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Climate-ready technologies:

Combating poverty by raising productivity in rainfed rice environments in Asia

Edited by

Digna O. Manzanilla, Rakesh Kumar Singh, Yoichiro Kato, and David E.Johnson

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The International Rice Research Institute (IRRI) is the world's premier research organization dedicated to reducing poverty and hunger through rice science; improving the health and welfare of rice farmers and consumers; and protecting the rice-growing environment for future generations. IRRI is an independent, nonprofit, research and educational institute, founded in 1960 by the Ford and Rockefeller foundations with support from the Philippine government. The institute, headquartered in Los Baños, Philippines, has offices in 17 rice-growing countries in Asia and Africa, and about 1,400 staff members representing 36 nationalities.

Working with in-country partners, IRRI develops advanced rice varieties that yield more grain and better withstand pests and disease as well as flooding, drought, and other harmful effects of climate change. More than half of the rice area in Asia is planted to IRRI-bred varieties or their progenies. The institute develops new and improved methods and technologies that enable farmers to manage their farms profitably and sustainably, and recommends rice varieties and agricultural practices suitable to particular farm conditions as well as consumer preferences. IRRI assists national agricultural research and extension systems in formulating and implementing country rice sector strategies.

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OVERVIEW

Raising productivity in unfavorable rice environments: combating the roots of poverty—from genes to rice on the table

Digna O. Manzanilla, David E. Johnson, and Gelia T. Castillo

The Consortium for Unfavorable Rice Environments (CURE) has been supporting innovation and technological advances over the past fifteen years to reduce risks, raise productivity, and contribute to poverty reduction in rainfed rice ecosystems in Asia. The Consortium has worked to improve lives in resource-poor rice communities through building a network of networks and linking groups and individuals facing similar constraints. This enables the sharing of information on opportunities for progress. Advances in recent years have enabled the development of stress-tolerant varieties and management options that help farmers reduce risks and raise productivity in areas affected by drought, flooding, or salinity. These have helped improve harvests for smallholder farmers in many parts of Asia.

Unfavorable rice environments account for nearly half of the rice lands in Asia and make up a home to millions of farmers who live in poverty and rely on rice farming for their livelihood. These areas are unstable and have low productivity, ranging from an average across years of 1.0–2.5 tons per hectare, due to the vulnerability to weather patterns such as drought that can reduce harvests by as much as 40% across a region and reduce yields to zero in some localities. Conversely, a flood can drown a rice crop once the flooding exceeds 10–12 days, losing 100% of potential production. Large areas are affected by multiple stresses, such as drought followed by flood, that prevents farmers from fully utilizing the available land. Reduction in cropped area due to early-season drought is one of the main concerns in the drought-prone lowlands.

Farm families are the stewards of the majority of the rice environments and as such have an important role in sustainable development. About a hundred million families in Asia depend on rice, and these farmers probably obtain less than half of the productivity that can be achieved in their fields. Dr. Robert Zeigler, former director general of the International Rice Research Institute (IRRI), said "Closing these gaps is one of the greater challenges of our time." These farmers help "fill the rice baskets of Asia," and yet their harvests are susceptible to flooding, salinity, and drought. Such areas comprise, as example, the central dry zone in Myanmar where the average rainfall is below a thousand millimeters, and the Ayeyarwady delta, where crops are threatened by salinity in some areas and flooding in others. Crops commonly suffer drought in Northeast Thailand, an area which greatly contributes to the rice export of the country, and in other areas, deep flooding is a common problem. These vast areas of rice production had been relatively untouched by the Green Revolution until recently. Newly available rice varieties that are able to tolerate stresses now provide entry points, and together with other options, can help farmers improve the productivity of their fields.

Along with the technological advances, a commitment to partnerships among the national governments and nongovernment institutions has brought advances to farm communities and has started to create a difference for farmers through the use of climate-ready varieties and appropriate management practices. Moreover, even in upland systems, where scientific impacts have been few, different programs have identified opportunities for farmers with specialty rice varieties that can command premium price in the market. Indeed, the second green revolution is developing momentum that promises to include those that were left behind in the first revolution.

Bringing to the fore, a consortium for partnership and inclusive growth

To provide technical and financial support for the development of varieties and management options in fragile rice ecosystems, CURE was formed in 2002 as a merger of existing consortia for the upland and rainfed lowland ecosystems. CURE has since demonstrated the advantages of working together for a common cause. The consortium of member-countries in Asia serves as a platform for partnerships between the national rice systems of national agricultural research and extension systems (NARES) and IRRI scientists. In Southeast Asia, the Consortium includes Cambodia, Lao PDR, Indonesia, Philippines, Thailand, Vietnam, and Myanmar, and in South Asia, India, Bangladesh, and Nepal. Within Southeast Asia and South Asia, the top 14 countries in the world in terms of rice consumption are found. CURE was initially supported by the Asian Development Bank (ADB) with the project titled, "Integrating and Mobilizing Rice Knowledge to Improve and Stabilize Crop Productivity to Achieve Household Food Security in Diverse and Less-Favorable Rainfed Areas of Asia," or ADB-RETA 6136, 2004-2007.

The collaborative research works focusing on unfavorable rice environments gained additional support from donors or funding institutions aiming to support farmers in unfavorable environment. These included fast-tracking the delivery of rice varieties and management options. Funding sources included the Generation Challenge Program, the German government (BMZ), the Japanese government, and Bill & Melinda Gates Foundation, which contributed largely through its project "Stress-tolerant rice for poor farmers in Africa and South Asia" (STRASA), among others.

The main activities of CURE have been predominantly supported by the International Fund for Agricultural Development (IFAD), through the project, "Enabling poor rice farmers to improve livelihoods and overcome poverty in South and Southeast Asia through the CURE" (IFAD TAG 1108; 2009-2013). This was followed by the second phase, again with IFAD funding, titled, "Reducing risks and raising rice livelihoods in Southeast Asia through the Consortium for Unfavorable Rice Environments (CURE 2). This second phase of CURE project covers the period of 2014-2018, and focuses on Southeast Asia. While IFAD channeled its funding to Southeast Asian countries, the CURE continued to serve as an avenue for collaborative works and exchanges of information across South and Southeast Asia where several projects were contributing to the development, validation, and eventual releases of stress-tolerant varieties. To maximize the potential gains from genetic improvements, crop and natural resources management practices have also been packaged. Enhancing partners' capacity to conduct research and development has also been addressed through capacity building, and knowledge products have been made available to add value by sharing knowledge and information brokering.

CURE has aimed at "inclusive growth" and helping those left behind by the earlier Green Revolution. This has involved sharing technologies, rice germplasm, knowledge, science, and experiences among scientists, extension workers to the farmers and consumers effectively as collective actions. Changes that can help this happen, and to help farmers get out of poverty, include increased availability of options to enable farmers adapt to change and opportunity, reduced risk, and better and more assured harvests.

Advancing science and acquiring breeding materials

Progress in rice breeding using marker-assisted backcrossing (MAB) coupled with benefits from years of conventional breeding allowed the development of a substantial number of climate-ready varieties that have been released in recent years. There have also been advances in management options for water, nutrients, pest management and crop establishment options, and these have been linked to developments in decision-support tools through smartphone and other ICTs. The aim has been to spread CURE materials as far as possible to countries and national partners. By the mid-2000s, IRRI's program had already made significant advances with the identification of drought-tolerant donors exhibiting tolerance in multi-location trials, and where high-yielding varieties can already perform more than double the yields of existing popular varieties. Tolerant versions of the mega-varieties, such as IR64, BR11, TDK1, Swarna, Sambha Mahsuri, and CR1009, which incorporated (introgression) were developed with major QTLs, such as *SUB1* gene for submergence. Other QTLs are *Saltol* (salinity), *Pup1* (phosphorous deficiency). To date, there are more than 100 newly released stress-tolerant rice varieties available in 10 countries of Asia (Table 1). These varieties have been shown to contribute at least 1 ton per hectare yield advantage in stress conditions, and this is the first time that such a range of stress-tolerant rice varieties has been available in the region.

In Myanmar, for example, activities in the drought-prone areas in the 2014 wet season included: identification and validation of genotypes adapted to drought-prone environments, those tolerant of alkaline soils (inland salinity) in the dry zone, and multi-location trials and on-farm participatory varietal selection (PVS) for drought-tolerant genotypes. Meanwhile, in the Philippines, research activities included on-farm demonstration of new drought-tolerant, *Sahod Ulan* varieties. In Indonesia, partners evaluated the INPARI series for adaptability for drought tolerance and blast resistance, identified promising rainfed lowland rice lines through multi-location on-farm trials; multi-location testing in stations, and PVS. From 2008 to 2014, nine varieties were released, namely, Inpara 3, 4, 5, Inpari 30 or Ciherang-Sub-1, Inpago 6, Inpago 3, 4,

Released stress-tolerant varieties, 2009-2016.

Country	Drought (20)	Submergence (24)	Salinity (35)	Upland (9)
Bangladesh	BRRI dhan 56 BRRI dhan 57 BRRI dhan 66	BINA dhan 11, 12 BRRI dhan 51 (Swarna-Sub 1) BRRI dhan 52	BRRI dhan 53, 54, 55 BINA dhan 8, 10 BRRI dhan 61	
Indonesia	Inpago Lipi1 Inpago Lipi2	Inpara 1, 2, 3 Inpara 4 (Swarna-Sub1) Inpara 5 (IR64-Sub1) Inpara 8 Agritan Inpari 29 (Rendaman) Inpari 30 (Ciherang-Sub1)	Inpari 34 Salin Agritan Inpari 35 Salin Agritan	Inpago 4, 5, 6 Inpago 7, 8, 9, 10 Inpari 28 (Kerinci) Inpago 11
India	Sahbhagi dhan CR Dhan 201 IET 21924 CR Dhan 202 IET 21917 CR Dhan 204 IET 21922 CR Dhan 205 IET 22737 DRR Dhan 42 IET 22386 DRR Dhan 43 IET 22080 DRR Dhan 44 IET 22081 Tripura KharaDhan 1 Tripura KharaDhan 2 Tripura Hakuchuk 1 Tripura Hakuchuk 2 Tripura AusDhan	Swarna-Sub1 Samba Mahsuri-Sub1 Narendra Mayank Narendra Jal Pushpa Narendra Naraini Ciherang-Sub1 (BINA dhan 11) CR 1009-Sub1 Rajdeep NDR 8011 IR64-Sub1	CR dhan 402, CR dhan 403 CR dhan 405 (Luna Sankhi) CR dhan 406 (Luna Barial) CSR 43 NDRK 5088 (Narendra Usar dhan 2008) Gosaba (Gozaba) 5	CR Dhan 203
Lao PDR		XBF1 (TDK1-Sub1)		
Myanmar	Yeanelo – 4	Yemyoke Khan saba (Swarna-Sub1) Yemyoke Khan saba-2 (BR11-Sub1)	Sangankhan Sinthwelatt CSR36 IR10T107	Yeanelo-2
Nepal	Sukhadhan 1, 2, 3 Ghaiya 1 Sukhadhan 4, 5, 6	BINA dhan 12 (Samba Mahsuri-Sub1) Swarna-Sub1		
Philippines	Sahod Ulan 1, 3, 5, 6, 8	Submarino (IR64-Sub1)	Salinas 1- 20 Salinas 22, 23 and 24	NSIC Rc23 (Katihan 1) NSIC 2014 Rc25 (Katihan 2) NSIC 2014 Rc27 (Katihan 3) NSIC 2014 Rc29 (Katihan 4)
Vietnam	OM 7398, OM 8928, OM 7347	OM 8927 (recommended) IR64-Sub1 (recommended)	OM 5629, OM 5981, OM 6377, OM 6677	

Inpari 34, and Inpari 35, which are all targeted to address different types of stresses. In Myanmar, IR64-Sub1 or Yemyoke khan-saba 1 and BR11-Sub1 or Yemyoke Khan-saba 2 were released for submergence-prone rice areas.

