41	400	3.2	1.53	81
T5	0-0-0	2,000	2,300	3.27 bc	0.94 b	–	236	392	0.5	–	–122
T6	0-0-0	2,000	–	2.88 c	0.55 c	–	6	347	27.2	–	63

[a]Agronomic efficiency of applied N in kg grain per kg N applied was calculated in comparison to treatment 6. [b]Treatment costs did include costs for fertilizer and application. Costs of collection/production of organic matter were not included. [c]The average exchange rate during the trial period was US$1 = 10,000 Kip. [d]Values in a column followed by a common letter are not significantly different at $P = 5\%$ according to Duncan's multiple range test.

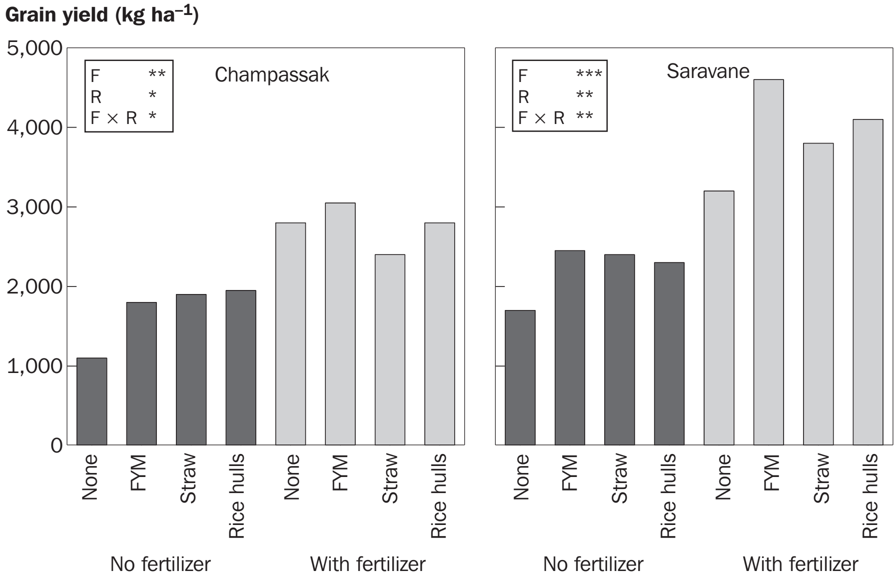

Fig. 5. Grain yield response to on-farm residues (2 t ha^{-1} on a dry-weight basis) with and without inorganic fertilizer. The inorganic fertilizer was applied at 60-13-17 kg ha^{-1} of N, P, and K, respectively. *, **, and * indicate a significant difference at *P* = 0.05, 0.01, and 0.001, respectively. F = inorganic fertilizer, R = residue, FYM = farmyard manure.**

Saravane, the responses to inorganic and organic fertilizers were additive, but significant negative interactions were observed in Champassak. These results confirm that organic fertilizers are a possible source of nutrients for increasing rice yields for cash-poor farmers. But, as most residues contain little N and P (see Table 3), large yield increases as a result of using organic fertilizers alone will not be possible. However, combinations of organic and inorganic fertilizer can increase yields substantially and contribute to sustainable improvements in soil fertility. Linquist and Sengxua (2001) also tested green-manuring technologies (data not shown) but did not recommend their use in Laos mainly on account of the high P requirements of green manures and the low indigenous-P supply of most soils in Laos (green manure crops were found to need twice the P input of that necessary for rice).

The benefits from combined use of organic and inorganic fertilizers are also indicated by partial nutrient balances conducted for several nutrient management options shown in Table 5. The balances account only for nutrients applied and for nutrient removal with the crop; however, they can be used as an indicator for sustainability. The partial balance for treatments with very limited fertilizer use (T1 and T2) was highly negative for N, P, and K. The use of improved varieties and application of organic materials reduced P and K losses slightly, despite higher yields (T6). Integrated fertilizer options combining organic and inorganic fertilizers resulted in positive or almost balanced N and P balances (T3 and T4), but the K balance remained negative, reflecting the dominant use of 16-20-0 NPK fertilizer. Application of organic materials

Table 5. Partial nutrient balance of different nutrient management options for lowland rice in the 2003 wet season in Laos (n = 12). Traditional varieties were used in treatment 1 whereas improved modern-type varieties were used in all other treatments. Treatment-dependent nutrients applied are shown as input from inorganic and organic fertilizer.

Treatment		T1	T2	T3	T4	T5	T6
				(kg ha^{-1})			
Grain yield		2,270	2,790	4,170	3,724	3,550	3,130
Straw yield		4,330	4,120	5,310	5,250	5,090	4,280
Nutrient removal	N	27.0	28.1	44.0	39.1	36.6	31.8
(with grain and	P	7.5	7.2	10.8	9.8	9.1	8.1
1/2 straw)	K	35.4	33.8	40.5	38.5	31.8	33.2
Input from	N	4.5	7.1	66.0	34.7	0	0
inorganic fertilizer	P	0.4	0.7	10.8	6.0	0	0
	K	0	0	4.0	3.1	0	0
Input from	N	1.0	2.1	10.0	10.0	60.6	10.0
organic fertilizer	P	0.3	0.6	3.0	3.0	18.3	3.0
	K	1.0	2.1	10.0	10.0	28.5	10.0
Balance	N	–21.5	–18.9	32.0	5.6	24.0	–21.8
	P	–6.8	–5.9	3.0	–0.8	9.2	–5.1
	K	–34.4	–31.7	–26.5	–25.4	–3.3	–23.2

and commercial organic fertilizer (T5) resulted in positive or neutral balances for N, P, and K, but, as indicated below, this option is not economically viable.

An average input of about 30 kg N ha^{-1} per crop from biological N fixation (BNF) has been reported for rice systems (Roger and Ladha 1992, Greenland 1997) although this amount can be lowered by the application of inorganic N (Roger 1996). Therefore, BNF might explain the negative N balances of treatments without significant inorganic N inputs (T1, T2, and T6 in Table 5), whereas positive N balances in the other treatments indicate N losses to the environment. It is questionable whether natural nutrient replenishment could compensate for the estimated P and K losses in T1, T2, and T6 (Table 5). Rainwater does contain considerable amounts of S but hardly any N, P, or K (Linquist and Sengxua 2001). The irrigation water in central and southern Laos can contribute about 0.5 kg P ha^{-1} and about 20 kg K ha^{-1} for a fully irrigated crop (Linquist and Sengxua 2001), but irrigation will also increase leaching losses.

The average yield increases shown in Table 2 and related higher nutrient exports are a recent development, and the capacity of existing systems to maintain current yield levels without increased nutrient inputs is uncertain. Nutrient balances for T1 and T2 (Table 5) might be extreme because of the very low average nutrient inputs, but they confirm the results shown in Figure 4. Negative K balances in the rainfed lowland environment have also been reported by Wihardjaka et al (1998) in Central Java. Medium levels of inorganic fertilizer inputs and low average yields resulted in slightly positive partial NPK balances for most farmers in a study in northeast Thailand (Wijnhoud et al 2003), but Vityakorn (1989) concluded that the biophysical sustainability of rice-based rainfed lowlands in Thailand might be limited to lower paddies because of nutrient inflows from fields higher in the toposequence. The partial nutrient balances in Table 5 confirm that recycling organic residues can reduce nutrient losses considerably, but even their use might not prevent unsustainable nutrient losses and unbalanced nutrient availability. In addition, increasing opportunity costs of labor make the use of organic fertilizers less attractive in many rainfed environments (Pandey 1998). Therefore, inorganic fertilizers will continue to have an important role, not only for increasing yields but also for maintaining the productivity of rainfed lowland rice environments.

Existing fertilizer management recommendations for rainfed environments are often derived from irrigated environments and are, as a consequence, rather rigid with regard to the rates and the optimal application timing. They are therefore not very helpful for farmers who have to cope with considerable variations in water availability in time and space. This problem concerns mainly N (urea) application, as P and K are normally applied prior to or at about the time of transplanting, when sufficient water is available. To solve this problem, Linquist and Sengxua (2003) have developed the concept of "windows of opportunity," in which "time-periods" instead of specific crop development stages are recommended for N application. This increases the possibility that adequate soil-water conditions for N application will occur at the recommended application time, thereby minimizing N losses due to nitrification-denitrification processes. The best N fertilizer response was observed when N was applied in three splits: around transplanting, at active tillering, and around panicle initiation (PI). The first N split can be applied in the period from just before transplanting to 30 days after transplanting without a significant effect on yield. The last application can be made between 2 weeks before and 1 week after PI (Fig. 6).

Agroeconomic evaluation of different fertilizer options

The general objective of researcher-driven nutrient management trials is to establish fertilizer-yield relations, to determine achievable yields, and/or to test the efficiency of different application strategies. To reach this goal, crop management conditions between sites/seasons are kept as uniform as possible, and close-to-optimal crop management practices are used. Economic parameters are rarely included. In contrast, farmers almost never pursue the goal of yield maximization for a specific crop. Instead, they follow several (sometimes contradicting) objectives, including optimizing returns on their investment (land, labor, and capital), to integrate all their activities on- and off-farm, to fulfill social/cultural obligations, to keep production risks at acceptable levels, and to sustain their resource base. This results in a considerable variation in crop management practices, which can be accentuated by the varying crop management skills of individual farmers. To evaluate the effects of such factors on the agroeconomic performance of nutrient management options, which will determine their acceptability and adoption by farmers, surveys or farmer participatory experiments can be used.

The first survey with this objective, following the introduction of improved crop production technologies in the lowland environment of central and southern Laos, was conducted by Pandey and Sanamongkhoun (1998) during the 1996 wet season.

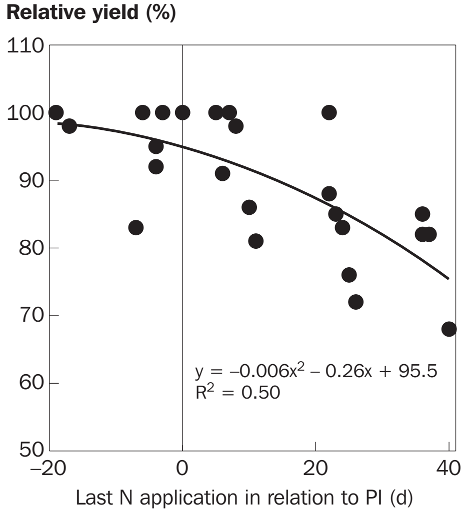

Fig. 6. "Window of opportunity" for N application at panicle initiation (PI). Relative yield (relative to the highest yield at each site) in relation to the timing of the last N application. The x-axis is the timing of the last N application relative to PI (i.e., PI is day 0).

Although 66% of the farmers reported using some fertilizer, the area being fertilized was only 48% of the area covered by the survey, and application rates were low (farmers who used fertilizers applied on average 37 kg ha^{-1}, with N and P_2O_5 being in equal proportions). About 60% of the farmers had commenced using inorganic fertilizers only in 1994. Fertilizers were used for both improved and traditional varieties, and were mostly applied on the middle terraces in the toposequence. Farmers who applied very low fertilizer rates usually confined the use of fertilizer to seedbeds or those parts of fields where rice did not grow well. The adoption of inorganic fertilizer use (and the use of improved varieties) was mainly determined by accessibility of the village. Soil type, contact with extension agents, education, and family size had no significant bearing on adoption. High-risk environments reduced the use of both inorganic fertilizer and modern varieties. The observed nutrient response to inorganic fertilizer (only N response was evaluated) was comparable to that in the rainfed environment of other countries (8 to 17 kg grain per kg of N applied), while the nutrient-to-grain price ratio was higher than in most other countries in the region (the price of 1 kg N was equivalent to 4.4 kg paddy). The highest net returns per land unit were observed when inorganic fertilizer use was combined with the use of improved varieties, confirming the higher fertilizer response of modern varieties reported by Linquist and Sengxua (2001). Based on this survey, Pandey (2001) concluded that more widespread use of inorganic fertilizers and/or the use of higher fertilizer application rates are unlikely

Table 6. Average farm-gate prices for fertilizer, paddy, and labor in southern Laos from 2003 to 2005.[a]

Fertilizer type	$N\text{-}P_2O_5\text{-}K_2O$ 16-20-0	$N\text{-}P_2O_5\text{-}K_2O$ 15-15-15	$N\text{-}P_2O_5\text{-}K_2O$ 46-0-0	Commercial organic fertilizer	Paddy	Labor
			(US$ kg^{-1})			(US$ day^{-1})
	0.26	0.29	0.28	0.11	0.12	1.53

[a]The average exchange rate during the trial period was US$1 = 10,000 Kip.

unless the return to investment can be improved through either lower fertilizer prices or increased fertilizer response.

Recent rapid changes in socioeconomic conditions in Laos, changes in farmers' crop management practices (see Table 2), and the considerable advances in the development of appropriate crop management technologies were the rationale behind the farmer participatory testing of different fertilizer management options between 2003 and 2005. Evaluated were unfertilized treatments with traditional and modern varieties, different combinations of organic and inorganic fertilizer rates, and one treatment testing "commercial" organic fertilizer. The last option was included on account of the establishment of factories for the production of organic fertilizer in all the main lowland rice-producing regions, providing a product of variable composition (including poultry manure, peat, rice straw, etc.) with variable nutrient content. In addition, farmers were being subjected to considerable marketing pressure to purchase and use the organic fertilizer.