Plant breeders have been working to bring together the ability to produce high yields along with tolerance to drought, flooding, and salinity in acceptable rice varieties. Such materials have now been released in the national programs, and are contributing to curbing the cycles of poverty in rice-growing areas.

Integrating crop management practices with stress tolerant varieties

Due to the considerable variability in the unfavorable environments, "blanket" recommendations for "best management practices (BMPs)" are generally not available. Instead, recommendations best suited to the conditions of a farmer's field tend to be locally specific. Building on research in the irrigated areas, predictive tools have been developed that allow extrapolation of findings from one area to other sites with similar conditions. The CURE network has facilitated such an approach and allows for knowledge sharing across countries in South and Southeast Asia. It also allows sharing experiences across the regions (e.g., approaches that work well in the coastal area of eastern India also have a good chance of working in the coastal areas of Thailand or Myanmar).

Evidence as to the sort of impacts that crop management can bring is now becoming available. For instance in Bihar, combining the farmer's variety with improved management practices can increase yield by about 50% compared to the farmer's variety and farmer's practice. Use of BMPs in other countries has shown that combining improved varieties and improved management options can give a yield advantage of 4–11% in the Philippines; about 15% in Indonesia; about 50 % in Thailand, and about 80% in Cambodia. In Myanmar, undertakings are supported by the Livelihoods and Food Security Trust Fund (LIFT) project that focused on developing a better understanding of rice systems where salinity is the major problem. In these studies, the timing of the dry season crop and tolerance to salinity was critical. Recommendations are now being developed in forms such as BMPs that outline how farmers can grow the new varieties with appropriate crop and management practices. CURE and research partners have been developing and refining these options for submergence-, salinity- and drought-prone areas, and in marginal uplands.

Given the variability in the unfavorable environments, it is likely that different locations will require differing varieties and management according to the location. Likewise, we can look across the stakeholders, particularly the farmers, by first assessing what the better farmers are doing, and then finding out if we can encourage those who are not performing well to improve their level of productivity. The hope is that evidence of cooperation will inspire CURE members to give similar attention to predictive tools, and sharing protocols, varieties, and management practices with partners with similar rice ecosystems.

Bridging technology gaps with models of delivery

Models have been developed with country partnerships to deliver technologies to farming communities. STRASA identifies priority villages or areas using GIS-based tools where conditions are suited to varieties such as Swarma-Sub 1, and the list of varieties for testing by the farmers is agreed with the national government. The project distributes mini-kits, with 2 kilograms of seeds to five selected farmers in each village, and subsequently introduces appropriate management practices. Upscaling this approach involves a second model which clusters farmers with large demonstration areas of 100 hectares each, and seeds of varieties are distributed in packages with information and guidance on how to grow them.

In the Philippines, a bottom-up approach is employed to facilitate the adoption of technologies. The project involves seed growers located within the target area to help ensure an effective local seed supply. Demonstration trials are conducted at the village level with involvement of agricultural technicians. There is a farmer-to-farmer diffusion, which involves the provincial agricultural officers and other local champions.

In Bangladesh, partners are asked to describe the negative traits or problems related to cultivating improved varieties including the environmental limitations or factors that affect rice such as flash floods coming after planting and low/high temperatures in different areas. In Thailand, there are community seed producers in at least 4,000 centers, but it is indicated that accessibility to good seeds is not enough. The Ministry of Agriculture has planned to set up more community seed centers. The Thai government also provides training for farmer-leaders to guide them on producing good-quality seeds for their community. In Indonesia, the provincial Assessment Institutes for Agricultural Technology (AIAT) conducts trials, and support variety screening in provinces for their suitability. AIAT produces and provides seeds to interested farmers, as well as to seed growers, while the government subsidizes the cost of seeds.

Seed quality and availability are major concerns of partners and significant constraints to efforts to raising productivity in fragile environments. Partners in all CURE member countries have identified strategies to ensure that new stress-tolerant varieties have been included in national programs or formal seed systems. In those countries where the formal sector is yet to meet national seed requirements, community-based seed systems (CBSS) have been instrumental in introducing new varieties and encouraging early dissemination. Later, the CBSS have become linked to formal systems. In India, Nepal, Philippines, Vietnam, Lao PDR, Myanmar, and Indonesia, CBSS have supported the government's move to fast-track seed dissemination particularly in areas where the formal sector has not operated well, and where commercial seed growers are yet to be convinced that production of seeds is investment-worthy. In Nepal, country-specific recommendations are provided to extension officers who also receive training by the project. The partners in Nepal have successfully implemented a CBSS that is now one main source of good-quality seeds of newly released stress-tolerant varieties. Partners also understand the importance of available management technologies, which the farmers are aware of, and for which there is a good understanding of where and when the technology can be applied.

In Vietnam, the seed supply systems cannot meet the full extent and diversity of the unfavorable rice environments that require different rice varieties for each ecosystem. This highlights the importance of teaching farmers to produce quality seed that can be saved for the next cropping season, not only for their own farms, but for other farmers as well. Further, there are several local or indigenous rice varieties with specific traits and quality that are only grown in particular areas. Such cases also can be addressed through PVS and community seed banks as farmers can choose which varieties are grown in their community. For instance, after a severe flooding in 2014, the Vietnamese government was prompted to release submergence-tolerant rice varieties through the Cuu Long Delta Rice Research Institute (CLRRI). Subsequently, it was proposed that farmers become involved in seed production to maintain seed supplies, and that the agricultural sector be restructured to focus on integrated rice-cash crop system.

Dr. Digna Manzanilla, IRRI social scientist, who took over the consortium leadership in 2013, has emphasized on the delivery mechanism for the new technologies and in conserving traditional varieties as well. A substantial number of varieties are already available, but these have yet to reach the target communities. In terms of impact pathway, extension agents also need to be part of CURE's efforts to provide the bridge between development and delivery of technologies. To accelerate country impacts from the gains in research and partnerships, CURE has sought strategies to link farmers to markets through assessment of the rice value chain. This has involved assessing whether there is a market for seeds or for milled rice, as strengthening farmers' capacity to engage in trade is key to increasing their livelihoods. An example of this has been in strengthening the heirloom rice value chain and "capturing value, preserving heritage", funded by the Philippine government and implemented by IRRI in partnership with the Philippine Department of Agriculture. The crafting of the project on heirloom rice and its funding support from the Philippine government is an outcome of the partnership between CURE, as an IFAD grant, and the IFAD loan project in the Philippines titled, "Cordillera Highlands Agricultural Resources and Management Project (CHARMP2)." The activities have contributed to the linking of the Cordillera farmers to the domestic and international markets for premium traditional rice. This model for research for development (R4D) embodies the role that partnerships can play in leading to better gains in research to benefit a greater number of farmers. The importance of rice value chain analysis, which includes millers and traders as equally important players and the need for technology packages of the new varieties and management practices must be highlighted if real gains are to be achieved in the unfavorable areas.

In the northern mountainous region of Vietnam, partners have developed a model for restoring their most popular and economically important traditional varieties to the farming community, and which are now sold in target markets. The model involves groups of farmers who produce seeds for sale in the local markets. Meanwhile, in Myanmar, the Department of Agricultural Research introduced new stress-tolerant varieties as part of the government extension activities. This has been further promoted in the last two years, since farmers faced problems related to drought to which the President has responded to by ordering the free distribution of rice seeds (since the market access for the new varieties is still rather weak).

Learning lessons in many countries have created opportunities for sharing and establishing regional cooperation among countries. While farmers in some countries have limited access to seeds, rice farmers in India, Bangladesh, and Nepal have faster access to newly developed high-yielding, climate-ready varieties (RICE Today, April-June 2015, vol. 14). This success in South Asia is in part attributed to the regional seed cooperation agreement that expedites the release and dissemination of rice varieties to farmers in the stress-affected regions. This cooperation with varieties/seeds is resource-efficient and time-saving in releasing a variety in one country, since the release of a new variety from the initial evaluation of a breeding line can take between three to six years.

Dr. Abdelbagi Ismail, who leads the STRASA project says: "With this seed cooperation agreement, a rice variety that has been tested, approved, and released in one country can also be released in other countries without undergoing further testing and evaluation, as long as the varieties will be grown in similar agroclimatic conditions. The regional cooperation is a particularly effective platform for the three countries as they share similar agroecosystems and borders. In 2014, Nepal joined with the governments of Bangladesh and India to sign a protocol on regional seed cooperation in a workshop on seed issues. "It will provide a platform to share good practices among countries and the exchange of technologies and quality seed can help attain higher rice productivity in the region. This cooperation can be expanded and replicated to other parts of the world."

This regional cooperation is showcasing what can be achieved through releasing varieties in one country that are already popular in another. For example, BR11, BRRI Dhan 28, and BRRI Dhan 29, which are modern high-yielding varieties released in Bangladesh, are now widely grown in eastern India. Some Indian rice varieties such as Swarna, Sarju 52, and Sambha Mahsuri are now popular in Nepal. The Indian government has been proactive in carrying out the regional cooperation agreement. In fact, starting in 2015, the Department of Agriculture in India allotted 30% of its funds to programs such as the National Food Security Mission and Bringing Green Revolution in Eastern India; a component of this included promotion of climate-ready rice developed in partnership with IRRI. The regional seed cooperation was carried out smoothly not only because these three countries share similar guidelines for varietal evaluation and release, but because each country shares a similar goal; that is, delivering the technologies needed by farmers.

Factors leading to increased impact through varietal development and seed distribution will include farmers' preference for varieties for consumption and sale in the market. While CURE working groups have produced varieties and associated management options that provide increased productivity and reduced risk, even subsistence farmers are asking for varieties with good market. To address this concern, IFAD has maintained that all countries should take a second look at their extension programs to assess if these are taking into account farmers in unfavorable rice environments and whether CURE is reaching the target populations. During CURE meetings and activities, this has been addressed to try to ensure that varieties have adequate demand to enable them to be disseminated at a wider scale and eventually benefit an increasing number of communities.

Strengthening partnerships within and across countries

The use of farmers' field results in PVS as evidence of performance in local environments has reduced the time required for varietal release in some countries, and the more extensive participation of farmers has increased the availability of seeds. In reported activities and accomplishments of the partners, there are indications that information and ideas are moving between countries and should be further encouraged.

Sharing of experiences is also an important element in policy advocacy. "Seeing is believing" can also be applied in upscaling concepts and technologies from the local to the national levels. Nothing is more convincing to a farmer than seeing technologies and management practices working in real-life field situations, which are similar to those in his or her farm. To policymakers, evidence on the ground are likely to encourage replication in other areas. This is what seeds have done and will continue to do as newer and better ones adaptable to climatic peculiarities and agro-ecological circumstances come to the fore.

As CURE has placed greater emphasis on seed distribution, other considerations include the importance of farmer- and market-oriented approaches. These emphasize on the rice value-chain, and include the roles of the miller and the trader in the evaluation of new varieties. The opinion of the rice miller on new varieties intended for the markets is critical and must not be overlooked, even for varieties used mainly in subsistence production. Sensitizing policymakers to the opportunities with new technologies for the unfavorable environments can also help rapidly speed progress with outscaling. Connecting with the national, provincial, and local extension systems is key to the rapid deployment of seeds suitable to differently-stressed rice environments. Cross-site visits for exposure to exciting developments in varietal performance must be organized not just for policymakers but for farmers, researchers, and extension workers. Incentives for seed producers have been considered by the national governments and institutions in each partner country. The issues of quality seeds, seed purity, and seed certification have emerged in many countries along with the need for community seed centers. The institutional aspects related to seed selection, production, distribution, and adoption are now critical challenges in achieving the full potential of the available opportunities.

Looking ahead for wider spread of innovations

Partners within the CURE network have made considerable progress in unfavorable rice environments. It is time to assess how it has helped lessen hunger and reduce poverty. We need to capture the experience, the drivers of change, what worked and what did not work, and how can one success story be replicated, or can inspire and guide the stakeholders in another country with similar social, economic, and biophysical conditions. We need to conduct follow-up studies of the performance of the varieties at the farmers' fields, and if the process of adoption can further tell the impediments to technology adoption.

Stories from NARES partners have been captured in the following narratives to outline the progress with stress-tolerant rice varieties and management options—from the genes to a variety that stands the impact of climate change, to the products that translate to food on the table, and even to the surplus that goes to the market for extra farm income. The cooperation among countries of Asia is essential if regional RICE security is to be maintained for Asia. CURE offers a way to this regional solidarity through the common goal of supporting rice producers in the unfavorable environments to improve their livelihoods. ■

Foreword

"Never give up on what you really want to do. The person with big dreams is more powerful than one with all the facts"

—Albert Einstein

What was once a dream by many in the rice science community is now a reality. Albert Einstein was right about dreaming big. The scientific community does not only have men and women with the strong drive and commitment to address the plight of resource-poor farmers in fragile rice ecosystems in Asia, they also have the power of facts derived from years of dedicated scientific endeavors. These are relentless efforts that develop new climate-ready rice varieties that give extra protection in times of unpredictable climatic conditions and the combination of crop and resources management options that can maximize genetic potentials.

To date—through partnerships among research and development stakeholders—men and women farmers' groups, research institutions, agricultural centers, and non-government entities, among many others, are working together to develop and scale up climate change adaptation mechanisms. The International Rice Research Institute (IRRI), in partnership with the national agricultural research and extension systems (NARES) of Asian countries through the Consortium for Unfavorable Rice Environments (CURE), is pleased to share success stories of how science is making waves in developing and enhancing farmers' access to newly released climate-smart varieties and associated management practices.

Raising productivity for fragile rice ecosystems to improve sustainability and raise livelihoods has been the battle cry of CURE since its inception in early 2000. Back then, year after year, farmers in every cropping season face tremendous challenges from drought, salinity, submergence, low productivity in marginal uplands, and all sorts of problem soils—sometimes even a combination of one or more of these—resulting in low harvests that heavily affect the supply of food in the households. Farmers had limited varieties and management options.

Fortunately, we are moving on from the limitations of the past as more and more farmers benefit from outputs of rice research that allow them to grow the crop even in areas that have previously been left idle and unproductive. New climate-ready varieties and management options that both men and women can apply give a yield advantage of at least 1.0 ton per hectare from these stressed environments. Genes responsible for tolerance of a particular stress can now be combined to make new rice plants with better vigor and chances of survival amidst the brunt of climatic fluctuations.

We are more than honored to be working with partners that make rice farming, even in the most fragile environments, a constant and better source of food and income for farmers.

This resource book is a legacy that captures the success stories of how farming communities now benefit from varieties and technologies backed by science. Cases in each partner country in Asia capture the driving forces that brought about the realization of a dream to see that even stressed environments can give life and vigor to seeds of the future. Stories on the appropriate mechanisms for intervention to reach more users are recounted by partners. People, households, and districts could and should ultimately be reached, not just by CURE projects, but also by other related projects that allow for partnerships to grow. Each story gives evidence of how “spaces” or enabling mechanisms have allowed for new varieties and crop management options to be developed, released, and moved on to the strategies and programs of dissemination of governments and related partnerships. Such spaces are in terms of fiscal/financial, environmental, social, cultural, economic, and institutional arrangements and learning spaces, to name a few crucial enablers. Space has to exist or be created so the intervention can grow to achieve the desired scale.

Collective and collaborative work can help us better achieve our goals at a faster pace and as far as all our resources put together can achieve. The challenges in these rice ecosystems are huge and the work has just begun. There is so much more to be done and, with our joined hands, we will continue to make a difference in the lives of millions of farmers who depend on rice for their food and livelihood.

This book tells the stories of our achievements so far, and what else we can do to help the rice farming communities we are committed to serve, so that they can continue to improve their incomes and wellbeing in spite of the challenges of climate change.

Jacqueline Hughes
Deputy Director General for Research
International Rice Research Institute (IRRI)

Acronyms

ACIAR	Australian Center for International Agricultural Research
ADS	Agricultural Development Strategy
AEC	ASEAN Economic Community
AIAT	Assessment Institute for Agricultural Technologies
ARC	Agricultural Research Center
ASTV	Accelerating the Adoption of Stress-Tolerant Varieties
AWD	Alternate Wetting and Drying
BATWG	Bogale Agriculture Technical Working Group
BLB	Bacterial Leaf Blight
BMGF	Bill & Melinda Gates Foundation
BMP	Best Management Practice
BPH	Brown Planthopper
CBSP	Community-Based Seed Production
CBSS	Community-Based Seed System
CCAFS	Climate Change Agriculture Food Security
CESD	Crop and Environmental Sciences Division
CLLRI	Cuu Long Delta Rice Research Institute
CORIGAP	Closing Rice Yield Gaps in Asia with Reduced Environmental Footprint
CPC	Commune People's Committee
CRC	Community Rice Seed Center
CRI	Ching Rai Rice Research Center
CSB	Community Seed Banks
CURE	Consortium for Unfavorable Rice Environments
DADO	District Agriculture Development Office
DAFO	District Agricultural and Forestry Office
DAR	Department of Agricultural Research
DARD	Department of Agriculture and Rural Development
DARE	Democratizing Agricultural Research and Extension
DAS	Days After Sowing
DDC	District Development Committee
DFC	Directorate of Food Crops
DFID	Development Fund for International Development
DGAIF	Director General of Agricultural Infrastructure and Facilities
DISSPRO	District Seed Self Sufficiency Program
DOA	Department of Agriculture
DPC	District People Committee
DSR	Dry Seeded Rice
DTR	Drought-Tolerant Rice
DWR	Deepwater Rice
EFICAS	Eco-Friendly Identification Climate Arrant and Agriculture System
EMP	Ethnic Minority Policy
FENS	Farmers' Evaluation New Selection
FFS	Farmers' Field Schools
FGD	Focus Group Discussion
FR	Floating Rice
FWDR	Far Western Development Region
GAP	Good Agriculture Practice
GP	Gerakan Penerafan
HXBF2	Hom Xe Bang Fai2
HXBF3	Hom Xe Bang Fai3
IAAD	Indonesian Agency for Agriculture Development
IAARD	Indonesian Agency for Agricultural Research and Development
IAAS	Institute of Agriculture and Animal Science

IAERI	Indonesian Agricultural Environment Research Institute
ICATAD	Indonesian Center for Agricultural Technology Assessment and Development
ICFORD	Indonesian Center for Food Crops Research and Development
ICM	Integrated Crop Management
ICRR	Indonesian Center for Rice Research
IEC	Information, Education and Communication
IFAD	International Fund for Agricultural Development
IFAD-TAG 706	IFAD-funded Technical Assistant Grant 706
IM	Improved Management
INGO	International Nongovernment Organization
IRCM	Integrated Rice Management System
IRRI	International Rice Research Institute
ISARI	Indonesian Swampland Agriculture Research Institute
IWRMP	Irrigation Water Resource Management Project
KDML 105	Khow Dawk Mali 105
KDPC3	Khammouane Development Project Component 3
KKN	Khon Kaen Rice Research Center
LDD	Land Development Department
LIFT	Livelihoods and Food Security Trust Fund
LKP	Layanan Konsultasi Padi
LP	Least Preferred
LUFSIP	Lao Uplands Food Security Improvement Project
MABC	Marker-Assisted Backcrossing
MARD	Ministry of Agriculture and Rural Development
MAS	Marker-Assisted Selection
MCNV	Medish Comite' Nederland-Vietnam
MET	Multi-Environment Trial
MHS	Mae Hong Son Rice Research Center
MOA	Ministry of Agriculture
MOAI	Ministry for Agriculture and Irrigation
MOFA	Ministry of Foreign Affairs
MOST	Ministry of Sciences and Technology
MOU	Memorandum of Understanding
MP	Most Preferred
MRSDS	Myanmar Rice Sector Development Strategy
MYT	Multi-location Yield Trial
NAFRI	National Agriculture and Forestry Research Institute
NARC	Nepal Agriculture Research Council
NARES	National Agricultural Research and Extension Systems
NCA	Norwegian Church Aid
NKI	Nong Khai Rice Research Center
NKSP	National Food Security Program
NMR	Northern Mountainous Region
NOMAFSI	Northern Mountainous Agriculture and Forestry Institute
NRM RRC	Nakhon Ratchasima Rice Research Center
NRRP	National Rice Research Program
NSC	National Seed Company
NSEDP	National Socio-Economic Development Plan
NSV	National Seed Vision
NT2	Nam Theun2 Power Company
NTPC	Nam Theum Power Company
NUDP	Northern Uplands Development Programme
PAC	Prachanthakan Agriculture Cooperation
PACT	Project for Agriculture Commercialization and Trade
PAFO	Provincial Agricultural and Forestry Office
PDR	People's Democratic Republic

POP	Package of Practices
PRE	Prae Rice Research Center
PRRC	Prachinburi Rice Research Center
PTT	Pengelolaan Tanaman Terpadu
PVS	Participatory Varietal Selection
QTL	Quantitative Trait Locus
QTLs	Quantitative Trait Loci
RAS	Rice Agro-advisory Service
RCM	Rice Crops Management
RMU	Restatement Management Unit
SDC	Swiss Agency for Development & Cooperation
SFE	Service Fraternel d'Entraide
SKN	Sakon Nakhon Rice Research Center
SPGs	Seed Producers' Groups
SPR	Seed Replacement Rate
SQCC	Seed Quality Control Center
SSC	Sundar Seed Cooperative
SSNM	Site Specific Nutrient Management
SSPACL	Sundar Seed Producer Agriculture Cooperative Limited
SSR	Simple Sequence Repeat
STRASA	Stress-Tolerant Rice for Africa and South Asia
TABI	The Agro-biodiversity Initiative Project
THPC	Theun-Hinboun Power Company Limited
TIS	Technical Innovation Services
TSC	Technical Sub-Committee
UAERC	Upland Agricultural Research Center
UMT	Upper and Middle Terrace
UNISD	United Nations International Strategy for Disaster Reduction
UNOPS	United Nations Office for Project Services
URRN	Uniform Rice Regional Nursery
USAID	United States Agency for International Aid
VB	Valley Bottom
VDC	Village Development Committee
WHH	Welthungerhilfe
WUPAP	Western Uplands Poverty Alleviation Project
XBF1	Xe Bang Fai 1
YAU	Yezin Agriculture University

Indonesia

Submergence-prone environments

Indonesia rises above the floods through submergence-tolerant rice

Indrastuti A. Rumanti, A. Hairmansis, and A. Jamil

The success of the continuous development and dissemination of submergence-tolerant rice varieties in Indonesia is rooted from a systematic process of engagement and resource mobilization through the strong support of the Indonesian government, and collaboration with IRRI-CURE to equip farmers with technologies and knowledge for sustainable living.

Unfavorable rice environments in Indonesia

Flood-prone rice environments in Indonesia are defined as rice areas that are vulnerable to flash flood and stagnant flood (Nugraha et al., 2013). With the increase of precipitation due to climate change, flood-prone rice areas have subsequently increased. Flash flood occurs mainly in lowland rice areas with poor drainage and in freshwater swampy areas (*lebak*), while stagnant flood-prone areas mainly affect lebak areas. An estimated 1.4 hectares of *lebak* areas have been reclaimed and utilized for agricultural use. These are distributed in East Kalimantan (509,426 hectares), South Sumatera (365,685 hectares), Riau (211,587 hectares), South Kalimantan (208,893 hectares), and Lampung (126,465 hectares) (Nursyamsi et al., 2014).