Average prices of inputs and outputs are given in Table 6. In most cases, they varied only slightly between regions and seasons; exceptions were the comparatively high price for commercialized organic fertilizer in Savannakhet Province (US$0.17 per kg) and the low paddy price during the 2003-04 dry season in Champassak ($0.09 per kg). The average inorganic nutrient-to-paddy price ratio ranged from 2.2 to 2.4 (the price of 1 kg N was equivalent to 2.2 to 2.4 kg paddy) depending on the fertilizer type, which is roughly half the ratio reported by Pandey (2001), and this represents much more favorable conditions for inorganic fertilizer use. Reported labor prices were used to calculate costs related to fertilizer use based on average labor requirements. Costs for the collection/preparation of organic fertilizers were not included.

An overview of agroeconomic results for all treatments using improved modern-type varieties is presented in Table 4. The results were separated for the wet (mostly rainfed) and dry seasons (irrigated), and, within the wet season, for sites with coarse- (sandy) and medium (loamy)-textured soils. This distinction was made on account of the potential effects of soil texture on water-holding capacity, soil fertility, and fertilizer response. This association was reflected in the lower yields with or without very low application rates (T2) and a lower fertilizer response (T3–T6) for coarse-textured soils. General yield trends are identical for all three data sets and yields increase in the sequence T2 < T6 < T5 < T4 < T3 even though yield differences were not always statistically significant because of the high variability between fields. Average yield was lowest for coarse-textured soils in the wet season and highest for medium-textured soils in the wet season. Occasional pest pressure (weeds, birds) and suboptimal water supply (Champassak) contributed to the lower yields and yield response in the dry season, but these effects could not be quantified.

When compared to the unfertilized treatment (T2), all fertilizer options with the exception of the use of commercial organic fertilizer (T5) resulted in acceptable value/cost (V/C) ratios. Many agroeconomic studies have shown that small-scale farmers accept and adopt technologies only if they provide at least a return of 50% to 100% on their investment (V/C ratio ≥1.5 to 2) (CIMMYT 1989). The highest V/C ratios were achieved by the organic fertilizer treatment (T6) on account of the low costs of organic material (though not included in the treatment costs was the cost of production/collection of the organic matter). The results obtained from the use of organic fertilizer, with an average yield improvement of 0.4 to 0.6 t ha^{-1} relative to the unfertilized situation, were similar to results reported by Linquist and Sengxua (2001), and confirmed that the application of organic materials at medium rates (about 2 t ha^{-1}) represents a good option for farmers having no access to inorganic fertilizer. However, these yield gains represent the upper possible and sustainable limit given that the total straw yield was 2.4 to 3.4 t ha^{-1} (rainfed and irrigated production, respectively) and recognizing that farmers often have other potential uses for rice straw. When organic fertilizer had to be purchased for application (T5), this was always associated with negative returns. The comparison of the yield gains achieved with commercially available organic fertilizer (T5) and "conventional" organic fertilizer (T6) indicated that the former was approximately as effective as the latter, but the yield response was at a very high cost. Thus, commercial organic fertilizer cannot be recommended to rice farmers in the lowland environments of Laos.

Intentionally, none of the treatments tested was based on the application of inorganic fertilizer alone because the application of organic materials is highly recommended for the lowlands of Laos to avoid soil nutrient depletion, especially with respect to K and micronutrients (see Table 5). Hence, the agroeconomic response to inorganic fertilizer alone had to be estimated by comparing treatments T3 and T4 with T6 (Table 4). The observed value/cost ratios indicate an acceptable return to inorganic fertilizer on medium-textured soils (V/C ratios ≥1.5) but returns to investment were low on coarse-textured soils (V/C ratios ≤1.2). Although these calculations might have underestimated the actual response to inorganic fertilizer because of negative interactions of organic and inorganic fertilizer in some cases (Fig. 5), they do confirm repeated observations of limited response to inorganic fertilizer on very sandy soils in the wider region (Ragland et al 1987, Willet 1995, Haefele et al 2006). Although further studies are needed before final conclusions can be made, the results reported here suggest that fertilizer recommendations for coarse-textured soils (loamy sands or coarser) should give priority to the application of organic sources of plant nutrients, possibly accompanied by low rates of inorganic fertilizer (note the decreasing rate of return with higher fertilizer rates). Additional reasons for such a recommendation are that coarser-textured soils are often found in higher landscape positions, which are also more drought-prone and therefore represent a higher risk for any investment in inputs. It must be emphasized that this conclusion is targeted only at rainfed lowlands with coarse-textured soils; there are no indications that finer-textured soils in purely rainfed systems react any different than similar soils within irrigated schemes. This is confirmed by an analysis of 75 experiments in central and southern Laos from 1991 to 1999 by Linquist and Sengxua (2001), which showed good fertilizer response (mean agronomic efficiency of 15 kg grain per kg N applied) without excluding sites adversely affected by drought, flooding, or insect damage.

Future challenges and research opportunities

This overview of the results of nutrient management research for rice-based lowland systems in Laos shows that impact-oriented technologies are available, and that they are an important component of ongoing efforts to increase and maintain system productivity. Recommendations for extension and farmer use have been formulated, and are also available through the Internet at the IRRI Knowledge Bank. These guidelines describe the principles of nutrient management for rainfed lowland rice in Laos and provide simple advice on where, when, and how to use fertilizer. However, further development and testing of such guiding principles for input use and assisting with decision support tools should be a priority for rainfed lowlands in and beyond Laos. The frequent occurrence of abiotic stresses typical for these environments requires site-specific adaptation of nutrient management at the field level to make the best use of the scarce resources available to smallholder farmers. Particularly, substantial differences in field water availability caused by even small height differences in the toposequence can greatly influence production potential and risk (Oberthuer and Kam 2000). Consequently, a framework for site-specific nutrient management should consist of a combination of (1) regional nutrient management principles based on on-farm research with (2) farmers' site-specific knowledge of local water and soil resources, and (3) real-time (in-season) interventions based on field observations. The regional component refers to a "recommendation domain" with similar system components and conditions, for example, the lowlands in Laos or rainfed lowlands in northeast Thailand. Within this domain or region, farmers would have to choose from a few options developed and evaluated for specific production situations within the domain/region. In practice, these options could be presented in the form of a decision tree (Lampayan et al 1994). The last element would consist of flexible management advice allowing adjustment during the season as proposed by Linquist and Sengxua (2003).

Another important research issue is an adequate CNRM strategy for diversified cropping systems. Rice farmers often are reluctant to fully use existing irrigation capacity. Increasing energy (fuel) costs combined with stable or even declining paddy prices can be expected to exacerbate this problem. Only crops with a higher market value (relative to rice) will have the potential for increasing returns from dry-season irrigated cropping. Resulting challenges are to identify new sustainable cropping systems and to develop adjusted integrated nutrient management options. Changes in the cropping system will affect many factors determining soil fertility, including the annual duration of submerged soil conditions, the amount and quality of residues recycled, the residual effects of nutrients applied in one crop on the other crop, and disease and pest cycles. Understanding and managing these factors and their effect on soil fertility will be necessary to optimize the productivity of the new systems.

Further important changes in lowland rice production systems might occur in the near future to reflect recent advances in stress-tolerance breeding. Discoveries of quantitative trait loci for improved tolerance of acid soils and Al toxicity, of submergence, and of P deficiency (Mackill 2006) are targeting unfavorable environments like the lowlands of Laos, while marker-assisted breeding is allowing the rapid transfer of such traits into locally adapted germplasm. Largely unknown at this stage is the effect the use of such germplasm might have on natural resource management and the soil resource base, especially in fragile systems with limited buffering capacity. Without adequate nutrient replacement, the use of such germplasm could induce increased and accelerated soil nutrient depletion. Where fertilizers are applied, higher stress tolerance could contribute to higher fertilizer-use efficiency, higher productivity, and reduced nutrient losses. More stress-tolerant germplasm could also lead to the clearing and use of currently unproductive land, thus reducing remaining "wasteland" areas further. Agronomic research should examine such issues in advance to evaluate the possible consequences of such changes, while at the same time developing strategies for the best use of new and appropriate technologies.

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Notes

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CHAPTER 24

Improving upland rice-based cropping systems in Laos

B. Linquist, S. Kazuki, B. Keoboualapha, S. Phengchan, and K. Phanthaboon

Upland rice is the main crop grown in the highlands of northern Laos and along the Lao-Vietnam border in southern and central Laos. Upland rice is traditionally grown in slash-and-burn systems; the importance of this system and the production practices in it are described in Chapter 3.

The Lao-IRRI project began research on upland rice systems in 1991. Then, little was known about the Lao upland systems and their constraints, although Fujisaka (1991) had conducted a preliminary survey of the upland rice systems in northern Laos. Much of the early upland work conducted by the Lao-IRRI Project focused on characterization of the upland environment for biological, physical, and social factors. During the 1990s, the Houay Khot Research Station in Luang Prabang Province was upgraded (it is now the headquarters of the Northern Agriculture and Forestry Research Center, NAFReC) and most of the upland rice research was conducted at this station (and some research was also being conducted by the Lao-Swedish Forestry Program at the nearby Thong Khang Research Station). Research conducted during this period focused on variety collection and evaluation, weed management, evaluation of alternative crops to grow in upland rice-based systems, evaluation of a wide range of cover crops, and nitrogen-fixing trees. This work, which was conducted through 1995, is reported on by Roder (2001). It is not the purpose of this chapter to summarize this book, but rather to focus on the challenges currently facing upland rice farmers and the progress of research for developing solutions for the highlands.

A couple of key changes took place in the mid-1990s that have changed the direction and urgency for upland rice research. First, the government policy of land allocation started in the mid-1990s and, second, there has been considerable village migration from remote areas to roads (with the opportunities of markets, schools, electricity, and clean water). These factors have led to increased pressure on land, have shortened the fallow periods between crops, and have led to increased rice deficits (this is described in more detail later). This situation provided a sense of urgency for improved systems and in 2000 a shift took place from primarily on-station research to on-farm integrated and participatory research. The primary focus of this chapter is the on-farm research that took many of the technologies developed from 1991 to 1999 on-farm to test and further develop with farmers.

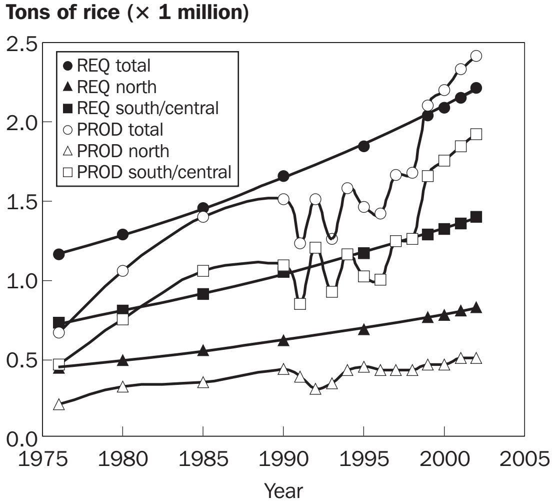

Fig. 1. Lao rice production and rice requirement by region from 1976 to 2002.

The upland rice system in Laos: a system in peril

Government statistics show that Laos is sufficient in rice domestically, but, in northern Laos, rice deficits (and consequently poverty) are common. Government statistics (Fig. 1) and survey data (i.e., ADB 2001) indicate that the situation is getting worse.

The current situation is ultimately the result of increased population pressure on limited land resources. Population pressure is increasing for several reasons. First is growth due to the annual population growth rate of 2.8% (UNDP 1999). Second is the land allocation policy that started in the mid-1990s with the intent of stabilizing or reducing slash-and-burn agriculture. This multistep process limits farmers to three or four upland fields—in effect allowing for a maximum of only two or three years of fallow. Third is village migration, causing increased pressure along roads. With roads, electricity, and water available along major road corridors, many remote villages are moving to the roads. Thus, upland field areas near the roads are under increasing pressure.

Land allocation was enforced to stop pioneering shifting cultivation (the cutting and burning of old or virgin forests) in order to protect forests and watersheds. Farmers are permitted to practice rotational shifting cultivation among the three to four fields they are allocated. According to the National Statistics Center (NSC 2004), the frequency of pioneering shifting cultivation is about half the level it was in 1997-98; however, rotational shifting cultivation is on the increase. The increase in rotation shifting cultivation is expected with a decline in pioneering cultivation.

The traditional rotational system for upland rice in slash-and-burn systems is a single year of rice followed by a long fallow. Roder (2001) reported that as late as

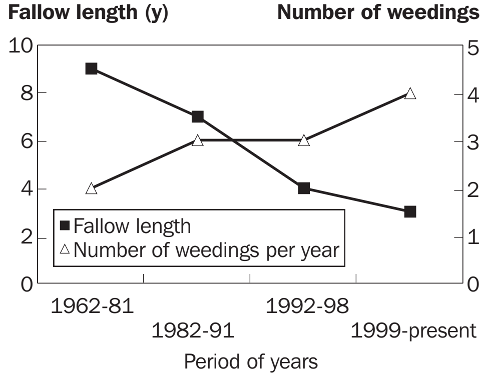

Fig. 2. Changes in fallow period and number of weedings required per season in upland rice from 1962 to 2002 (from Trosch 2003).

the 1950s fallow periods were as long as 40 years. Results from a study conducted in the northern provinces of Luang Prabang and Oudomxay (Trosch 2003) show that average fallow lengths declined from 9 years in the period from 1961 to 1981 to only 3 years now (Fig. 2). In fact, several villages in this survey reported only 2-year fallows. These short fallows are the result of farmers adhering to the land allocation policy and practicing rotational shifting cultivation among the plots they have been allocated. While it is not possible to state a figure for a minimum sustainable fallow period, it is generally accepted that 2- or 3-year fallows are not sustainable under current management practices. Short fallow periods have rendered these systems unsustainable as soil quality (because of nutrient depletion and erosion) is declining, weed pressure and labor inputs are increasing, and yields are declining, with the end result being lower returns on productivity and increased poverty. This has been confirmed in a number of surveys in which farmers report yield declines and increased poverty as a result of short fallows (i.e., Trosch 2003, ADB 2001).