In 2013, the recorded damage of flood incidence in Indonesia reached 303,002 hectares due to high rainfall. The flooding spread out in Aceh (17,203 hectares), South Sumatra (12,190 hectares), West Java (39,171 hectares), Central Java (24,357 hectares), East Java (32,220 hectares), Banten (30,141 hectares), South Kalimantan (16,691 hectares), South Sulawesi (65,979 hectares), and Southeast Sulawesi (25,829 hectares). And in 2014, flood severely damaged 73,876 hectares of rice areas (Directorate of Food Crop Protection of Indonesia) Fig. 1 shows the areas in the country affected by different abiotic stresses, and Table 1 flood- and drought-prone rice areas in selected provinces.

Thus, the development of submergence-tolerant rice varieties in the country has become inevitably key to improving rice production in flood-affected areas. These flood-tolerant varieties released in Indonesia are site-specific, meaning, they perform better under flash floods and will produce higher yield compared with other high-yielding varieties under the same condition.They can survive under total submergence during vegetative stage, and recover well as the flood water level subsides.

The target areas of these kinds of varieties include rainfed lowlands along coastal areas, basin, swampy, and in areas where irrigation channels are dysfunctional. The swampy areas spread out into Jambi, South Sumatra, Riau, Central Kalimantan, South Kalimantan, West Kalimantan, East Kalimantan, Southeast Kalimantan, Papua, and Maluku provinces. Meanwhile, the basin and coastal environments are found in almost all the provinces of Indonesia, including Java island where majority (51.71%) of the country's rice is produced [Asia-Europe Meeting (ASEM), 2015].Three of the flood-tolerant varieties, namely, Inpara 3, Inpara 4, and Inpara 5, released in 2009, have covered about 74,670 hectares in the country as of 2014 (Directorate of food crops, 2014) (Table 2).

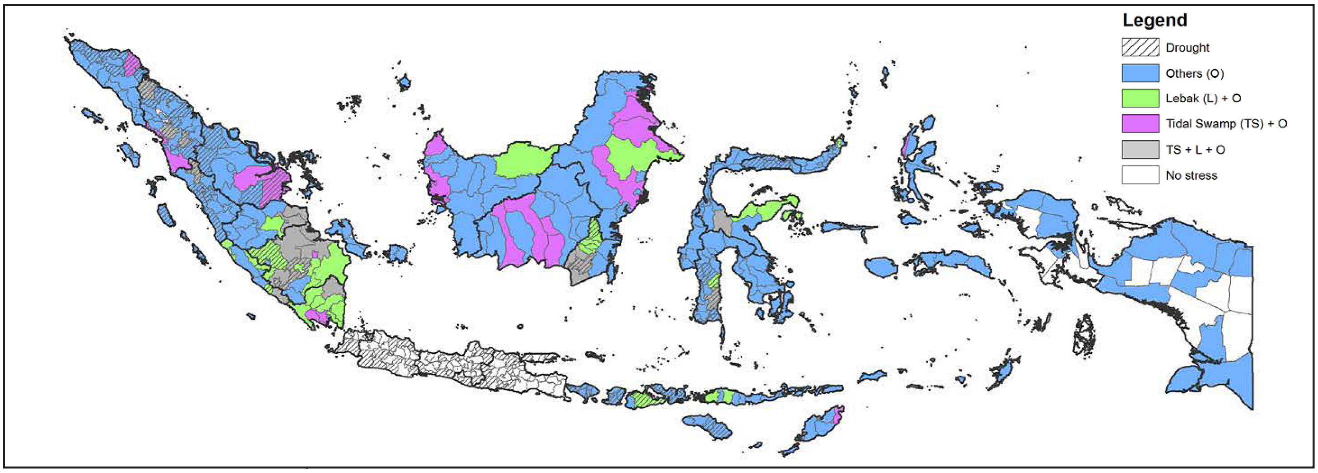


Fig. 1. Abiotic stresses in Indonesia, 2012.

Table 1. Potential flood- and drought-prone lowland rice areas in Indonesia.

Province	Swampy lowland			Swampy tidal land			Area		Under dev't planning (hectares)
	Potential area (hectares)	Existing (hectares)	Under dev't planning (hectares)	Potential (hectares)	Existing (hectares)	Under dev't planning (hectares)	Potential (hectares)	Existing (hectares)	
Central Kalimantan	62,707	42,018	2,000	144,443	123,013		207,150	165,031	-
South Kalimantan	198,268	99,451		205,732	164,533		404,000	263,984	38
West Kalimantan	4,109	-	-	93,376	62,690	30,300	97,485	62,690	19
East Kalimantan	22,296	42	22,254	17,087	8,593	8,494	39,383	8,635	51
South Sumatra	306,490	202,301	82,749	240,087	215,239	14,589	546,577	417,540	-
Jambi	41,425	16,412	6,109	54,835	46,123	8,124	96,260	62,535	82
Riau	4,687	1,457		75,314	43,634	18,681	80,001	45,091	39
Lampung	46,404	28,922	5,710	51,305	22,283	1,450	97,709	51,205	48
Central Sulawesi	195			1,776	1,170	1,000	1,971	1,170	-
Subtotal	**686,581**	**390,603**	**118,822**	**883,955**	**687,278**	**82,638**	**1,570,536**	**1,077,881**	**277**
Total potential area						**1,570,536**			
Total existing area						**1,077,881**			
Under development planning						**201,460**			

Table 2. Submergence-tolerant varieties released in Indonesia, 2014.

Rice variety	Pedigree number	Year released	Planted areas* (hectares)
Inpara 3	IR70213-9-CPA-12-UBN-2-1-3-1	2009	67,059.37
Inpara 4	IR05F102 (Swarna Sub1)	2009	1,125.65
Inpara 5	IR07F286 (IR64 Sub1)	2009	6,484.54
Inpari 29 Rendaman	B13138-7-Mr-2-KA-1	2012	-
Inpari 30 Ciherang Sub1	IR09F436	2012	-
Inpari 8 Agritan	B11377F-Mr-34-2	2014	-

*Planted areas were based on 2014 data of the seed bureau of Indonesia. No data is available yet for Inpari 29, Inpari 30, and Inpara 8.

Developing flood-tolerant rice varieties

In recent years,flooding has become more frequent in Asia, which severely reduced rice production in the region. Flashflooding, in particular, can occur at any growth stage of the rice crop—from directly after sowing to flowering stage. Moreover, the duration of flooding may last for several days to several weeks. In some cases, flashflooding occurs repeatedly during a season (Collard et al., 2013). Flooding that occurs in freshwater swamps brings with it iron toxicity due to wetness of soil with low pH, making the rice plant extremely vulnerable to different stresses. Thus, introducing and combining at least two tolerant or resistant characteristics into one rice variety is advantageous.

In the last two decades, breeding rice for flood tolerance was sucessful (Mackill et al., 2012).However, this does not mean that the variety development was simple and easy. In fact, many researches reported both the difficulty and success of developing flood-tolerant rice. An immense effort was demanded in identifying the gene for flood tolerance. After the discovery of *FR13A* as a source for submergence tolerance, the International Rice Research Institute (IRRI) was able to produce breeding lines in the 1990s, namely, IR49830 and IR40931. But, these lines were poorly adopted because farmers' specific preferences for quality were not present.

A milestone in the history of breeding for submergence tolerance was the identification of a major quantitative trait locus (QTL) controlling this trait, which was named *SUB1* (Xu and Mackill, 1996; Xu et al., 2006). Learning from the previous experience of farmers' preference for cooking quality, IRRI developed a large-scale marker-assisted backcrossing (MABC) in order to incorporate the *SUB1* gene into several popular varieties from South and Southeast Asia, which were dubbed as "mega-varieties." These varieties are characterized with numerous desirable attributes such as high-yielding capacity and superior grain quality, but were deficient in flood tolerance. The *SUB1* gene conferred tolerance for complete submergence from 10 to 18 days. Using the high-level of precision of MABC, the essential features of the mega-varieties (i.e. yield, grain quality, agronomic traits) were retained (Iftekharuddaula et al., 2011; Neeraja et al., 2007; Septiningsih et al., 2009).

Inpara 3 (IR70213-9-CPA-12-UBN-2-1-3-1) was the first submergence-tolerant variety released in Indonesia in 2009, followed by Inpara 4 (Swarna-Sub1) and Inpara 5 (IR64-Sub1) in 2010. Meanwhile, IR64, known as a mega variety since 1988 up to 2004, was grown in most irrigated rice areas,which significantly contributedto the national rice production in Indonesia (Directorate for Seed, 2014). Thus, *Sub1* gene was incorporated into IR64 through the collaboration with IRRI in developing new high-yielding, submergence-tolerant rice varieties with wide adaptability.

Unfortunately, wide dissemination of Inpara 4 and Inpara 5 progressed slowly because farmers preferred rice with long slender grains, tungro resistance, and no chalkiness. Surprisingly, aroma was not considered an important trait by Indonesian farmers. At that time, the Ciherang variety started to dominate the rice areas in the country. Then, it became more popular than IR64 because the latter is susceptible to bacterial leaf blight. To accommodate the farmers' preference, the Indonesian government collaborated with IRRI to incorporate the *SUB1* gene into Ciherang, which was eventually known as a new mega variety in the country.

Flood-tolerant varieties were deve-loped through MABC underwent two or three backcrosses, and the performance of these varieties was evaluated to determine the effect of *SUB1* in a particular genetic background. Ciherang

Table 3. Yield and survival rate (%) of selected varieties under 15-day submergence and controlled conditions in Sukamandi field station.

Variety	Grain yield (tons/hectares)		Survival rate (%)	
	Under submergence	Control	Under submergence	Control
Ciherang Sub1	3.88	5.95	76.95	100
Ciherang	1.99	5.40	47.60	100
Inpara 3	2.76	5.04	76.04	100
Inpara 5 (IR64 Sub1)	4.11	4.90	88.28	100
LSD (0.05)	0.95	Ns	19.28	-

Septiningsih et al., 2014.

with *SUB1* had higher survival rate than the original parents (Table 3).

Breeding flood-tolerant rice using MABC method is faster than using conventional breeding alone, which takes four to five years to develop a new variety. Breeding by MABC allows a breeder to select the lines that that the gene during early generation. Consequently, this expedites the process. (Septiningsih et al., 2009).

Boosting rice breeding programs

Several promising lines developed at IRRI were sent to Indonesia to evaluate their performance in the farmers' field where flooding would usually occur. Several breeding processes had been done to improve IRRI's line for other important traits. B13138-7-MR-2-KA was one of IRRI's lines crossed with Pokhali and Angke to improve their resistance to bacterial leaf blight and salinity.

The Consortium for Unfavorable Rice Environments (CURE) supported multilocation yield trials (MYT) of several lines with parents from local Indonesian varieties. From these lines, two varieties were released as Inpari 29 rendaman (B13138-7-MR-2-KA) and Inpari 30 (Ciherang-Sub1).

The successful release of submergence-tolerant varieties encouraged the Indonesian institute to intensify its breeding program of varieties with similar characteristics, especially since the national government has support for the development of breeding facilities and capacity enhancement of young breeders. The Indonesian Center for Rice Research (ICRR) under the Indonesian Agency for Agriculture Research and Development (IAARD) has a breeding program for improving a combination of two or three characteristics of one rice variety to equip it against complex abiotic stresses.

A good example is B11377F-MR-34-2, a promising line for swampy areas. It was successfully developed through the national breeding program using a local variety as donor. The line has several important traits, such as submergence tolerance, bacterial leaf blight resistance, iron toxicity tolerance, and good grain quality.

Table 4. Characteristics of submergence-tolerant rice varieties and farmers' feedback.

Variety	Amylose content (%)	Rice texture	Grain shape	Number of days to maturity	Average yield (tons/hectare)	Farmers' feedback
Inpara 3	28.6	Hard	Medium slender	127	4.6	Submerged for 6 days; blast resistant; moderately tolerant for iron and aluminum toxicity
Inpara 4 (Swarna-Sub1)	29.0	Hard	Medium slender	135	4.7	Submerged for 14 days, moderately resistant to BPH; resistant to BLB; has long panicles; called "dau bong" by farmers, which means panicles are not totally exposed, thus, less vulnerable to bird attack; has compact seeds; less signs of grain spots or any grain disease based on grain discoloration*
Inpara 5 (IR64-Sub1)	25.2	Hard	Slender	115	4.5	Submerged for 14 days; resistant to BLB; has short maturation period; has dense seeds; less susceptible to pests and diseases; thin rice husk (bigger grain and higher weight)*
Inpari 29 Rendaman	21.1	Soft	Long slender	110	6.5	Submerged for 14 days
Inpari 30 Ciherang-Sub1	22.4	Soft	Long slender	111	7.2	Submerged for 14 days; high-yielding; has wide adaptability; has soft rice texture; and is resistant to BLB***
Inpari 8 Agritan	25.8	Hard	Long slender	115	4.7	Submerged for 14 days; moderately resistant to BLB, and blast; tolerant of iron toxicity of up to 500 ppm; early maturing; has long and compact panicles; has high milling recovery**

Note: Flood-tolerant varieties can survive 6–14 days of submergence.
*Source: Manzanilla et al., 2011 ; *Source: Rumanti et al., 2014; ***Source: AIAT Aceh

The *SUB1* gene was confirmed as a gene source of submergence tolerance in B11377F (Rumanti et al., in progress). In 2014, the line was released as as Inpara 8 Agritan. Table 4 shows other flood-tolerant rice varieties and farmers' feedback about the improved varieties.

The recently released flood-tolerant varieties Inpara and Inpari were targeted for swampy areas and irrigated areas affected by floods, respectively. In most of the Inpara varieties, breeders also incorporated tolerance for iron and aluminum toxicities, and resistance to blast as a solution to prevailing problems of rice production in the area. It was crucial to incorporate traits preferred by farmers. Inpara 3 is becoming as popular as Ciherang, of which areas of coverage have been increasing over the years. In Barito Koala District of South Kalimantan, areas planted with Inpara 3 have greatly increased since it was first introduced to the farmers in 2011 (Fig. 2). Even though the farmers had noted a peculiar taste of Inpara 3 compared with that of the local varieties, it was still received well because of its high yield, among other good characteristics. Moreover, it is stable, even if grown in drought lowland, tidal swampy area, or even in acidic soil because it has iron toxicity tolerance. Farmers also prefer Inpara 4 and Inpara 5 because they are high-yielding, even though they remain susceptible to blast and tungro.

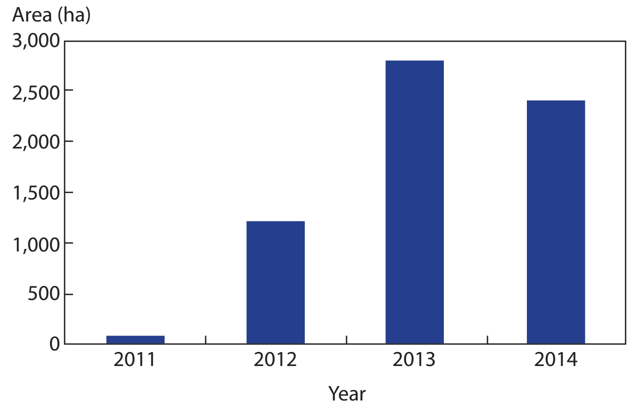


Fig. 2. Increasing land area covered by Inpara 3, 2011–2014, Barito Koala, South Kalimantan (Khairullah I and Koesrini, 2015)

Benefits of using the varieties

Demonstration plots were set up by the Assessment Institute for Agricultural Technology(AIAT) in each province in the country to introduce new technologies, including the improved varieties. In swampy areas, Inpara 3 generated an additional income for farmers compared with non-submergence varieties such as Ciherang and Mekongga. In Jambi, Inpara 3 was recognized to have a higher yield than Ciherang. Having a total yield of 7.04 tons per hectare, farmers could earn an additional income of up to about IDR10,000,000 (USD 757.3) compared with that of Ciherang. While in North Sumatra, Inpara 3 gave around IDR3,000,000 (USD 227.2) higher than that of Mekongga. On average, Inpara 3 would yield from 0.82 to 1 ton higher than Ciherang or Mekongga, increasing the farmers' income to about IDR2,950,000 (USD 223.4) – IDR 3,600,000 IDR (USD 272.6). With the coverage area reaching up to 67,059.37 hectares (as of 2014), Inpara 3 could generate approximately 197.8 to 241.4 billion IDR (USD 14,979,176.4 to USD 18,280,956.5) total additional income compared with cultivating nonsubmergence-tolerant varieties. Profitability assessment of using Inpara 3 variety in Jambi and North Sumatra revealed a benefit-cost ratio of 2.29 and 1.38, respectively (Table 5). Growing Inpara 3 in selected provinces can generate additional yield of at least 1.1 ton per hectare. Meanwhile, profitabiity assessment of Inpari 30 against Ciherang in selected locations reveals that growing Inpari 30 could yield as much as 9.7 tons per hectare, (in West Jawa), which was 4.1 tons per hectare, higher than the yield of Ciherang. This meant an additional income of IDR 1,476,000 or USD 111.8 for farmers (Table 6).

Cultural space

Improving farming practices with Sub1 rice varieties. Most local farmers in Kalimantan practice traditional cultivation, and grow local rice varieties which have good qualities in terms of grain shape, cooking quality, and storage capacity. The common local varieties that demand a high price are Siam Rukut, and Siam Karangdukuh. Traditional cultivation of these varieties take eight to nine months per period. They are photosensitive rice with long maturation

Table 5. Economical analysis for Inpara 3 in swampy area of Jambi and North Sumatera, Indonesia

Cost	Inpara 3 – Jambi*	Inpara 3 – NS**	Ciherang – Jambi*	Mekongga – NS**
Input: fertilizer, pesticide ect.	6,775,000	6,775,000	6,775,000	6,775,000
Labor	4,800,000	3,350,000	3,350,000	3,000,000
Total	11,085,000	11,085,000	11,085,000	11,085,000
Income				
Yield (ton)	7.04	4.25	4.32	3.50
Price/kg (IDR)	3,600	3,600	3,600	3,600
Selling price (IDR)	25,344,000	15,300,000	15,552,000	12,600,000
Net income in IDR	14,259,000	4,215,000	4,467,000	1,515,000
Net incomein USD	1,079.8	319.2	338.3	114.7
B/C	2.29	1.38	1.40	1.14

Sources: *Jumakir et al., 2012; **Helmi, 2015

Table 6. Economic analysis for Inpari 30 in selected locations, 2015.

Location	Yield (t/ha)	Additional yield (ton)	Additional income (IDR)*	Additional income (USD)
Maluku	6.6	1.1	3,960,000	299.9
Bima, W. Nusa Tenggara	9.0	3.5	12,600,000	954.2
West Jawa	9.6	4.1	1,476,000	111.8
East Jawa	7.2	1.7	6,120,000	463.5
Yield of Ciherang	5.5	-		

*rice price: 3,600 IDR per kg (USD 0.27)

period, flowering in June to July. The seedling nursery of local varieties starts in October, and needs four to five months to grow. Harvesting is done in the next four months after transplanting (August to September).

Given such traditional practice, it is still possible to introduce improved varieties such as Inpara 3, Inpara 4, and Inpara 5, which have long, slender, and hard grains preferred by farmers. Moreover, the improved varieties have early to medium maturation period, so they can be planted in the farmers' field during the seedling nursery periods of local varieties. Farmers normally use only about 20% of their land for seedling nursery, leaving the rest (80%) of the areas idle or neglected within the next four to five months. It was during this period that the IAARD through the AIAT, and Indonesian Swampland Agriculture Research Institute (ISARI) took the opportunity to introduce Inpara varieties through a system called *sawit dupa* (one seeding, twice harvesting). During the planting season that began in October, an early wet season in Indonesia, submergence varieties were introduced in the 80% idle or neglected areas of farmers during October-February/March. Local varieties were planted soon after harvesting of improved varieties in August to September. The *Sawit dupa* system was adopted by farmers, which successfully increased the cropping index and land productivity. In Barito Koala district, the same system was currently used, giving a benefit to farmers of about 43.8 to 48.4% yield increases compared with one season system using local varieties (Nursyamsi, et al., 2014).

National workshops on the rice technology in submergence-prone areas were held at ICRR on 19-21 August 2014, and 8-9 September 2015, and at ISARI on 18-19 August 2015. Improvement of crop management by using the new *Sub1* rice varieties was discussed among various stakeholders as well as ways on how to scale out all the technologies to more farmers.

A poster of best management practices for submergence-prone lowlands is also being prepared and tested at ICRR under the support of CURE program, which maximizes yield advantage of *Sub1* rice varieties by integrated crop management.

Political and financial spaces

Setting up a network for widespread dissemination. There are three major organizations under the Ministry of Agriculture, namely, IAARD, Technical Directorate, and the Agency of Human Resource Development (Figure 3). All of these research institutes including ICRR were coordinated by IAARD, whose main task is on research commodity-based technologies development and dissemination. To be widely adopted by farmers in all regions with unfavorable rice environments, the new technologies would be disseminated through AIAT centers, which have been set up by IAARD in 34 provinces across Indonesia with unfavorable rice ecosystem. Out scaling of submergence-tolerant varieties such as seed multiplication and distribution were supported by the Ministry of Agriculture in collaboration with the Directorate of Food Crops, and the Director General of Agricultural Infrastructure and Facilities through the national programs.

On the other hand, the technical directorates are focused on finding ways to meet food security. They are tasked to make policies and programs to increase national rice production. Several

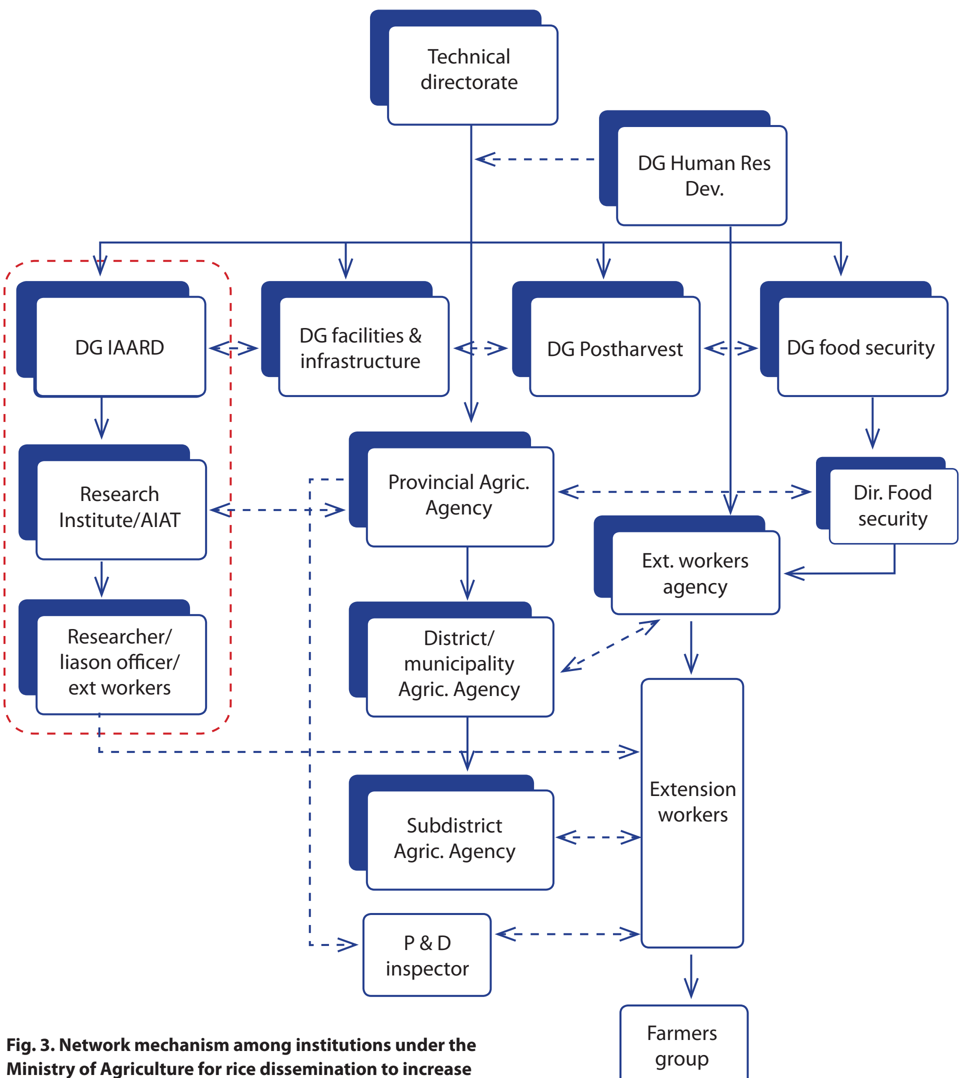


Fig. 3. Network mechanism among institutions under the Ministry of Agriculture for rice dissemination to increase rice productivity in Indonesia.

programs had been developed such as the Special Effort Program and the Seed Self-Sufficient Villages Act to encourage farmers to increase their rice productivity. Under these programs, farmers will adopt all technologies, including improved rice varieties developed by IAARD or a particular university in the country. The adoption of varieties are farmer preference-based. The agency of agriculture resource development is coordinating with extension workers in the whole country.