Upland production constraints

Results from a 1992 household survey (Roder 2001) indicate that farmers perceive weeds to be the main problem in their upland rice fields, with 85% of farmers mentioning them (Fig. 3). Pests are the next biggest problem mentioned by farmers. Pests include rodents (54%), insects (34%), domestic animals (15%), wild animals—mostly wild boars (11%)—and disease (8%). Drought is mentioned as the third biggest problem (47% of the farmers mentioned it). Other problems mentioned were land availability (41%), labor (24%), soil fertility (21%), and soil erosion (15%). The latter problems (and weeds), just mentioned, are likely to be of greater significance now, following land allocation and the resulting short fallow systems. These problems will not all be discussed in this section; weeds are discussed briefly above as well as in Chapter 20, land availability issues are discussed above and in Chapter 3.

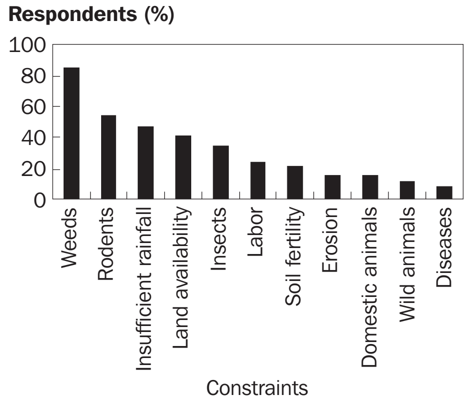

Fig. 3. Constraints to rice production in slash-and-burn systems (household survey conducted in 1992 with 129 correspondents from four districts in Luang Prabang and Oudomxay provinces). Land availability includes the constraint of short fallow and insect pests are mostly white grub. Data from Roder (2001).

Weeds. Weeds and weed management are addressed in detail in Chapter 20, so here the problem is discussed only briefly. Fallow length and the labor required for weeding are closely related. Long fallows that are dominated by perennial weeds require only two weedings, whereas fallows of only two or three years (dominated by annual weeds and grasses) require four to five weedings (Fig. 2). Weeding alone accounts for about 50% of the total labor requirement of upland rice (150 person-days per year or more). As fallows shorten, farmers have to work harder but receive lower rice yields.

Drought as a problem. Upland rice is rainfed and drought is often a problem. Analysis of rainfall data and upland rice yields at Houay Khot suggests that early-season drought (i.e., May) has little effect on rice growth, provided the drought is not severe enough to kill the crop. Upland rice is most sensitive to drought during tillering and panicle initiation and total rainfall from June to August is significantly correlated with upland rice yields (Fig. 4).

Soil fertility. Relatively little research has been done on the soil fertility status of upland soils. Soil nutrient deficiencies of 10 soils (from Pak Ou District, Luang Prabang) were measured in a pot study. Results show that nitrogen (N) and phosphorus (P) were deficient in all soils, potassium (K) in 50% of the soils, and sulfur (S) in 80% of the soils (Table 1). When P was not added, biomass decreased the most (only 29% compared to when all nutrients were added). K was only marginally limiting as average yields decreased to only 83% when K was not added.

From 1991 to 2003, 26 fertilizer trials were conducted in upland rice fields. Only 7 of the trials resulted in a significant grain yield response to applied fertilizer (Table 2). In all cases where there was a significant yield response, the response was

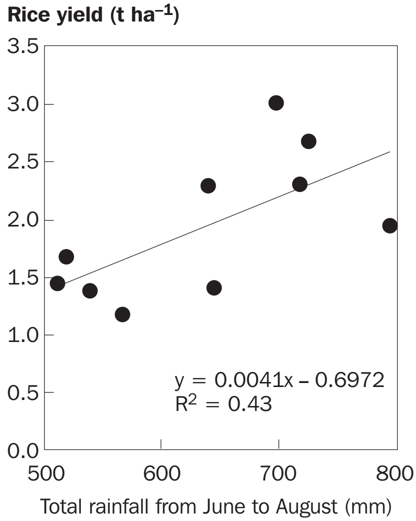

Fig. 4. Upland rice grain yield in relation to total June to August rainfall at Houay Khot, Luang Prabang. Data are from 1992-2003; however, in two years, rainfall data were not available.

Table 1. Relative biomass of rice grown in soils (from five villages in Pak Ou District) in response to different nutrients. "All" indicates the addition of all nutrients to the pots, whereas the other pots had all nutrients minus N, P, K, or S. Fallow length and soil parameters are provided for each site.

Relative biomass response to nutrients						Site and soil (0–15 cm) parameters				
Village/site	All	–N	–P	–K	–S	Fallow (years)	Total N (%)	Organic C (%)	Bray P (mg kg^{-1})	pH
HS-1	100	31	29	89	54	2	0.22	2.13	5.77	5.95
HS-2	100	57	32	96	45	4	0.23	2.48	4.30	5.97
HS-3	100	54	41	99	60	7	0.19	1.91	5.47	5.03
HS-4	100	62	28	76	76	9	0.20	2.13	4.53	4.75
HL-1	100	25	35	70	29	7	0.22	2.17	4.60	5.81
HL-2	100	51	18	76	72	5	0.26	2.56	2.23	4.80
PC-1	100	26	35	70	32	3	0.17	1.65	3.95	6.04
PC-2	100	28	31	81	31	59	0.17	1.84	3.90	5.85
MM-1	100	58	21	87	86	6	0.28	3.11	3.13	4.74
MM-2	100	63	16	89	92	?	0.27	2.96	5.35	4.52
Mean	100	46	29	83	58					
% sites deficient		100	100	50	80					

Table 2. Summary of fertilizer trials conducted on upland rice from 1994 to 2003.

Fertilizer applied ($kg\ ha^{-1}$)			Number of sites tested	Sites with significant yield response	Comments
N	P	K			
30	0	0	18	3	–
30	20	0	2	0	–
40	30	0	2	2	N increased yields at both locations. P had no effect on yields at either location.
0	20	20	1	0	–
100	50	50	3	2	When NPK was added, yields doubled at two sites (no response at one site). No significant response to P applied alone.

to N (applied either alone or with P and K). There was never a response to P applied alone for several possible reasons:

1. The application rates were too low to observe a response given the high field variability. Where N rates were only 30 kg ha^{-1}, a yield response occurred at only 15% of the sites. In contrast, when N rates were 40 kg ha^{-1} or higher, the yield response was significant at 57% of the sites. In fact, where 100 kg N ha^{-1} (+P) was applied, yields doubled at two of the three locations (the site where there was no response had been in a 15-year fallow and soil fertility would have been high).
2. In most cases (70%), N was applied alone. It is possible that at some sites P would be limiting and there would not be a response to N unless P were also applied.
3. Traditional varieties were used in all cases. Traditional varieties are usually not highly responsive to fertilizer.
4. Fertilizer uptake may have been low due to runoff.

In summary, upland soils are deficient in N and P. Fertilizer responses would have been more visible in the field if higher rates were used, both N and P applied, and responsive varieties used. Such nutrient deficiencies are expected in soils, especially under short fallows. Soil fertility needs to be managed in a sustainable and economically viable manner. These issues will be discussed below.

Pests and diseases. The main upland rice pest mentioned by farmers is rodents. Rodents and their management are discussed separately in Chapter 19.

White grub (scarab beetle) is the main insect pest to upland rice. It has a one-year life cycle. During the dry season, adults live 1 to 2 m underground. With the onset of rains, adults emerge, flying to nearby trees in search of food and mates. Eggs are laid about the time farmers plant rice. The larvae eat living roots of plants (including rice). White grub damage is most severe in dry years as the white grub may largely denude the rice crop's root system.

Studies monitoring white grub in Luang Prabang and Oudomxay at weekly intervals indicate that the damage increased until about 6 to 8 weeks after planting, after which it declined. In these studies, up to 50% of the hills were damaged by white grub but the number of damaged tillers was relatively low (less than 25%). No studies have evaluated yield loss due to white grub or white grub control.

While these are the most common pests and diseases identified by farmers, nematodes and root aphids may be problems, especially in intensive cropping systems. Some diseases that occur are blast, leaf scald, and brown spot. Again, these diseases are more typically found under more intensive systems with which most farmers are not yet familiar.

Development of alternative systems

These issues have created a demand from farmers and government agencies for alternative agricultural solutions. Such technologies have not been adequately introduced along with land allocation. Solutions can focus on (1) improved rice production systems or (2) developing alternative cash crops that allow for income generation and cash to buy rice. Experiences from other Asian countries suggest that farmers are much more likely to diversify into other crops once they have achieved self-sufficiency in rice. Thus, rice sufficiency is a platform for diversification. Lao-IRRI and NAFRI have been working together to develop sustainable rice-based systems for the Lao highlands since 1991. Research has focused on improving both upland rice and highland paddy systems. In this chapter, upland rice systems are discussed while highland paddies are covered in Chapter 25.

As agricultural systems intensify, traditional slash-and-burn systems with forest fallows are replaced by annual cropping systems (Fig. 5). Agricultural intensification generally results in the intensification of land use and labor. In Laos, traditional upland rice production practices have not changed despite shorter fallows. Research is being conducted to identify improved cropping systems that are sustainable under the current land-use practices, thus focusing on systems with zero (annual cropping) to 2- or 3-year fallows. A multifaceted research approach is used that combines the development of suitable varieties with alternative rice-based cropping systems (Fig. 5).

Improved short-fallow systems

Varieties. Traditional upland rice varieties are grown extensively in the Lao uplands; in fact, no known improved upland varieties are being grown. The diversity of varieties is high, with most villages growing 10 to 20 different varieties and a single farmer growing, on average, two or three varieties. These varieties have been selected for long-fallow conditions and are usually not suited to the short fallows that many farmers are currently using.

Since 1991, the Lao-IRRI Project has been collecting and preserving traditional Lao varieties. The Lao gene bank currently has over 13,000 accessions, with about half being upland rice varieties (Chapter 9). These varieties are being screened to identify

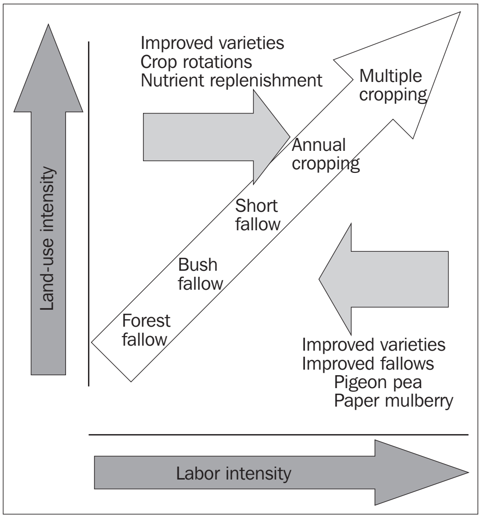

Fig. 5. Pathways for the intensification of shifting cultivation (after Raintree and Warner 1986). Research areas are highlighted.

early and medium-duration varieties that perform better under short fallows. Final testing and evaluation of varieties are done through participatory variety selection (PVS) trials under farmer management and have been conducted in all the northern provinces. Final selection of varieties is based on farmer preference and yield. Currently, two glutinous upland rice varieties have been identified that yield 0.3 to 0.5 t ha^{-1} more than local check varieties (an 18–27% increase in yield) (Fig. 6). Nok is an early-duration variety that has good yield and receives high farmer preference ratings because of its large seeds and panicles, ability to perform in poor soils, and high quality (aroma and softness). Makhinsoung is a medium-duration variety that also receives high farmer preference ratings, but its grain quality is lower than Nok's.

While most of the research has focused on glutinous rice, the program has started evaluating nonglutinous varieties that are preferred by certain ethnic groups (i.e., the Hmong and Aka). These varieties originate from Laos and other countries. On-farm testing began in 2003.

Cropping systems. In slash-and-burn systems, fallows provide several important functions, which include the following. First, they allow time for nutrients to be replenished in the soil. Nutrients are added to the system through nitrogen (N) fixation, rainfall, leaf litter, and exploitation of deep soil layers by deep-rooted plants. Second, weeds are reduced. Under long-fallow systems, annual weeds die out and are replaced by perennial weeds, which are much easier to control. Third, biomass builds up. High biomass generally (not always) means more nutrients but also more biomass to burn. A hot burn kills many weed seeds. Finally, pest cycles are broken.