The strong commitment and support of the government in Indonesia is evident in the increase of the national budget for agriculture sector from the year 2015 through the Special Efforts Program to produce main food crops (rice-maize-soybean), and achieve self-sufficiency (UPSUS Program). Supports and incentives are given to farmers through this program to access certified seed, fertilizers, and agricultural machineries.

Several national programs that support the increase of rice production in Indonesia have also been established. These include the following:

Optimizing unfavorable environments as buffer

The rapid decrease of irrigated lowland rice areas caused by land conversion has prompted the national government to explore new rice areas. One of the potential areas to meet the challenge is the swampy areas. The disemination of submergence-tolerant varieties such as Inpara 3, Inpara 4, Inpara 5, Inpari 30, and Inpara 8 were conducted in most provinces where the unfavorable condition is apparent. In 2015, ISARI set up a 50 hectare demonstration plot for swampy environment in South Kalimantan to introduce new technologies developed by IAARD such as submergence-tolerant varieties, mechanization, and specific crops management for swampy environment.

Multiplying and disseminating certified seeds

To provide certified seeds for dissemination and other programs, the national government is also providing additional budget for seed purification and multiplication. ICRR as a rice research center has been supporting the government's programs by being involved in seed multiplication, especially for varieties released by IAARD. The seed production for inbred varieties includes the submergence-tolerant varieties described in Table 4. Great effort has been exerted by the ICRR to provide good and certified seeds, which guarantee the seed quality that defines the genetic and physical traits as well as yield of rice varieties.However, the impact of the improved varieties will only be significant

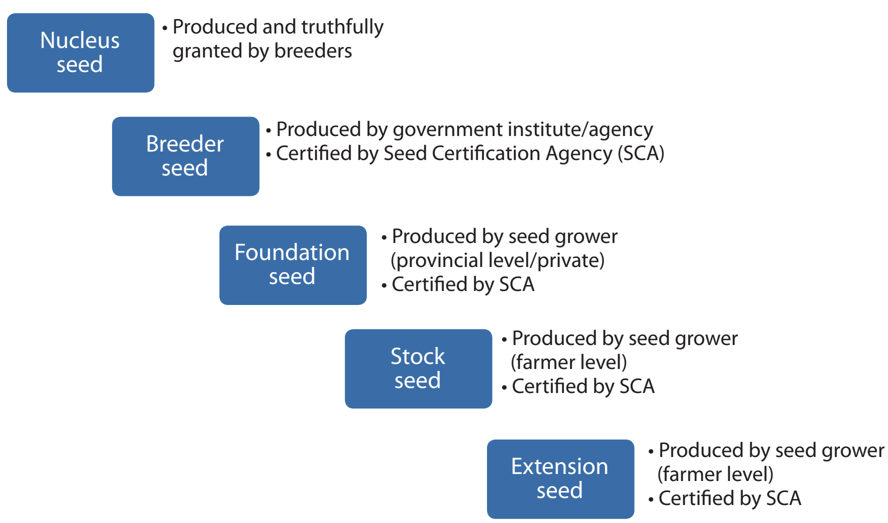


Fig. 4. Certified seed chain in formal system in Indonesia (MoA act No. 39, 2006).

if good quality seeds were made available and accessible to farmers. This is done through two seed systems: the formal and informal seed system.

In the formal system, seeds are classified into five types (Fig. 4), which also shows the different sources of the seeds.

The certified seeds produced by ICRR include breeders' seeds, foundation seeds, and stock seeds to provide for seed growers. Table 7 shows the stock of seeds available at ICRR to be sold to seed growers, AIAT, and the provincial agriculture agency to produce seeds of lesser quality, while the seed distribution data of stress-tolerant varieties in 2015 are shown in Table 8. Moreover, in line with the government's program, seeds are given to farmers as seed loan.

In 2012, the seed directorate reported that the formal seed system only provided 55.9% of the total seed requirement, while the 44.1% should be provided through the informal system; that is, by seed exchanges or purchases among farmers, and preservation or storage of seeds by the farmers themselves, among other means. Informal seed system is commonly practiced in remote and subsistent areas where farmers have difficulty accessing input for their agricultural ventures. It is also common in unfavorable environments, where the need for the volume of seed is minimal. Thus, companies are not willing to engage

Table 7. Seed stock of submergence-tolerant varieties in ICRR, December 2015.

No	Varieties	Commercial		Non-commercial			Total (Kg)
		BS (Kg)	FS (Kg)	BS (Kg)	FS (Kg)	SS (Kg)	
1	Inpara 3	661	922	-	-	695	2,278
2	Inpara 4	662	362	-	-	1,094	2,118
3	Inpara 5	697	-	-	-	784	1,481
4	Inpara 8 Agritan	739	564	-	-	836	2,139
5	Inpari 29 Rendaman	487	350	-	-	1,449	2,286
6	Inpari 30 (Ciherang-Sub1)	2,263	360	-	197	5,196	8,016

Table 8. Seed distribution by ICRR to seed growers and farmers, 2015.

No	Varieties	Seed Class			Total
		BS (kg)	FS (kg)	SS (kg)	
1	Inpara 3	395	760	1,290	2,445
2	Inpara 4	977	956	151	2,084
3	Inpara 5	65	6	348	419
4	Inpari 29	119	107	767	993
5	Inpari 30 (Ciherang-Sub1)	944	4,192	3,939	9,075
6	Inpara 8 Agritan*	7	10	5	22

Table 9. Beneficiaries of stress-tolerant varieties, 2015.

Country	Ecosystem	Varieties	Area (ha)	No. of farmers
Indonesia	Submergence	Inpara 30	402.00	165.04
		Inpara 28	27.50	25.00
		Inpari 19	5.00	5.50
		Inpara 3	90.00	110.40
		Inpara 2	16.50	15.00
		Inpara 4	16.50	15.00
	Upland	Inpago	20.00	22.00
	Drought	Inpari 19	3.70	3.30
	Subtotal		**581.20**	**361.24**

or invest their businesses in unfavorable environments, making the availability of seeds of stress-tolerant varieties scarce. Given such circumstance, farmers would opt to buy any variety available in the store without validating the variety's suitability to their land condition. This could lead to low yield because of the variety's susceptibility to abiotic stresses such as submergence. Thus, rice productivity in unfavorable environments in Indonesia is commonly low.

Based on these information, the Directorate of Food Crops adopted the CBSS developed by CURE project to support subsistent farmers. In 2015, the CBSS was introduced through the '1000 seed self-sufficient villages' program in most of irrigated areas, which would serve as a model.The objective was to get an idea of the informal seed system, such as how the seed growers respond to new improved varieties, among others. Under this program, the national government provided facilities and capacity-building activities to seed growers. Even though it was conducted in irrigated areas, seed growers showed interest and were willing to produce submergence-tolerant varieties such as Inpari 30 (Ciherang-Sub1), Inpara 3, and Inpara 4. Data from the Directorate of Food Crops revealed that Inpari 30 was grown in Aceh, North Sumatra, Riau, West Kalimantan, Central Kalimantan, East Nusa Tenggara, West Nusa Tenggara, South Sumatra, Yogyakarta, West Java, Central java, East Java, South Sulawesi, and West Papua (Table 10). While Inpara 3 and Inpara 4 were used in West Kalimantan, Central Kalimantan, South Kalimantan, and Jambi, most of which were nearby swampy areas. Thus, the seed production is expected to fulfill the need of farmers in swampy environment as well. Fortunately, Inpari 30, a new submergence-tolerant variety, was acceptable to the farmers, who were

Table 10. Program of 1000 seed self-sufficient villages in Indonesia, 2015.

Provinces	Areas (ha)	No. of farmer groups
Inpari 30 (Ciherang Sub1)		
Aceh	30	3
N. Sumatera	70	7
Riau	25	5
W. Kalimantan	155	16
C. Kalimantan	60	6
East Nusa Tenggara	10	1
S. Sumatera	40	4
W. Nusa Tenggara	20	2
Lampung	10	1
Yogyakarta	10	1
W. Java	45	5
C. Java	7.5	2
E. Java	10	1
S. Sulawesi	10	1
W. Papua	5	1
Inpara 3		
W. Kalimantan	90	14
C. Kalimantan	30	3
Jambi	0.5	1
Inpara 4		
S. Kalimantan	15	3

Source: Directorate of food crops, available data as of 6 November 2015.

also willing to produce its seeds. The available quality seeds recommended for dissemination, and seeds that come from other farmers were generally easily accepted by farming communities, as in the case of Inpari 30. It did not take six to ten years for farmers to adopt Inpari 30 like other new varieties because it resembles Ciherang's morphological and cooking qualities that farmers prefer.

Various farmers' groups who were involved in the program learned how to produce good and healthy seeds, practice good harvest and postharvest management, and credit for agricultural input, and facilities such as drying floor and barn. Provinces with many farmers' group participants were in West Kalimantan, followed by North Sumatra, and Central Kalimantan. Farmers' groups that received a loan in the first year (2015) could be models for other farming communities in the succeeding years. They could share their knowledge to other farmers, and eventually help other farmers' groups develop new 'seed self-sufficient villages' near them.

REFERENCES

Collard, B.C.Y., Septiningsih, E.M., Das, S.R., Carandang, J.J., Pamplona, A.M., Sanchez, D.L., Kato, Y., Ye, G., Reddy, J.N., Singh, U.S., Iftekharuddaula, K.M., Venuprasad, R., Vera-Cruz, C.N., Mackill, D.J.,& Ismail, A.M. (2013). Developing new flood-tolerant varieties at the International Rice Research Institute (IRRI). Sabrao *Journal of Breeding and Genetic 45 (1): 42-56*.

Directorate of food crops of Indonesia. (2014). *Distribution of varieties in Indonesia in 2014*. Ministry of Agriculture of Indonesia. E-file.

Directorate for seed of Indonesia. 2013. *Distribution of varieties in Indonesia in period of 1977-2012*. Ministry of Agriculture of Indonesia. E-file.

Helmi. (2015). Increasing rice productivity in Lebak through swampy varieties usage (English abstract). Jurnal Pertanian Tropik 2 (2): 78- 92

Iftekharuddaula, K.M., Newaz, M.A., Salam, M.A., Ahmed, H.U., Mahbub, M.A.A., Septiningsih, E.M., Collard, B.C.Y., Sanchez, D.L., Pamplona, A.M.,& Mackill, D.J. (2011). Rapid and high-precision marker assisted backcrossing to introgress the *SUB1* QTL into BR11, the rainfed lowland rice mega variety of Bangladesh. *Euphytica 178:83-97*

Jumakir, R.P., Bustami,& Endrizal. (2012). National Proceedings of ICATA: *Productivity and diffusion of improved variety: Inpara 1 and Inpara 3 in swampy areas of Jambi (English abstract)*. Book 1. Bogor, 19-20 November 2011.

Mackill, D.J., Ismail, A.M., Singh, U.S., Labios, R.V., & Paris, T.R. (2012). Development and rapid adoption of submergence-tolerant (Sub1) rice varieties. *Adv. Agron. 115: 303-356*

Manzanilla, D.O., Paris, T.R., Vergara, G.V., Ismail, A.M., Pandey, S., Labios, R.V., Tatlonghari, G.T., Acda, R.D., Chi, T.T.N., Duoangsila, K., Siliphouthone, I., Manikmas, M.OA., & Mackill, D.J. (2011). Submergence risks and farmers' preferences: Implications for breeding Sub1 rice in Southeast Asia. *Agriculture System 104: 335-347*.

Makarim, AK. (2000). Bridging the rice yield gap in Indonesia. In: Papademetriou MK, Dent FJ, Herath EM (eds). Bridging the rice yield gap in South East Asia region. p.112-121.

Neeraja, C.N., Maghirang-Rodriguez, R., Pamplona, A., Heuer, S., Collard, B.C.Y., Septiningsih, E.M., Vergara, G., Sanchez, D., Xu, K., Ismail, A.M., & Mackill, D.J. (2007). A marker-assisted backcross approach for developing submergence-tolerant rice cultivars. *Theor. Appl. Genet. 115: 767-776*.

Nursyamsi, D., et al. (2014). *Pengelolaan Lahan Rawa Lebak untuk Pertanian Berkelanjutan (Management of Lebak Area for Sustainable Agriculture)*. IAARD Press, Jakarta.

Rumanti, I.A., Suwarno, Nugraha, Y., Jamil, A. (2015). *Inpara 8 Agritan, a new tolerant variety released in Indonesia*. CURE Newletter No. 5, 2015.

Rumanti, I.A., Nugraha, Y., Wening, R.H., Suwarno, Nasution, A., Kusdiaman, D., Septiningsih, E.M. (in progress). Multi-traits of swampy rice development in Indonesia. 2nd ICSAFS.

Septiningsih, E.M., Pamplona, A.M., Sanchez, D.L., Neeraja, C.N., Vergara, G.V., Heuer, S., Ismail, A.M., & Mackill, D.J. (2009). Development of submergence-tolerant rice cultivars: the Sub1 locus and beyond. *Ann. Bot. 103:151-160*.

Septiningsih, E.M., Hidayatun, N., Sanchez, D.L., Nugraha, Y., Carandang, J., Pamplona, A.M., et al. (2014). Accelerating the development of new submergence-tolerant rice varieties: the case of Ciherang-Sub1 and PSB Rc18-Sub1Euphityca 200 (2)

Indonesia

Drought-prone environments

Reaping gains with less rain: Best management practices for drought-prone rice areas in Indonesia

Aris Hairmansis, Indrastuti A. Rumanti, Yudhistira Nugraha, Yoichiro Kato, and Ali Jamil

Technological advancement in farming practices in Indonesia is instrumental not only in mitigating the damages caused by land conversion, climate change, and El Niño, but also, in pushing forward the national agenda of increasing rice productivity in the country.

Rice production in Indonesia

In its efforts to meet the demands of the nation's ballooning population and to attain food self-sufficiency, the Indonesian government under President Joko Widodo has promoted directives in rice research toward increasing productivity with large buffer stocks to secure the food supply.[1] Moreover, besides establishing infrastructure to support food security, updating the farming system and providing access to technology are also important to help boost productivity, as raised by Hari Priyono, secretary-general of the Agriculture Ministry of Indonesia.[2]

While the government's strategy will draw on the best rice science to further improve yields on favorable land, that is, in irrigated lowland areas, it also aims to expand production in frontier areas, where rice crops must withstand harsher environments with constantly-evolving disease and pests.

About 60% of the rice production in Indonesia comes from irrigated lowland areas, while the rest are produced in unfavorable rice ecosystems including rainfed lowland, tidal swamp land, flood-prone land, and upland. The total rice area in the country is about 8.05 million hectares, which consist of 4.89 hectares of irrigated rice areas, and 3.16 hectares of non-irrigated rice areas (Ministry of Agricuture, 2014).

It is estimated that drought-prone rainfed lowlands in the country covers about 2.08 million hectares and is the largest rice producer second to irrigated areas (Toha et al., 2008).

Rainfed lowland rice areas are characterized as a fragile environment with many abiotic and biotic constraints. Drought is the major problem hampering the rice production in this ecosystem. Other important limiting factors in rainfed lowland areas are low soil fertility and high weed infestation (Toha et al., 2008). More importantly, the global climate change has shifted the pattern of cropping calendar in agricultural land. Because of these changes, about 50% of agricultural areas in Indonesia experience shorter rainy seasons and longer dry seasons, in which rainfed lowland areas are the most affected (Ministry of Agriculture, 2015).

The rice yield in rainfed lowland area of Indonesia averages from 3.0 to 3.5 tons per hectare, lower than national rice

[1] International Rice Research Institute. (2015). Rice is key to Indonesia's food security, officials say. Available via irri.org/news/media-releases/rice-is-key-to-indonesia-s-food-security-officials-say

[2] Parlina, I. and Salim, T. (2015). Jokowi confident on food security in 3 years. *The Jakarta Post*. Available via www.thejakartapost.com/news/2015/02/13/jokowi-confident-food-security-3-years.html

production, which is 5.1 tons per hectare. The average yield gained by farmers in this area is also much lower than the yield obtained in research scale, which ranged from 6.5 to 7.5 tons per hectare (Toha et al., 2008). Thus, an increase in rice yield in rainfed lowland areas is urgently needed to reduce the yield gap and increase farmers' income in this ecosystem. And, improving farmers' management practices is one of the ways to raise the rice yield gap in these areas.

DRIVERS OF CHANGE

Besides lobbying for food-self sufficiency by the Indonesian government, maintaining an economic edge and managing the country's environmental vulnerability are other factors that heighten the need for technologies that improve rice productivity in Indonesia.

Commitment to achieve rice self-sufficiency. Even though Indonesia is the third largest rice producer in the world (after China and India), the country still imports rice to meet the demand (Fig. 1). Thus, the new Indonesian government is committed to achieving rice self-sufficiency within 5 years (2015-2019).

To achieve the target, rice production must be increased both in irrigated and non-irrigated rice areas, including unfavorable rice environments. The commitment of the government is so strong that it has increased its 2015 national budget for agriculture through the Special Effort Program to achieve food crops (rice-maize-soybean) self-sufficiency (*Upaya Khusus* or UPSUS). Support and incentives are given to farmers through this program to access certified seeds, fertilizers, and agricultural machineries.

The government's strategic plan to open 1 million hectares of new rice areas. Based on the data from 1981 to 1985 and from 1998 to 1999, land conversion rate from rice area to non-rice area in Indonesia is about 50,000 hectares per year. [3]

Most of the land conversion occurred in Java Island, the central rice production area of Indonesia. The rapid decrease of irrigated lowland rice areas caused by land conversion has prompted the national government to anticipate it through opening new rice areas. The Indonesian government targets increasing rice areas of 1 million hectares by 2019 (Ministry of Agriculture, 2015). One of the potential areas to meet the challenge is unfavorable areas such as rainfed lowland areas.

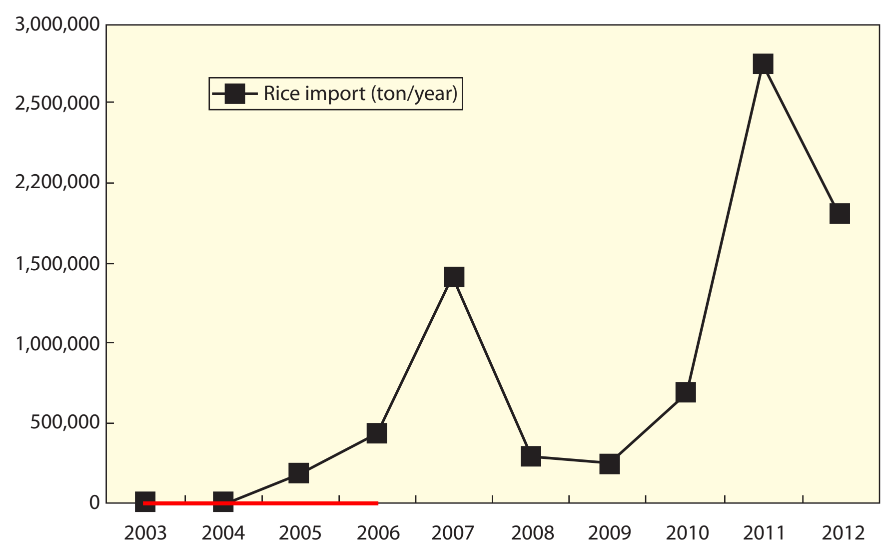


Fig.1. Rice import trend in Indonesia (adapted from Sembiring, 2015).

[3] www.fao.org/docrep/005/ac623e/ac623e0g.htm.

El Niño episodes. Indonesia has frequently suffered from El Niño, which had caused extreme droughts in agricultural lands. Since 1950, El Niño has occurred 22 times in the country, six of which were severe.[4] In 2015, the last El Niño in the country significantly damaged rice areas, mainly rainfed lowlands. Improvement in rice management practices could be one of the important strategies to minimize the effect of this extreme condition.

Unstable fertilizer price. Although the prices of fertilizers are strictly regulated by the Indonesian government, majority of Indonesian farmers still need to buy fertilizers at a higher price than regulated prices (Osorio et al., 2011). In case of fertilizer shortage, the price in the market can rise much higher than the regulated price. The fluctuations in fertilizer prices are also influenced by the natural gas price in the global market. Such predicament tends to force farmers to reduce their fertilizer application. The implementation of best management practices (BMP) by using site-specific nutrient management will help farmers reduce their fertilizer requirement for their fields.

Establishment of ASEAN Economic Community (AEC). The establishment of a common market within ASEAN countries by 2015 had led to tighter competition in trade among the member countries in the rice market. The Indonesian government has anticipated this and has made certain agricultural reforms and policies such as increasing the national rice production, while maintaining a competitive rice price. However, increasing rice production can only be achieved by optimizing all potential rice areas and producing rice most efficiently. Thus, the implementation of BMP is one of the strategies to help increase rice production efficiency.

Best management practices

Best management practices or BMP for drought-prone rainfed lowland rice refer to integrated rice management practices from crop establishment to postharvest based on the current best technologies, which are available and suitable to local condition (Alam et al., 2013). The BMP process includes several steps such as selection of high-quality seeds of drought-tolerant rice varieties, land preparation, planting system (transplanting or direct seeding), water management, balanced nutrient management, integrated weed, pest and disease management, harvest and postharvest handling, among others. Similar to integrated crop management (ICM), which is based on participatory approaches, the improvement in farmers' management practices through BMP should also have farmers' involvement.

The project has produced information materials on BMP for drought-prone rainfed lowland. These materials serve as general guidelines of BMP that can be adjusted according to a farmer's field conditions.

The process

The BMP process for drought-prone rainfed rice areas are the following:

1. Selection of suitable drought-tolerant rice varieties

The Indonesian Centre for Rice Research (ICRR) has developed some rice varieties that are well-adapted to rainfed lowland condition (Table 1). Varieties such as Situ Bagendit and Inpari 10 have good tolerance to drought as an adaptive strategy in drought-prone rainfed lowlands. On the other hand, varieties such as Inpari 11, Inpari 12, Inpari 13, Inpari 18, and Inpari 19 have short maturity and are good options to avoid terminal drought in the rainfed areas. Farmers can select their preferred varieties based on traits such as maturity, grain quality, or resistance to pest and disease.