Two-year weedy fallows are not sustainable under current management practices and improved systems will require some form of fallow enrichment. Since N is gener-

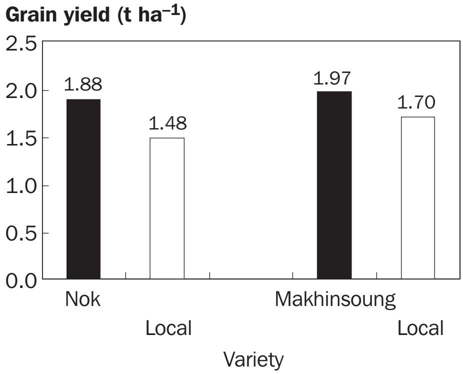

Fig. 6. Grain yields of Nok and Makhinsoung compared with those of local check varieties. Data are over 5 years and represent more than 25 locations in most provinces of northern Laos.

ally the most limiting nutrient, shrubby legumes are often used for fallow enrichment. These legumes not only add N to the system (through N fixation), but many are deep rooting and are able to extract nutrients from soil layers that rice cannot. Through leaf fall, these nutrients are moved to the soil surface, where rice and other crops can use them. Many shrubby legumes also grow fast and can develop a high amount of biomass in a relatively short period of time.

Through on-station research conducted from 1991 to 2000, four promising fallow species emerged: leucaena (*Leucaena leucocephala*), pigeon pea (*Cajanus cajan*), paper mulberry (*Brousonnetia papyrifera*), and crotalaria (*Crotalaria anagyroides*). All are legumes except paper mulberry, which is an indigenous fallow in northern Laos. The system involves establishing the species with rice in the first year. Following the rice harvest, the species are left to grow as a 2- or 3-year fallow, after which, they will be cut, burned, and planted to upland rice again. Through participatory on-farm research with these species, farmers preferred paper mulberry and pigeon pea as potential fallow species. Based on further discussions with farmers, the requirements of a good fallow or rotational species are that it

- provides some economic benefit,
- is easy to grow and maintain,
- needs minimum labor, and
- maintains or improves rice yields.

The challenge for research is to not only identify such species but ones that also address the long-term challenge of sustainability so that yields are maintained, soil fertility is replenished, weeds remain under control, and soil erosion decreases. The two most promising systems (paper mulberry and pigeon pea) are discussed separately below.

Table 3. Effect of rotational crops on rice yields, weeds, nematode infestation, and soil parameters. From a three-year study at Houay Khot, Luang Prabang. Rice was grown in all treatments in the 1st and 3rd years. In the 2nd year, different crops were grown.

Rotational crop	Rice yield ($t\ ha^{-1}$)			3rd-year observations				
	1st y ($t\ ha^{-1}$)	2nd y	3rd y ($t\ ha^{-1}$)	Weeds (fresh wt.) ($t\ ha^{-1}$)	Nematodes (# g^{-1} root)	Soil pH	Soil Total N (%)	Soil Olsen P ($mg\ kg^{-1}$)
Continuous rice	3.4	1.8	1.3	5.1	63	6.3	0.26	5.2
Pigeon pea	3.3	–	2.3	3.2	13	6.5	0.28	7.0
Cowpea	3.4	–	1.6	5.2	33	–	–	–
Stylo	3.2	–	1.8	3.3	21	–	–	–
Maize	3.5	–	1.8	3.3	10	6.3	0.24	4.6
Natural fallow	3.2	–	2.2	4.9	2	6.0	0.25	5.8
LSD (5%)	ns		0.5	1.4	33	ns	ns	2.0

Source: Roder et al (1998).

Rice-pigeon pea. Pigeon pea is one of the most promising crops for rotation with rice. The rice-pigeon pea system is as follows: pigeon pea is planted with rice in the first year (Photo 24.1). Pigeon pea will continue to grow after the rice has been harvested. Pigeon pea is a perennial and pods can be harvested once a year—usually in March and April for the local varieties. The pigeon pea remains in the field (it can survive for 2 to 3 years) until the field is ready to be prepared for the next rice crop and then is cut. When planting the next rice crop, pigeon pea will need to be planted again.

Roder et al (1998) provided a review of the pigeon pea research conducted in Laos through 1996. Research included pigeon pea variety evaluation and evaluation of pigeon pea as an improved fallow. In summary, local pigeon pea varieties were well suited for use as a fallow crop. Improved varieties yielded higher but local varieties performed better in terms of total biomass production and weed suppression. Compared with other potential rotational crops, pigeon pea was also better. In a 3-year crop rotation trial, it was reported that rice yields were higher following pigeon pea (Table 3). Furthermore, pigeon pea decreased weeds and nematodes in rice and increased available soil P. These results were supported by another study that compared 1-year fallows of pigeon pea and leucaena with natural fallow and continuous rice. After the third year, rice yields (rice yields are generally low because of drought) were highest following the pigeon pea fallow (Fig. 7).

Two main problems with using pigeon pea as a fallow crop for rice were mentioned by Roder et al (1998). First, 15 months after planting, only 9% of the pigeon pea survived (despite it being a perennial) because of weed suppression. Second, upland rice yields were up to 60% lower when rice was grown with pigeon pea. Recent research on pigeon pea has focused on trying to solve these problems. Findings suggest that

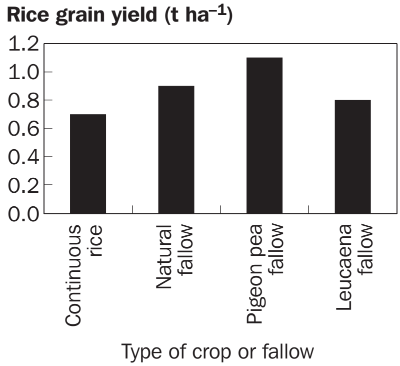

Fig. 7. Rice grain yields in the third year following either continuous cropping or different types of fallow. Pigeon pea and leucaena were planted with rice during the first crop at a spacing of 1.25 × 1.25 m. In the third crop, leucaena was cut and allowed to recopice and pigeon pea was cut and replanted.

using a low pigeon pea density (1.25 × 1.25 m) in combination with delayed planting (planting pigeon pea 3 weeks after rice) results in good pigeon pea growth and does not reduce rice yields. Roder et al (1998) used close plant spacing (1.0 × 0.25 m) and often planted at the same time. Furthermore, using wide pigeon pea spacing appears to increase pigeon pea vigor. In one study conducted in nine farmers' fields, pigeon pea was planted at 1.25 × 1.25 m spacing and 78% of the pigeon pea was still surviving 18 months after planting. Wider spacing is likely to reduce grain yields. When plants are planted close together, grain yields for local varieties averaged over 1 t ha^{-1}, compared with about 0.5 t ha^{-1} with wide plant spacing.

Despite its promise as a fallow crop, farmers have been slow to adopt because of the limited market potential of pigeon pea in Laos. In 2003, when a market was available, farmers showed considerable interested in the system. Economically, it appears to be a viable option. In the first year, rice yields are the same as without pigeon pea. Assuming a 0.5 t ha^{-1} pigeon pea yield at US\$0.16 kg^{-1} (the price being offered in 2004), a farmer can expect to receive \$80 from the pigeon pea in the first year, more than a 25% increase in average household income. This figure does not take into account the second-year pigeon pea harvest (a second-year harvest is possible but yields are lower), a yield increase of rice following a pigeon pea fallow, and reduced weeding requirement after pigeon pea. From the labor standpoint, pigeon pea is also attractive. Planting at a wide spacing requires little labor (about 1 person-day) and seed (4 kg ha^{-1}). No additional labor is required until harvest. Although the harvest requires a significant amount of labor, demands on labor are low during March and April.

Table 4. Survival and growth of different paper mulberry planting materials established in upland rice and yield of upland rice.

Planting material	Survival at end of first wet season (%)	Paper mulberry height (cm)	Rice yield (t ha^{-1})
Seedling	80	139	2.13
Root sucker	42	85	2.05
Root cutting	5	51	2.13

Evaluation of a pigeon pea-rice rotation is continuing, with research focusing on different fallow lengths. Different varieties are also being evaluated, with special attention being given to pod borer resistance. Pod borer insects bore into pigeon pea pods and can significantly reduce yields.

Rice-paper mulberry rotations. Paper mulberry has become an important cash crop in northern Laos. The inner bark is harvested and used for paper production. Paper mulberry is an indigenous fallow species and research has focused on the feasibility of intensifying paper mulberry as a rotational crop between rice crops (Photo 24.2). After establishing paper mulberry into upland rice, it will continue to grow after the rice has been harvested. The paper mulberry is harvested 1.5 to 2 years after establishment and harvesting can continue until the next rice crop, at which time all the paper mulberry is harvested and the trees cut down in order to prepare the field for rice. The paper mulberry will regenerate from roots and stems during the rice-growing season to continue the next cycle. Research on rice-paper mulberry rotations has focused on the following aspects:

1. Paper mulberry establishment into upland rice fields: Three planting materials were tested (seedlings in polybags, root suckers, and root cuttings). Survival and growth were best for the seedlings, followed by root suckers (Table 4). In all cases, paper mulberry growth was slow during the first year of establishment and did not reduce rice yields. However, because of slow initial growth, weeding is still necessary after the rice harvest until the paper mulberry has become fully established.
2. Rice production following paper mulberry: When paper mulberry regenerates from its roots and stems, it is highly competitive with rice (unlike the establishment phase). To sustain rice yield, the regenerated paper mulberry needs to be managed carefully by maintaining a low density and a canopy that is below the rice. Densities of more than 1 plant 4 m^{-2} have been shown to reduce rice yields (Fig. 8).
3. Nutrient cycling: Research is ongoing to study nutrient cycling in these systems to determine whether such systems are sustainable in terms of maintaining or building soil fertility.
4. Models are being developed to estimate paper mulberry bark yield.

Although this system is indigenous to Laos, few farmers have intensified the system by planting and closely managing paper mulberry. As long as the market remains

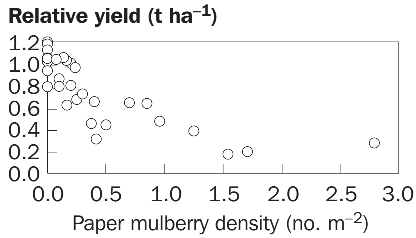

Fig. 8. Relative yield of rice at varying densities of paper mulberry.

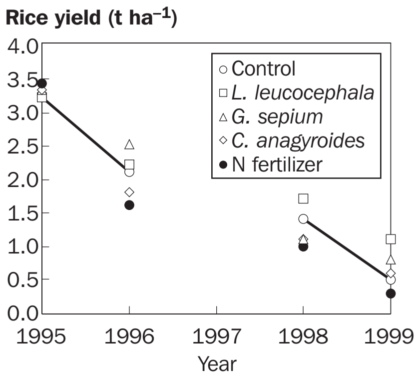

Fig. 9. Rice yields during a 5-year cropping period with different shrubby legumes planted with rice. Legumes were planted in hedgerows at 1.5-m spacing with 4 rows of rice grown in between. In 1997, rice was planted but no rice harvest data were available.

good for paper mulberry, this system has potential. It is also attractive in that most of the labor requirement for paper mulberry is during periods when labor demand is low. The main limitation is that cattle and buffaloes graze on paper mulberry leaves, so the area needs to be protected.

Alternatives for annual cropping

Annual cropping, as referred to here, is the yearly production of annual crops on a given plot of land. Developing improved annual upland rice-based systems presents a unique challenge compared to other cereal crops. Yields decline rapidly when rice is continuously cropped. In a 5-year experiment conducted in Luang Prabang, upland rice yields declined from more than 3 t ha^{-1} to 0.5 t ha^{-1} when rice was grown every year (Fig. 9). Such results are seen elsewhere in Laos (Table 3, Fig. 7), Asia (George et al 2001), and South America (Evenson et al 1995, Sanchez 1983). The reasons

Table 5. Comparison of variety performance under continuous rice cropping. At all sites, rice had been grown every year for at leas the previous two years.

Variety	Houay Khot	Tinpha (kg ha^{-1})	Long Lao	Variety mean
Chao Mat	2,430	1,565	1,925	1,973
Laboun	1,406	604	1,034	1,015
MHS	1,404	459	337	733
Nok	965	367	729	687
Vieng	959	240	169	456
ANOVA ($P<0.05$)	0.0001	0.0000	0.0000	

for this yield decline are not well understood, but research suggests that soil fertility decline is not solely responsible. Yields declined when N fertilizer (30 kg N ha^{-1} at booting) was applied or when rice was grown between legume hedgerows (Fig. 9). Results of other studies also indicate that nutrient limitations (including phosphorus) are not responsible for the rapid yield declines observed when rice is grown continuously (George et al 2002, Evenson et al 1995, Sanchez 1983). Increased weed pressure associated with successively cropped fields may be a cause of declining rice yields; however, it is probably not the sole cause. Even when weeds are well controlled (as in the experiments above), rice yields continue to decline. Some evidence suggests that the nematode *Meloidogyne graminicola* is a factor (Prot and Matias 1995). Indeed, nematode numbers and nematode infected roots are higher in successively planted rice (Table 3). Although the cause of the yield decline is not clear, it may be a combination of the above factors. Current research is focusing on understanding the cause as well as developing sustainable upland rice-based systems.

Varieties. There has been limited research testing varieties in continuous upland cropping systems. However, some varieties seem to do better than others when continuously cropped. In an experiment conducted in Luang Prabang in 2002 in a field in its third rice cropping cycle, several varieties produced yields from 1.4 to 2.0 t ha^{-1}, whereas the rest yielded 0.5 t ha^{-1} or less. In 2004, this work was continued at three sites that had been continuously cropped with upland rice for at least the previous 2 years. Five varieties were compared: Chao Mat, Laboun, Nok, Makhinsoung, and Vieng. Nok and Makhinsoung were two promising varieties for short-fallow systems and Vieng is a popular local variety in the Luang Prabang area. Across sites, Chao Mat (a nonglutinous variety) yielded 2.0 t ha^{-1}, which is above the national average for upland rice (Photo 24.3) (Table 5). Laboun, a glutinous upland variety from Savannakhet, yielded 1.0 t ha^{-1}. Vieng, the local variety, yielded less than 0.5 t ha^{-1}, whereas Nok and Makhinsoung yielded about 0.7 t ha^{-1}. These data clearly show that certain varieties perform better under intensive annual cropping systems. Nok and Makhinsoung, which are good varieties for short-fallow systems, do not perform well under intensive continuously cropped rice systems. It is not clear why some varieties perform well under these situations and others do not, but this is currently being investigated.

Improved varieties will be an important component of annual cropping systems; however, they will need to be integrated into appropriate cropping systems.

Cropping systems. Little research has been conducted on intensively cropped annual upland rice systems. Based on the research conducted, the following points can be made.

Crop rotations. Rotation with other crops will be necessary for sustainable systems; however, research to date to identify suitable rotational crops is not promising. Rice yields continued to decline when cowpea, maize, and stylo were used as rotational crops (Table 3). The most promising species has been pigeon pea (Table 3, Fig. 7), which can be grown as a perennial or an annual. Research is ongoing to study the potential of rice and pigeon pea in more intensive annual systems. Pigeon pea is not a host for nematodes (Roder et al 1998) and, if planted properly, can limit the growth of other weeds that may be alternative hosts for nematodes.

Nutrient replenishment is necessary. Nutrient replenishment will be necessary in any intensive cropping system where crop products are removed annually. In slash-and-burn systems, long fallows allow for natural soil rejuvenation. In annual systems, such enrichment can come from crops being rotated with rice (such as cover crops, green manures, or hedgerows) or from fertilizers. These are discussed separately below.

Nutrient replenishment from companion crops. Hedgerows are often promoted as a good source of nutrients for annual crops grown between alleys. A study was conducted in Luang Prabang to evaluate the growth of rice between different hedgerow species (leucaena, crotalaria, or glircidia). In all cases, rice yields declined (Fig. 9). Rice is currently being evaluated in a system where it is grown between stylo that is planted along the contour lines (Photo 24.4). Stylo could potentially be used as a forage for livestock or could be cut and left in the field. As discussed earlier, nutrient limitations do not seem to be the cause for the yield decline. However, if suitable crop rotations and varieties are used between the hedgerows, rice may grow better and the hedgerows may provide a valuable source of plant nutrients.

Cover crops are another option to be considered for upland rice. Again, little research has been done on the topic but there are several considerations. First, care must be taken that the cover crop does not compete for water, light, and nutrients with the rice. Cover crops have been most successful in areas with long wet seasons. In northern Laos, the wet season is short and rainfall is variable. Crops that offer the most promise in these conditions are those that can be established into rice late in the growing season and then become a dry-season fallow crop. Second, as mentioned above for the alternative fallow crops, farmers are not likely to grow a crop that does not itself provide some form of economic benefit. Finally, if the cover crops require a lot of labor to establish, manage, and harvest, many farmers may not be interested. For most farmers, labor is too limiting to spend growing a crop that cannot be harvested.

Scope for fertilizers. Farmers will unlikely apply fertilizers to upland rice in the near future for at least three reasons.

1. Varieties currently being used are traditional and have limited response to fertilizer. As discussed above, fertilizer trials to date have shown only a small response.
2. Fertilizer application is labor-intensive. Dibbling fertilizer (as opposed to broadcasting) may be necessary to prevent fertilizer runoff, especially on steep slopes. Dibbling requires significant labor. Furthermore, many fields are located a long way from the village and are accessible only by foot, making it difficult to get the fertilizer to the field.
3. Fertilizer application is risky. Even if the response to fertilizer is good, uncontrollable factors such as drought and pests can reduce yields, making the fertilizer application a waste.

Conclusions

Declining upland rice yields as a result of increased land pressure are resulting in rice deficits and poverty in northern Laos. The diversity and complexity of the uplands requires an integrated and participatory research approach to identify suitable and sustainable cropping systems. Although alternatives to upland rice can be developed, it has been our and others' experience that farmers prefer to grow at least a portion of their rice needs. Once rice security is assured, farmers are much more willing to test alternatives. In this paper, we have discussed some potential technology options that can maintain or increase upland rice yields in these systems. Given the diversity and complexity of the uplands, these alternatives have limited recommendation domains and may not be suitable for all upland rice-growing areas in Laos. Ongoing upland rice research will continue to be necessary to continue to meet the challenges faced by upland farmers.

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Notes

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CHAPTER 25

Montane paddy rice: opportunities for increasing food security in the highlands of Laos

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J. Basnayake, D. Guenat, and L. Douangsavang

Laos is the most mountainous country in Southeast Asia, with 35% of the area having slopes of 8–30% and 54% of the area having slopes of greater than 30% (FAO). The main mountainous areas are in the north (the focus of this chapter) and along the Lao-Vietnamese border. Lowland rice (paddy) is grown in the highlands either in flat valley bottoms or on terraced hillsides (see Chapter 3 for a description) and in this chapter will be referred to as "montane paddy." Food security is a problem in the highlands (ADB 2001) and increasing paddy productivity or expanding paddy area are two options for improving food security there.

Northern Laos has some extensive valleys such as those found in the provinces of Sayabouly and Luang Namtha, where lowland rice production is basically similar to that of the large plains in the southern and central agricultural regions of the country. Large irrigation schemes have been developed and the livelihood of farmers centers on lowland rice production. Extensive lowland areas are limited in the north, and in most areas farmers rely on their upland fields to grow upland rice and other rainfed upland crops. However, in many of these "upland" villages (villages normally have 35 to 100 households), there are small areas of paddy land ranging from less than 1 ha to about 10 ha (Photo 25.1).

This chapter is divided into four sections. In the first, the expansion of highland paddy area and the driving forces behind paddy expansion are discussed. The effects of montane paddy on food security and farmer livelihoods is discussed in the second, while the third presents a cost-benefit analysis of paddy development. The fourth section covers the research issues being examined and related progress.

In the first three sections, the report of Trösch (2003) is referred to extensively. In 2003, Trösch conducted a survey to better understand the role of paddy in the livelihoods of highland farmers. The survey was conducted in three districts (Phonsay, Pak Ou, and Namo) in the provinces of Luang Prabang and Oudomxay, and included 93 households in 9 villages (Table 1). Households with and without lowland paddy were selected in each village. The total lowland area per village ranged from 0.2 to 22 ha. The percentage of households owning lowland rice fields averaged 35%, and ranged from 2% (Houay Thoum in Pak Ou) to 89% (Namo Neau and Pangdou Tai in Namo). The average area of paddy (for those farmers with paddy) in each village

Table 1. Overview of lowland holdings in the nine villages surveyed in 2003.

Province (district)	Village (no. of households)	Lowland area (ha)	Households with lowland rice	Average size of lowland holding (ha)	Lowland area for each village household (ha)
Luang Prabang	Huayman (48)	2.25	5	0.45	0.05
(Phonsay)	Thapho (57)	6.3	13	0.48	0.11
Oudomxay	Namo Neau (56)	22.12	50	0.44	0.39
(Namo)	Pangdou Tai (18)	8.75	16	0.55	0.49
Luang Prabang	Hatsua (56)	3.64	5	0.73	0.07
(Pak Ou)	Haouyleaung (63)	12.6	20	0.63	0.20
	Haouythum (41)	0.2	1	0.20	0.005
	Latthahae (109)	16.73	28	0.60	0.15
	Packaek (125)	30	49	0.61	0.24

Source: Trösch (2003).

Table 2. Resource allocation in relation to area (ha) of lowland owned.

Lowland ownership category	Total land resources available[a] (ha)	Average amount of lowland (ha)	Average amount of upland[a] (ha)	Percentage of upland area used for upland rice
None	1.39	0	1.39	69
> 0 and < 1 ha	1.44	0.46	0.98	68
> 1 ha	2.41	1.55	0.86	38

[a]Does not include fallow fields.
Source: Trösch (2003).

ranged from 0.2 ha in Houay Thoum to 0.73 ha in Hatsua. With the exception of one farmer, all households surveyed owned upland fields. For the purpose of analysis, the households were divided into three categories based on how much lowland they owned: (1) those that had no lowland (n = 54), (2) those that owned less than 1 ha of lowland (n = 29), and (3) those that owned more than 1 ha of lowland (n = 10). Total land resources (not including fallow upland areas) were similar for households with little or no paddy area. Those with a small amount of paddy also had less upland area (Table 2). Households with more than 1 ha of lowland had less upland area than other households, but their total land resource of 2.4 ha was, on average, 1 ha more than for the other categories.

Table 3. Wet-season lowland rice area (000 ha) by province in the northern region of Laos.

Year	Bokeo	Houaphanh	Luang Prabang	Luang Namtha	Oudomxay	Phongsaly	Sayabouly	Northern region
1991	4.29	6.83	7.97	2.03	12.50	4.85	9.08	47.55
1992	4.88	7.21	7.73	2.54	5.04	4.75	11.94	44.08
1993	6.08	6.54	8.64	5.01	6.83	4.85	9.28	47.24
1994	6.45	7.55	8.77	5.15	7.01	4.69	13.96	53.58
1995	7.08	8.29	8.21	5.80	7.52	5.31	17.99	60.21
1996	6.88	9.61	9.13	7.21	8.25	5.63	19.43	66.14
1997	8.50	10.23	9.37	7.00	8.69	5.70	17.79	67.28
1998	9.15	9.52	9.53	7.07	7.82	5.72	20.25	69.05
1999	9.78	11.29	9.68	7.49	8.73	5.75	20.33	73.03
2000	10.20	11.40	9.80	7.90	9.20	5.40	21.50	75.40
2001	10.37	11.54	10.26	10.29	9.77	5.79	21.67	79.69
2002	11.53	11.47	10.67	10.74	9.81	4.94	21.62	80.77

Paddy development in Northern Laos

Expansion of the montane paddy area

In the northern region, the province of Sayabouly has the largest lowland paddy area (over 22,800 ha in 2002), with all of the other northern provinces having from 10,500 to 13,000 ha, with the exception of the most northerly province of Phongsaly, which has only 5,000 ha (Table 3). The lowland area in the north expanded steadily during the 1990s, a process that continues to the present day. In 1991, the total area of rainfed lowlands in the northern region was 47,000 ha; by 2002, it had increased to nearly 81,000 ha—an increase of almost 70% (Table 3 and Fig. 1). This 6% annual increase in lowland paddy area in the north was considerably higher than for the country as a whole (3.7% per year). There has also been an increase in the dry-season (irrigated) paddy area in the north. Until 1994, the total dry-season lowland rice area remained below 2,000 ha; however, from 1995 to 2000 this area expanded to almost 8,000 ha (Fig. 1), but since then has stabilized at 6,000 ha. The greatest expansion of lowland rice area in the north has been in the provinces of Bokeo, Luang Namtha, and Sayabouly, all of which have relatively large flat areas that are easy to convert to paddy cultivation. However, the expansion has not been confined to these provinces. Trösch (2003) reported that in the nine "upland" villages covered by her survey, lowland area increased only a little from 1962 to 1998; however, from 1998 to 2002, the total area of lowland paddy increased from an average of 3.5 ha per village to more than 12 ha per village (Fig. 2). Although the growth rate was not uniform between villages, all villages expanded their lowland rice area to some degree after 1992.

Why farmers have expanded their lowland paddy area

Three policy initiatives may have either directly or indirectly supported the expansion of rice paddy in the north. First, the government provides an exemption from the payment of land tax for the first three years after construction of lowland terraces. This

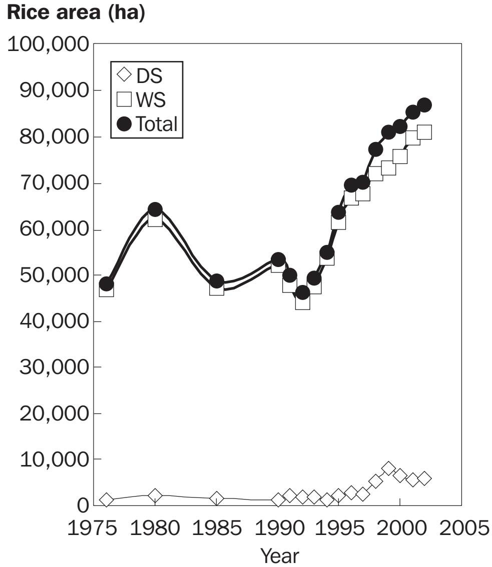

Fig. 1. Wet-season (WS) and dry-season (DS) lowland rice area in the northern region of Laos from 1976 to 2002.

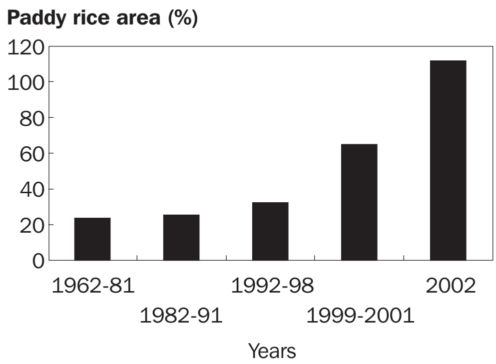

Fig. 2. Changes in rice paddy area from 1962 to 2002. Data adapted from Trösch (2003) and from a survey conducted in 9 upland villages (Luang Prabang Province: Phonsay and Pak Ou districts; Oudomxay Province: Namo District) and each had at least some paddy land.

Table 4. Reasons why farmers develop lowland fields.[a]

Reasons	Percentage of respondents
Lowland rice production requires less labor input than upland rice production (higher productivity) and so there is more time for other activities	25
Response to the government policy of stopping slash-and-burn shifting cultivation	21
Higher yields and higher yield stability (=> higher food security) than in upland rice cultivation	11
Farmer has had appropriate land for lowland cultivation	11
Farmer does not like shifting rice cultivation	11
Parents of the farmer already cultivated lowland rice	7
Time period in which lowland rice cultivation is labor-intensive is shorter than in uplands	7
Lowland rice cultivation has a higher sustainability than upland rice cultivation	4
Farmer does not have enough satisfactory fertile upland area since land allocation	4

[a]Responses are from 28 farmers who owned at least some lowland rice fields (Trösch 2003).

exemption amounts to about 12,000 kip per ha per year (about US$1.20 in 2004). Second, the Agricultural Promotion Bank of Laos (APB) provides credit to farmers interested in developing paddy land. The extent to which these initiatives have contributed to the rapid expansion of the lowland rice area in the north during the 1990s is unclear; however, it is generally acknowledged that these tax and credit incentives have probably not been the major incentive in influencing the decision of farmers to expand their paddy area (Trösch 2003).

The main policy initiative that seems to have encouraged the expansion of lowland paddy area in the north is that of land allocation. Although the objective of land allocation is to stop slash-and-burn agriculture in upland fields, the immediate effect has been to shorten fallows to only two or three years. Such short fallows are unsustainable and the declining upland rice yields in areas covered by the land allocation program have forced farmers to seek alternative production systems. One option available to farmers has been the expansion of lowland paddy area. Trösch (2003) reported that stopping shifting cultivation in response to the land allocation program, associated with the limited area of fertile land available under the land allocation policies, was one of the main factors influencing farmers' decisions to develop lowland paddy area (Table 4). Data showing the rapid expansion of the paddy area in the late 1990s (after land allocation) also support this consensus (Fig. 2).

Farmers also mention two other reasons for wanting to develop lowland paddy area (Table 4). First, lowland rice production requires considerably less labor input than upland rice cultivation. Roder (2001) reports that the labor input for upland rice cultivation in northern Laos averages almost 300 person-days per year (of which about

Table 5. Number of years of rice shortage according to land ownership.

Years of rice shortage	No. of respondents	Average rice area (ha)	
		Lowland	Upland
0	37	0.54	0.89
1–4	44	0.18	0.74
5–10	12	0.11	0.75

Source: Trösch (2003).

50% is for weed control) compared with about 120-person days per year for lowland rice. The labor saving with the move to lowland rice cultivation allows households to spend more time raising livestock and, to a lesser extent, cultivating alternative cash crops. The second major reason for farmers wanting to expand their lowland paddy area (cited by about 15% of the respondents) is the higher yield and increased sustainability from lowland rice cultivation relative to upland cultivation. Average upland rice yields are 1.5 and 2.0 t ha^{-1}, depending on length of fallow, rainfall, weed competition, etc. Montane lowland rice yields are generally from 3 to 4 t ha^{-1}, and are much more stable than upland yields because water shortages during the cropping season are less of a problem. Furthermore, in areas with access to water during the dry season, there is potential for two rice crops a year.

The main constraints cited by farmers to developing lowland paddies are a lack of suitable land for such development, the steepness of slopes, poor soils, and a lack of water (Trösch 2003).

Effects of paddy land ownership on food security and livelihoods

In discussing rice self-sufficiency, it is recognized that farming households also consume other crops such as maize and root crops (such as cassava) when rice supplies are inadequate. Depending on the household, rice consumption needs may come from upland and/or lowland rice fields. The amount of lowland owned had a direct effect on the food security of individual households. In a survey of Trösch (2003), households with an average lowland rice area of 0.54 ha experienced no rice shortages in the last 10 years, whereas households with an average lowland area of 0.18 ha had between 1 and 4 years with rice shortages; households with an average of 0.11 ha of lowland experienced rice shortages in 5 to 10 of the years (Table 5). These results are similar to those reported for northern Vietnam (Pandey and Minh 1998), where farmers with an average lowland holding size of 309 m^2 per capita experienced only one year or no food shortages in the previous 10-ten year period; however, if the average per capita holding was 154 m^2, they reported rice shortages almost every year.

In the Lao survey of Trösch (2003), farmers reported that, if they have lowland rice fields, in addition to improving their food security, they are able to grow more

Table 6. Effects on livelihood activities of a shift from upland rice to lowland rice cultivation.[a]

Effects	Percentage of respondents
More cash crops are grown	24
Better food security	19
Increased livestock production and fish farming	19
Stopped upland rice cultivation	16
More time for trading	11
Expansion of paper mulberry plantation	8
More time for working as wage labor	3

[a]Responses are from 37 farmers who owned at least some lowland rice area (Trösch 2003).

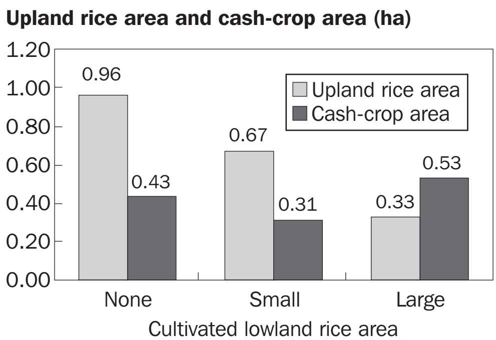

Fig. 3. Upland area used for upland rice and cash crops based on amount of lowland a household cultivates.

cash crops in their upland fields and allocate more time to raising livestock and trading (Table 6). Furthermore, 16% of the respondents reported being able to cease slash-and-burn agricultural practices. In general, the detailed household economic data support these reports. Households that had more than 1 ha of lowland used less than 40% of their upland holdings for rice production; the rest was used for cash crops and gardens (upland farmers refer to a garden as any field that is continuously cropped, i.e., Job's tear garden, teak tree garden, etc.) (Fig. 3). Households with little or no lowland area grew upland rice on almost 70% of their upland fields. Several reasons are possible for farmers in all lowland ownership categories continuing to cultivate upland rice. The main reason is to meet their household consumption needs. This is almost certainly the case for households with a small lowland area. Second, upland rice is usually harvested about one month earlier than lowland rice. Therefore, the cultivation of upland rice provides a supply of rice at a time when household rice stocks

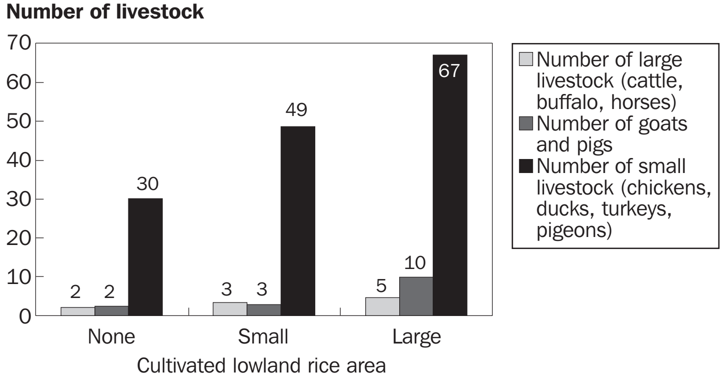

Fig. 4. Average number of livestock being raised by farmers with differing amounts of lowland rice area.

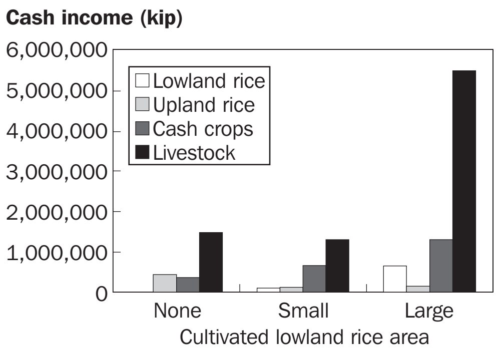

Fig. 5. Average cash income by source shown by the cultivated lowland rice area. This calculation includes only sold products. Small lowland area = >0 and <1 ha, large lowland area = ^{3}1 ha. US$1 = 10,560 kip.

have usually been depleted, as well as allowing farmers to spread labor demand during the period of the rice harvest. Third, upland rice is generally considered to be of higher quality than lowland rice, taste better, and, when sold, retail at a higher market price than lowland rice. Finally, upland rice is a good cash crop. Upland rice prices are stable and farmers are familiar with the crop. Other cash crops that are grown in upland areas of northern Laos include Job's tears, sesame, maize, chili, and cotton.

One of the most striking differences among the three lowland ownership categories was that farmers with areas of lowland rice had, on average, more small and large livestock than households that had no lowland (Fig. 4). The number of livestock per household also increased with larger holdings of lowland. In addition, these livestock became the most important source of household cash income (Fig. 5).

Benefit-cost analysis of paddy development

Paddy development requires terracing fields. On flat valley bottoms, this requires relatively little work; however, as the slope increases, more soil has to be moved to make flat-terraced paddies (Photo 25.2). In addition to developing the terraces, canals and weirs need to be constructed to carry water to the paddies (Photos 25.3 and 25.4). In some cases, canals may be required to carry water for a couple of kilometers. Weirs are often constructed of wooden logs, which are used to dam a stream. Although these irrigation systems can be simple and based on the use of local materials and labor, an opportunity cost is associated with their development. This cost is incurred in the initial years when the terraces are constructed. Subsequently, an annual cost is usually associated with the stabilization and maintenance of the system.

For an economic assessment of paddy development, it is necessary to account for the incremental costs and benefits that are realized, over several years. Costs of paddy development are incurred in the first few years, whereas the benefits accrue in the future. As the immediate benefit is valued more highly than the same benefit at some time in the future, the later benefits and costs need to be suitably discounted to make them comparable.

The major benefits from the conversion of sloping upland fields into terraced paddy land are the savings in labor input for rice production, together with the improved yield and increased frequency of cropping over time. The labor released associated with the move to increased lowland rice cultivation may, in turn, be used for income generation activities or for supporting other livelihood activities.

A full-fledged assessment of the economic value of paddy development requires accounting for all changes in the farming systems and labor use in nonfarm activities that are induced by the availability of paddies. Such a complete assessment is outside the scope of this chapter. Instead, a somewhat "partial" analysis is conducted by considering only the major changes in the farming system that are likely to be observed.

The estimates of the various parameters needed for a benefit-cost analysis are presented in Table 7. Most of these parameters were obtained from farm surveys.

Development of terraces involves considerable movement and relocation of surface and subsurface soil. As a result, it takes several years for rice yields to stabilize in a developed terrace. In the economic analysis, rice yield has been assumed to increase linearly from 1.5 t ha^{-1} in the first year to 3.4 t ha^{-1} in the third year. Lowland rice yields in northern Laos are typically 3 to 4 t ha^{-1} (Linquist et al 1998).

The economic performance of paddy development was measured in terms of the internal rate of return (IRR), net present value (NPV), and number of years required to recoup the cost of paddy development (or the break-even period). The IRR is the average return earned by the investment made. If the IRR is higher than the going interest rate at which farmers can secure a loan, the investment can be considered to be profitable. The NPV measures the total gain from investment made over the planning horizon. It is calculated by netting out all costs from the benefit streams and suitably discounting these streams for a different time value of money. For an investment to be profitable, the NPV must be greater than zero, with a higher NPV

Table 7. Values of parameters used for the base run.

Parameter	Values used in the base run
Discount rate (%)	10
Yield of upland rice (t ha^{-1})	1.7[a]
Yield of paddy rice (t ha^{-1})	3.4[a]
Cash cost of production of upland rice ($ ha^{-1})	10[b]
Cash cost of production of paddy rice ($ ha^{-1})	20[b]
Farm-gate price of rice ($ t^{-1})	70[b]
Cost of constructing terraces, weirs, and irrigation canals ($ ha^{-1})	300[c]
Frequency of rice cultivation in paddies	Once per year
Frequency of rice cultivation in uplands	Once every third year, with fallow in between
Planning horizon (years)	25
Loss of rice area because of terrace construction (%)	10
Number of years needed for the rice yield in paddies to reach the assumed yield	3[c]
Labor savings in rice production (person-days) per household	280[d]

[a]Data source: MAF (2002). Yield data are for northern region. [b]From survey data. [c]From survey data reported in Trösch (2003). [d]Assuming the average household size of six members and per capita rice requirement of 350 kg per year, the total production needed to meet the household requirement is 2.1 t. Given the assumed rice yields, the upland and lowland rice area required to produce this amount is 1.2 ha and 0.6 ha, respectively. The corresponding savings in labor, using labor use per ha from Roder (2001), is thus approximately 280 person-days (calculated as $1.2 \times 294 - 0.6 \times 122$).

indicating greater gains. The break-even period is an intuitive indicator of the profitability of paddy development. It measures the number of years needed for the initial investment in paddy development to break even. The shorter the break-even period, the more attractive the investment will be.

The estimated NPV measures the net gain in present value of switching the production of household rice needs from upland to lowland conditions by constructing terraces. Over the 25 years considered for the exercise, farmers have the potential to gain a total of $690 per ha after deducting all costs associated with terrace development (Table 8). The IRR indicates that the investment will yield an annual return of around 51%. By most commercial standards, an annual rate of return of 51% is considered to be good.

A more intuitive interpretation of the profitability is provided by the estimated break-even period. It takes approximately 4 years for farmers to recoup the cost of investment through higher rice yields and gains from savings in labor input. Farmers who have a planning horizon shorter than 4 years may not consider the construction of terraces a rewarding proposition under the assumptions of the economic exercise.

Table 8. Base run results.

Parameter	Resulting value
Net present value	$690 ha^{-1}
Internal rate of return	51%
Break-even period	4 years

The results are sensitive to the opportunity cost of the labor released as a result of terrace construction. The profitability of terrace construction increases rapidly with the increase in the opportunity cost of labor released. Thus, farmers who have a high opportunity cost of labor are likely to find rice production in paddies a more viable economic proposition than those whose opportunity cost of labor is low. The cost of developing a terrace is the major investment cost. The results of terrace construction can therefore be expected to be sensitive to this parameter. If the cost is half the amount assumed in the exercise (only $150 ha^{-1}), the IRR jumps to 98%.

The profitability of terrace construction is also determined by the number of years needed for the full development of the productive capacity of terraces after the initial soil disturbance. The faster the productive capacity of the paddy fields is stabilized, the shorter the break-even period will be. Thus, farmers are likely to find construction of terraces more attractive on the gentler slopes that require less soil disturbance. Alternatively, better technologies for terrace construction and stabilization to quickly achieve the yield potential of a fully developed terrace would be desirable.

Research issues and progress

Why conduct research on montane lowland systems?

Rice-based research on the montane lowland system in Laos is important for several reasons. First, poverty levels are greatest in the more mountainous areas (ADB 2001) and the provinces with the greatest levels of poverty are in the mountainous north. A clear association has been shown between the incidence of poverty and level of household rice sufficiency (ADB 2001). Yields of rice, farmers' staple crop, are declining in upland fields of the north, further aggravating rice deficits. Because of poor infrastructure, it is not cost-effective to transport rice from areas of rice surplus in central and southern Laos to these remote mountainous areas. Lowland rice systems exist in these mountainous areas but grain yields in these systems are generally low and variable.

Improving the productivity of lowland rice or increasing the area of lowland rice in montane areas can reduce the pressure on rice cultivation in upland areas, thereby allowing farmers to have the opportunity of implementing more sustainable cropping strategies in their upland fields. Farmers with greater areas of lowland rice are also more likely to diversify into other crops in their upland fields.

An important theoretical exercise is to estimate the potential reduction in upland rice cultivation that might accompany a move to greater lowland production in mon-

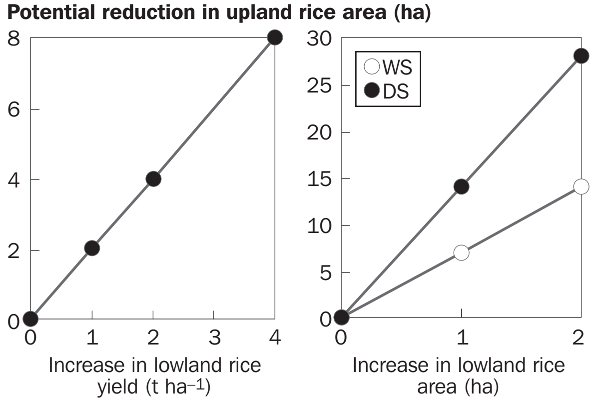

Fig. 6. The potential effect of increased lowland rice productivity or increasing lowland rice area on upland rice area.

tane areas. Assuming that upland rice yields average about 1.5 t ha^{-1} and that there is a 3-year cropping cycle with rice being grown after 2 years of fallow, an upland field would have a theoretical production potential of 0.5 t ha^{-1} per year. Lowland rice, on the other hand, can produce an average of 3.5 t ha^{-1} per year (or possibly as much as 7.0 t ha^{-1} per year if irrigation is available to allow double cropping). Using these assumptions, if rice yields from existing lowland fields can be increased by an average of 1 t ha^{-1} per year, this increased lowland production has the potential of replacing 2 ha of upland rice, which might then be allocated to the cultivation of other upland crops. When the increased lowland rice production comes from the development of new paddy areas, using the above assumptions, for every hectare of lowland developed, the upland rice area could potentially be reduced by 7 ha if rice is grown only in the wet season in the lowland area, or by 14 ha if dry-season rice production is also possible (Fig. 6). This exercise assumes that farmers grow rice only for subsistence purposes. However, Trösch (2003) reports that lowland farmers still grow upland rice as a cash crop even when they own large areas of lowland. Until good markets develop for other upland crops, it can be anticipated that upland rice will continue to be grown even by households that are able to meet their rice requirements through lowland cultivation.

A further reason for improving food security and rice productivity in montane areas is that 14% of Laos has been set aside as National Biodiversity Conservation Areas (NBCA). There are 20 such parks and most are located in mountainous areas with farmers living in and around them. Poverty and declining productivity of upland fields are forcing many of these farmers into foraging and using the conservation areas in an unsustainable manner. Ensuring food security in these areas by increasing the productivity from associated montane lowland areas may help protect these valuable conservation areas from overuse.

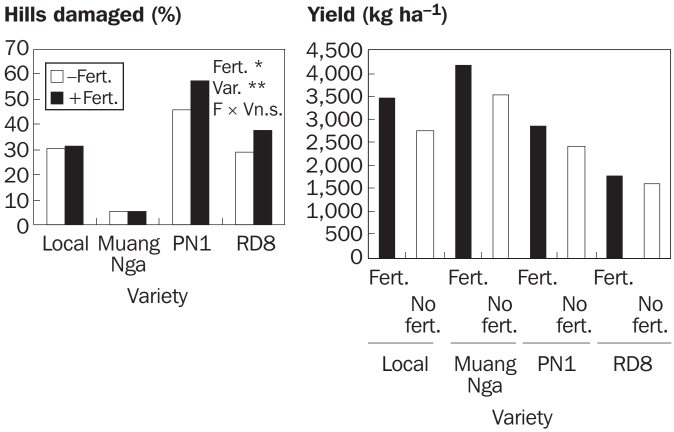

Fig. 7. Percentage of tillers damaged by gall midge and rice yields as affected by variety and fertilizer treatments. ns = nonsignificant.

Constraints to montane lowland rice productivity

Montane lowland rice yields in northern Laos are potentially higher than yields on the large plains of southern and central Laos because the lowland soils are generally more fertile in the north than in central and southern Laos (Linquist et al 1998). However, there are opportunities for increasing yields, stabilizing yields across years, and increasing paddy productivity; these issues form the basis of the research being conducted. In the wet season, gall midge is a major pest and, in some years, can cause severe reductions in rice yields. In the dry season, limited water for irrigation is the main constraint to growing lowland rice; however, there are opportunities for crop diversification where water supplies are available but inadequate for lowland rice. At high altitudes, cold temperature is a major potential constraint. Each of these issues is being examined, with the related progress being summarized in the following sections.

Gall midge. Traditional rice varieties perform well in lowland areas of the north, and can yield up to 4 t ha^{-1} in favorable years. However, yield fluctuations can be substantial from year to year. A major factor contributing to yield variability is the incidence of damage caused by the Asian rice gall midge (*Orseolia oryzae* Wood-Mason) (see Chapter 17). Gall midge damage is the most frequently cited constraint to production by lowland farmers in northern Laos. The damage is encountered only during the wet season, and is greatest in very wet years.

Increasing montane paddy productivity will require the use of improved varieties and better fertility management. However, the currently available improved varieties are highly susceptible to gall midge damage (Fig. 7). Furthermore, improving soil fertility increases gall midge problems (Fig. 7). Therefore, unless improved varieties with gall midge resistance are developed and introduced, substantial improvements in lowland rice yields in the montane lowland areas of northern Laos will probably not be feasible.

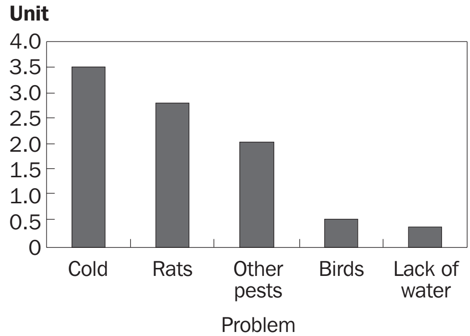

Fig. 8. Farmer-perceived problems to dry-season lowland rice cropping at high elevation. The higher the number, the greater the problem.

Two local varieties (Muang Nga and Mak Nge) have been identified as having resistance to gall midge. Muang Nga has been tested in the north with good results in terms of yield potential, while also confirming its gall midge resistance (Fig. 7). Muang Nga is a late-maturing wet-season variety that is proving to be popular in villages where farmers use late-maturing varieties. However, in villages where there is a preference for early- and medium-maturity varieties, crops of the later-maturing Muang Nga are targeted by pests after the harvest of earlier-maturing varieties. Mak Nge, a medium-duration variety, is currently still being evaluated by farmers. The breeding program is also focusing on the crossing of Muang Nga with improved popular early- and medium-duration varieties such as Thadokkham-1 (TDK1) and TDK5, in an attempt to produce a variety that combines the qualities of earlier maturity, fertilizer responsiveness, and resistance to gall midge.

Dry-season low temperatures. Low temperature is a constraint for farmers attempting dry-season lowland rice cultivation at high altitudes in northern Laos (Fig. 8). Temperature is related to elevation. Analysis of historical temperature data from meteorological stations throughout Laos show that, in the north, during November to January, there is, on average, a 0.92 ºC decrease in mean minimum temperature for every 100 m increase in elevation (Table 9) (Chanphengxai et al 2003). While these data are average monthly mean temperatures, daily minimum temperatures can go lower than 4 °C. For example, in 1999, minimum temperatures in Xieng Khouang reached below freezing during the same period (December 1999) and minimum temperatures dropped to only 2 °C in Luang Prabang (about 300 m elevation). The establishment phase of the rice crop during November to January is most vulnerable to low-temperature damage. Low temperatures result in poor seed germination and poor seedling growth. In December and January, the coldest months (Fig. 9), mean monthly temperatures in some northern provinces (e.g., Xieng Khouang) can be as low as 7 °C. Research on improving rice production at high elevations has focused on three main areas.

Table 9. Estimated mean minimum temperature (ºC) for November, December, and January for 100–1,500 m elevation in northern Laos.

Elevation	November	December	January
100	20.1	16.7	17.1
200	19.1	15.8	16.2
300	18.1	14.8	15.4
400	17.1	13.9	14.5
500	16.1	13.0	13.7
600	15.1	12.1	12.9
700	14.1	11.1	12.0
800	13.1	10.2	11.2
900	12.1	9.3	10.3
1,000	11.1	8.4	9.5
1,100	10.1	7.4	8.7
1,200	9.1	6.5	7.8
1,300	8.1	5.6	7.0
1,400	7.1	4.7	6.1
1,500	6.1	3.7	5.3

Source: ACIAR (2002, 2003).

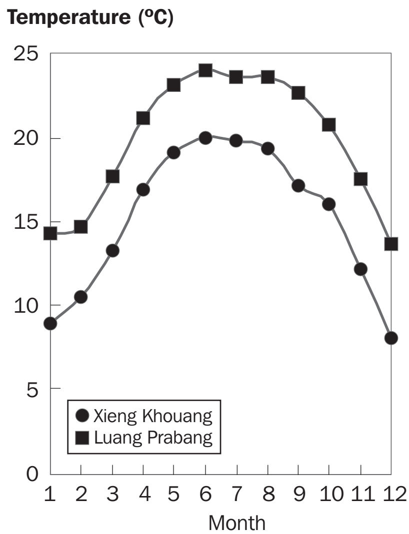

Fig. 9. Mean monthly minimum temperatures for Luang Prabang (300 m) and Xieng Khouang (1,100 m). Data are means from 1985 to 1997.

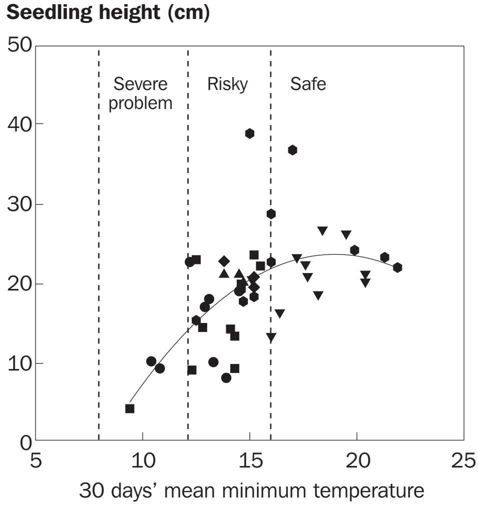

Fig. 10. Effect of 30 days' mean temperature on seedling height at Xieng Khoung.

1. *Identification of the critical mean monthly temperature for optimal sowing time*. Measurements of germination percentage and seedling growth indicate that the mean minimum temperature during the seedbed period needs to be at least 12 °C. When the mean minimum temperature is 12 °C during the period of seeding and early seedling growth, seedlings of the improved glutinous variety TDK5 can achieve a height of about 12 cm within 30 days after sowing; seedling growth and height increase rapidly with increasing temperature (Fig. 10). Using this critical temperature and the relationship between temperature and elevation described above, areas and periods have been identified where lowland rice production is risky. For example, at elevations above 900 m (as is common in Xieng Khouang), it is considered too risky to seed rice in November (Sihathep et al 2001).
2. *Improved nursery management to protect seedlings using plastic covers*. Covering the rice seedbed with plastic raises temperatures and results in improved seedling germination and growth (Photo 25.5). Two systems have been tested (Fukai et al 2003): the use of a plastic sheet to cover the seedbed, with the plastic being removed when the seedlings are about 5 cm tall; and covering the seedbed with a plastic dome until seedlings are sufficiently tall for transplanting. Nighttime temperatures inside the dome have been measured and are about 4 °C higher than the external ambient temperature, resulting in improved germination and seedling growth (Fig. 11). In areas where dry-season rice cropping can be affected by low temperature during the seedbed stage, the use of plastic domes in on-farm studies has been shown to increase yields by an average of over 0.5 t ha^{-1} (Table 10). An additional

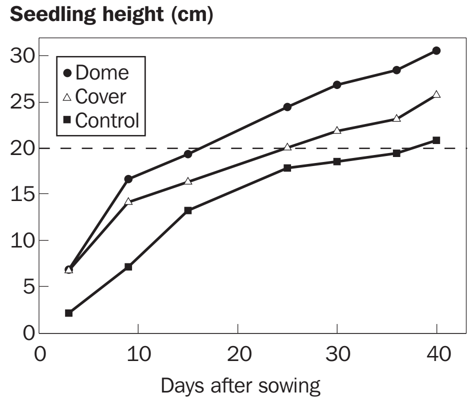

Fig. 11. Effects of nursery management practices on seedling height at Xieng Khoung.

Table 10. On-farm evaluation in Nam Bak (350 m), La (620 m), Namtha (550 m), and Sing (650 m) districts comparing the plastic dome with the traditional farmers' practice.

Province	District	No. of farmers testing	Treatment	Grain yield[a] (kg ha^{-1})
Luang Prabang	Nam Bak	3	Farmers' practice	2,020
			Plastic dome	2,416
Oudomxay	La	3	Farmers' practice	2,562
			Plastic dome	3,349
Luang Namtha	Namtha	2	Farmers' practice	2,951
			Plastic dome	3,483
Luang Namtha	Sing	2	Farmers' practice	2,463
			Plastic dome	2,973
Mean			Farmers' practice	2,458
			Plastic dome	3,021
			$P > 0.05$	0.0000

[a]The grain yield is the mean of farmers (2 or 3 replications) in each district. Statistics were obtained using each farmer (10 in total) as a replication.

benefit of the use of plastic domes that has been reported by farmers is that they help protect the seedlings in the nursery from rat damage.

3. *Improved crop management*. Good management with the use of appropriate varieties is needed to reduce the time the dry-season rice crop is in the field to allow time for field preparation for the main wet-season crop. Ideally, farmers would like to harvest their crop in April. However, low temperatures combined with late-duration varieties often result in farmers having to harvest in May or June (and sometimes even as late as July). Using plastic covers or

Table 11. Average number of days to flowering (TDK6) when 30-day-old and 45-day-old seedlings (grown under three nursery treatments) were transplanted in Xieng Khouang (Kham District) during the 2003-04 dry season.

Treatment	Age of seedlings		
	30 days	45 days	Av
Conventional	138	144	142
Plastic cover	134	136	135
Plastic dome	133	136	134
Mean	135	139	137

domes can shorten the time the rice crop is in the field by 4 to 8 days (Table 11). Improved varieties specifically adapted to the lowland conditions of northern Laos have yet to be developed. From among varieties developed for the main rice-growing areas in the central and southern regions, the variety best suited to high-altitude dry-season cropping on account of its relatively short maturity time and yield potential is TDK5.

Crop diversification in montane areas. Rice was grown on about 6,000 ha in the 2003 dry season. About 75% of this area was in the three provinces of Luang Prabang, Sayabouly, and Houaphanh (MAF 2003). The dry-season rice area is limited primarily as a result of inadequate water. The water requirement for rice cropping is much higher than for other crops. Studies are currently under way by the National Agriculture and Forestry Research Institute and its collaborators to identify alternative nonrice cropping options for lowland paddies that do not have adequate water for lowland rice cropping but may have enough water for other crops (such as vegetables, maize, soybean, and tobacco).

Expansion of the montane paddy area. Most of the large flat areas in northern Laos with easy water access have been developed for rice production through government and development programs. Increasingly, farmers are terracing hillsides for lowland rice cultivation. However, the potential for an expansion of lowland rice area in this manner has not been determined. Apart from socioeconomic factors such as the cost of developing terraces, social issues such as understanding how water is viewed as a community resource are also important considerations. For example, if a village upstream diverts water to develop paddy land, what are the effects on downstream villages? Other considerations include the socioeconomic conditions that make paddy development possible and attractive for farmers, and equity issues, particularly with respect to considerations of whether all farmers can be involved rather than only the more wealthy farmers in a community.

The expansion of paddy area also depends on the biophysical environment, particularly topography and water availability. Further research is necessary to help district- and village-level planners identify suitable areas for paddy development. The potential also probably exists for improvements in water-use efficiency (canals are often dug along hillsides with high potential for water loss) and in paddies, thereby allowing the potential for an expansion of irrigated area within the limits of water availability.

A further area of research that may allow more efficient use of limited water resources, while at the same time increasing yield potential, is that relating to aerobic rice cultivation. Aerobic rice can be grown under either flooded (anaerobic) or non-flooded (aerobic) conditions, and produce high yields. In some areas of Laos (such as in Luang Prabang), farmers already grow upland rice varieties in terraced paddies where water is not available for continual flooding. When the water supply is good, they keep the fields flooded, but when water availability is limited, they only irrigate the lower terraced fields. Research has begun in Laos to identify suitable varieties that are responsive to inputs and give high yields in such systems. A major potential production constraint in this system will come from weed competition, as weeds are much more difficult to control in nonflooded fields.

Conclusions

The development of montane lowland paddies and research to improve the productivity of these paddies offer good opportunities to improve food security and reduce poverty in the more mountainous areas of Laos. Furthermore, an expansion of lowland rice cultivation in montane areas also provides a basis for farmers being able to reduce rice production in associated upland areas, and adopt more sustainable agricultural practices in this environment. There has already been a recent expansion of paddy area in northern Laos in response to land allocation policies that have led to shorter fallows, under which upland rice cultivation is no longer sustainable. Furthermore, some data already suggest that farmers, if they have an adequate lowland area for rice cultivation, will adopt more sustainable agricultural practices in their upland fields.

Improved rice production in the montane environment will need to involve the use of improved varieties and the adoption of improved management practices. While some of the technologies developed by the Lao National Rice Research Program for improving lowland rice production in the central and southern regions have relevance for the montane lowland environment, a need remains for ongoing research to better understand and develop production systems specifically suited to helping alleviate some of the production constraints specific to the montane lowlands of Laos.

Despite the development of the larger valley bottoms for lowland rice cultivation in more mountainous northern areas having already been undertaken, opportunities remain for improving lowland rice production in these areas. Where the opportunity exists for the development of irrigation, improved yields might be achieved with wet-season crops through the use of supplementary irrigation, while second-cropping opportunities for dry-season cropping can be investigated where water supplies are adequate. In addition, expansion of lowland paddy area in some areas can take place through the development of additional rice terraces. However, additional research is necessary to determine the potential area that might be further developed, taking into account water flows, rainfall, water requirements of paddy rice, economic considerations, and topography. Research will also be required at the community level to develop appropriate water user rights, and on ways to develop paddy areas that are compatible with these rights.

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Notes

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Photos

Photo 3.1. A typical lowland rice field in Champassak Province that is nearly ready for harvest. Notice the different varieties being grown: black rice (Khao Kam) is being grown in the background.

Photo 3.2. Montane lowlands such as this are common in the mountainous regions of Laos. Lowland rice is grown in steeply terraced fields.

Photo 3.3. A typical upland rice field in Oudomxay Province. As this picture shows, the risk of erosion can be very high.

Photo 3.4. A woman in southern Laos during rice harvest. Notice the rice panicles hanging on racks in the background.

Photo 3.5. After harvesting and drying the rice, the rice is often stacked neatly into piles to protect it from rain and rodents. This is practiced in both the lowland and upland rice systems. Notice the *hor phi naa* (field spirit house) in the foreground.

Photo 3.6. In the montane lowland rice system, upland nurseries are common. Upland nurseries are usually adjacent to the lowland rice field. Farmers dibble plant a large handful of seeds into a hole. Seedlings are pulled after 5 to 6 weeks for transplanting.

Photo 3.7. Land preparation requires puddling the field in preparation for transplanting. It is commonly done by buffalo, although in southern and central Laos small tractors are often used. The field shown here is a montane lowland paddy. Notice in the background the farmer pulling seedlings from the upland nursery.

Photo 3.8. After upland fields have been slashed, the dried vegetation is burned in preparation for planting.

Photo 3.9. In upland rice fields, rice is dibble planted into the soil. The soil receives no land preparation. Dibble planting usually involves one person making the holes and the other putting in seed.

Photo 3.10. In upland rice cultivation, weeding requires more labor than any other task. A field requires from three to five weedings per year.

Photo 3.11. Hand threshing rice in an upland rice field.

Photo 3.12. Hmong montane lowland rice farmers in Luang Prabang using the wind to clean rice seed. Seed is carried in a basket up the ladder and slowly dropped. As seed is dropping, the wind carries away the chaff. Some upland farmers also use this technique to clean rice.

Photo 3.13. Rice is often grown with other crops. Here rice is being grown with maize and melon.

Photo 6.1. Kmhmu' village in Sam Tay, Sam Neua.

Photo 6.2. Model of a “ritual miniature starter field” ***(mat rèèk).***

Photo 6.3. Dibble planting.

Photo 6.4. Ritual platform with offerings.

Photo 6.5. *Kldoong* players from Meuang Hun.

Photo 6.6. Blessing the rice-child *(sngkhvan hmmaal koon hngo').*

Photo 6.7. The rice-mother blessing the rice-child on the rice stack.

Fig. 8. Blessing of the rice spirit-soul *(sngkhvan hmmaal hngo').*

Photo 6.9. Rice-stores or rice-houses *(c'ô').*

Photo 6.10. A *greh* decoration.

Photo 6.11. Drinking rice wine *(buuc kdong).*

Photo 6.12. Fermenting agent for rice wine *(pdô')*.

Photo 9.1. Diversity of panicle types in a single upland field.

Photo 9.2. Diversity of rice-growing environments in Laos.

Photo 10.1. Panicle and grain traits used in naming varieties.

Photo 11.1. Variety Hom nang nuan.

Photo 12.1. Purple-colored leaf sheath of a Lao black rice (*Khao kam*) variety.

Photo 12.2. Purple-colored panicle of a Lao black rice (*Khao kam*) variety.

Photo 12.3. Diversity of colors in the spikelet and milled and polished grain of Lao black rice (*Khao kam*).

Photo 12.4. Steamed black (*kam*) and white rice.

Photo 13.1. Ms. Lasoy with the nucleus seed of variety *Khao phae dam* (profuse-tillering black rice) in a small bamboo basket developed by her, and the parent line *Khao phae deng* (profuse-tillering red rice).

Photo 13.2. Mr. Bee holding the seeds of aromatic medium-maturing *Khao hom kang* (left hand) and aromatic early-maturing rice *Khao hom do* (right hand).

Photo 13.3. A couple of upland farmers with a basket full of large and attractive panicles of many distinct panicles selected for seed purposes at harvest time (note the sheaves of bulk harvest and individual panicles selected for seed purposes).

Photo 14.1. Diversity of spikelet traits in glutinous rice varieties.

Photo 14.2. Some traditional food preparations using glutinous rice.

Photo 20.1. Farmer in Oudomxay Province weeding a rice field where *Chromolaena odorata* is the dominant weed species.

Photo 20.2. *Mimosa invisa* in upland rice.

Photo 20.3. Rice field with *Ageratum conyzoides* as the dominant weed.

Photo 20.4. Knife and curved hand hoe, the tools predominantly used by upland rice farmers for weed control.

Photo 20.5. Biomass dominated by *Chromolaena odorata* one year after the rice harvest.

Photo 20.6. *Gliricidia sepium* being used for fallow improvement in upland rice.

Photo 24.1. Pigeon pea growing in an upland rice field. The pigeon pea was planted about 3 weeks after rice planting.

Photo 24.2. Paper mulberry that has regenerated from underground roots in a rice field. If paper mulberry is not managed carefully during this stage, it can reduce rice yields.

Photo 24.3. A variety trial conducted at the Houay Khot Research Station. These upland rice varieties are growing in a field where rice was grown in the two previous seasons. Most varieties performed very poorly, with yields of less than 0.5 t ha^{-1}; however, Chao Mat (on right) yielded 2 t ha^{-1}.

Photo 24.4. Upland rice growing between rows of stylo.

Photo 25.1. Hatsua village (Luang Prabang, Pak Ou District) showing upland rice in the foreground with lowland rice paddies that were developed by farmers along the stream. The village of Hatsua has approximately 4 ha of lowland rice paddy.

Photo 25.2. Lattahae village farmers (Luang Prabang, Pak Ou District) developing new paddy land for rice production.

Photo 25.3. A log weir built to divert water to lowland rice fields.

Photo 25.4. A canal being built to supply water to new paddy area.

Photo 25.5. Farmers evaluating plastic covers and domes over their dry-season nursery beds. In the foreground is the treatment with no cover or dome; note poor germination and small seedlings. (Photo from Shu Fukai.)