2. Land preparation

The technology used in land preparation depends on the planting system used, water availability, and available agriculture machinery. Having good land preparation will result in well-leveled land, reduced weed infestation, and less water loss.

[4] www.bmkg.go.id

Table 1. Rice varieties released for drought-prone rainfed lowland rice areas in Indonesia.

Varieties	Year released	Maturity (DAS*)	Yield (t/ha)		Amylose content (%)	Rice texture	Other characteristics**
			Potential	Average			
Situ Bagendit	2003	110–120	6.0	4.0–5.5	22.0	Soft	Has moderate resistance to blast, BLB III, IV
Inpari 10 Laeya	2009	112	7.0	4.8	22.0	Soft	Has moderate resistance to BPH1, 2, BLB III
Inpari 11	2010	105	8.8	6.5	21.4	Soft	Has resistance to BLB III, blast 033, and to 133; and moderate resistance to BLB IV, and VIII,
Inpari 12	2010	99	8.0	6.2	26.4	Hard	Has resistance to blast 033; and moderate resistance to BPH1, 2;
Inpari 13	2010	99	8.0	6.6	22.4	Soft	Has resistance to BPH 1, 2, 3, and blast 033
Inpari 18	2011	102	9.5	6.7	18.0	Soft	Has resistance to BPH 1, 2, and to BLB III; and moderate resistance to BPH 3
Inpari 19	2011	104	9.5	6.7	18.0	Soft	Has resistance to BPH 1, 2, and to BLB III; and moderate resistance to BPH 3

*DAS - Days after sowing, **BLB - Bacterial leaf blight, BPH - Brown plant hopper

3. Establishment of seedling nursery (in transplanting system)

Healthy and vigorous rice seedling is important in the transplanting system. A proper seedling nursery must be prepared to obtain good seedlings, and this entails preparation of seedbed nursery, seed sowing, fertilizer application, and seedling maintenance.

4. Weed management

Growth of weeds is one of the major problems in drought-prone rainfed lowland areas. It should be controlled as early as possible from land preparation. Weed control uses a combination of herbicide and manual weeding, and is dependent on the planting system, financial, and labor conditions.

Studies conducted in the rainfed lowlands of Central Java and West Nusa Tenggara indicated the importance of pre-emergence weed management in rainfed areas particularly when farmers used the direct seeding method (Fig. 2).

5. Rodent and golden snail management

Rodents and golden snails are two of the most devastating pests in the early stage of rice growth. Different methods can be used to control such pests. Synchronized planting and community action are two of the most efficient approaches in rodent management.

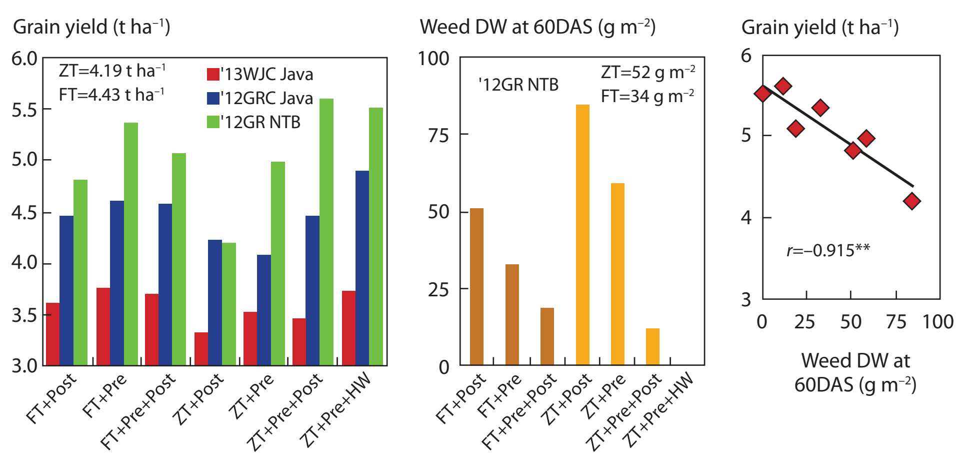


Fig. 2. The effect of different weed management on rice yield and weed infestation (CURE Working Group 1, unpublished data). The experiments were conducted under gogo rancah system in West Nusa Tenggara 2012 wet season (12GRNTB); and Central Java 2012 wet season (12GRCJava); and under walik jerami system in Central Java 2013 wet season (13WJCJava).

WS = Wet Season; ZT= Zero tillage; FT= Full tillage; Pre= Pre-emergence herbicide; Post= Post-emergence herbicide; HW=hand weeding

6. Planting system and crop establishment

Farmers in different rainfed areas used different crop establishment methods such as transplanting, wet direct seeding, or dry direct seeding (detailed information for each method are described in the information materials developed). In the transplanting system, rice can be planted using the square method or the alternate row method (*Jajar Legowo*). The use of the alternate row method will give better control on weeds. In addition, the rice transplanter for *Jajar Legowo* is now also widely available through a government program.

7. Nutrient management

Balanced nutrients are key in implementing BMP. Application of both organic and inorganic fertilizers is necessary to obtain high yield. Organic fertilizer should be applied during land preparation. Some tools that can be used to determine the amount of fertilizer needed in different locations include:

- Rice agro-advisory service (*Layanan Konsultasi Padi*)
- Soil test kits
- Cropping calendar (KATAM[5])
- Leaf color chart (for nitrogen (N) status)
- Omission plots (for Phosphorous [P] and Potassium [K] status)

8. Water management

Water management is the most crucial step in rice management in drought-prone areas. Bunds have to be maintained and controlled regularly to minimize water losses. Water should be kept about 3–5 centimeters above soil surface from early stage until about 2 weeks before harvest. Runoff water should be stored in a water reservoir if available. The reserved water can be used for supplemental irrigation particularly during reproductive stage, which is the most vulnerable stage to drought.

9. Pest and disease management

The most efficient way in pest and disease management is by using stress-tolerant rice varieties (Table 1). Occurrence of pest infestation and diseases needs to be regularly monitored to prevent an outbreak. Detailed pest and disease management in each location can be consulted with the local pest and disease-monitoring officer for the best approaches.

10. Harvest and postharvest activity

Proper harvest and postharvest handling are important to minimize yield losses and to maintain grain quality. The handling depends on the availability of agricultural machinery and labor.

Productive partnership

The collaborative research project between ICRR under the Indonesian Agency for Agricultural Research and Development (IAARD) and the International Rice Research Institute (IRRI) through the Consortium for Unfavorable Rice Environments (CURE) has developed and validated BMPs for drought-prone rainfed lowland rice areas. BMPs for rice in unfavorable rice environment are adapted from the concept of ICM called as *Pengelolaan Tanaman Terpadu* (PTT). The ICM approach was initially developed to maintain sustainability of rice production in irrigated lowland rice areas. The technology was developed by ICRR in collaboration with IRRI through the Irrigated Rice Research Consortium (IRRC).

The ICM approach was first carried out in irrigated lowland areas in 1999 at the experimental station of ICRR (Abdulrachman *et al*., 2005) (Table 2). In 2001, the approach was validated in eight Indonesian provinces, and showed an increase of 16.4% in rice yield during dry season, and 28.4% during wet season. Now, the ICM approach has been adopted nationwide. And, it has become a national program to increase rice production in irrigated rice areas of the country.

The ICM approach integrates management of crop, soil, water, nutrient, and pest and disease. So, each

[5] First developed by the Indonesia Agency for Agricultural Research and Development (IAARD), KATAM is a tool provided by the government of Indonesia to secure food production in the framework of the national rice production enhancement program (peningkatan produksi beras nasional, P2BN). It is also intended to help farmers adapt to the changing climate (Kaneko, S. & Kawanishi, M., 2016).

Table 2. Timeline of some of the major accomplishments in the development of BMP for drought-prone rainfed lowland areas.

Year	Major accomplishments	Institutions and partners
1999	ICM for irrigated rice initiated in Indonesia	Indonesian Center for Rice Research (ICRR) Indonesian Center for Food Crops Research and Development (ICFORD) International Rice Research Institute (IRRI)
2001	ICM for irrigated rice scaled out	ICRR ICFORD Assessment Institute for Agricultural Technologies (AIAT) IRRI
2009	Drought-tolerant rice variety released: Inpari 10	ICRR ICFORD AIAT
2010	Very early-maturing rice varieties released: • Inpari 11 • Inpari 12 •I npari 13	ICRR ICFORD AIAT
2011	Very early-maturing rice varieties released: • Inpari 18 • Inpari 19	ICRR ICFORD AIAT
2012-13	BMP trials initiated in: • Central Java • West Java • West Nusa Tenggara	ICRR ICFORD IRRI (CURE) AIAT Indonesian Center for Agricultural Technology Assessment and Development (ICATAD) Indonesian Center for Agricultural Land Resources Research and Development (ICALRD)
2014	BMP validated in: • South Sulawesi • West Nusa Tenggara • East Java • Central Java	ICRR ICFORD IRRI (CURE) AIAT ICATAD ICALRD
2015	• Technical guide for BMP developed • Rice agro-advisory service (LKP) for irrigated, rainfed and tidal swamp area released	ICRR ICFORD IRRI (CURE, IRRC) ICFORD ICALRD ICATAD

approach is unique to each kind of rice ecosystem. This is why the application of management practices should be based on participatory approaches. Farmers' involvement is highly needed to determine the most suitable management practices for their respective rice fields. A participatory rural appraisal (PRA) is recommended to be conducted before implementing ICM.

The success of the ICM approach in irrigated rice areas led to the implementation of the approach in unfavorable rice environments. Several studies have been conducted through collaborative research between ICRR and IRRI (CURE-IFAD Project) to develop and validate improved management practices referred to as BMP for rice in unfavorable rice environments, adopted from the ICM concept.

One of the main components in ICM is nutrient management based on the principles of balanced nutrient and site-specific nutrient management (Dobermann et al., 2002). A number of tools have been developed to assist farmers in determining the amount of fertilizer applied. One of the tools is the Rice Crop Manager (RCM), which was developed through collaborative research between ICRR and IRRI. RCM was then released as a web-based tool in Indonesia in early 2015 as Rice Agro-advisory Service (*Layanan Konsultasi Padi* or LKP; available online (http://webapps.irri.org/id/lkp/). This tool now includes a service for drought-prone rainfed lowland rice areas.

Validating the best management practices

Several studies have been conducted under Working Group (WG) 1 of CURE-IFAD project activities to validate the implementation of BMP in drought-prone environments. Technical guidance for the implementation of BMP in drought-prone rainfed lowland areas has also been developed through the project.

Some of the project achievements are summarized below.

- Experiment in farmer's field in drought-prone area of Indramayu, West Java during WS 2012-2013 showed the application of fertilizer based on the Rice Crop Manager increased rice yield by 4% to 11% compared with farmers' practices (see Table 3).
- In the WS 2014-2015, the SSNM practice (SSNM) was tested by 17 farmers in drought-prone rainfed lowlands of two districts in Nusa Tenggara. The results demonstrated that SSNM increased the yield from 12.4% to 22.5% (Table 4).
- In the 2014-2015 wet season, experiments were conducted in drought-prone lowland rice in two districts of East Java Province to validate the implementation of BMPs for drought-prone areas using two improved varieties namely, Inpari 10 and Inpari 19. Inpari 10 was selected because it is drought-tolerant and its grain quality is almost similar to that of Ciherang's, the most popular rice variety in Indonesia. Inpari 19 is a new rice variety released in 2011 and has short-maturity duration (104 days after sowing), which makes it suitable for rainfed areas as an escape strategy from terminal drought. The experiments were conducted by three farmers in each district. The implementation of BMPs in Malang led to an increase in rice yield by 10.4%, while in Pasuruan the yield increased by 18% (Fig. 3).

Focused partnership through CURE

Strong collaborative research has been conducted between IAARD and CURE. In the next phase, the project needs to be strengthened particularly in the development of pathways for technology dissemination and capacity building to accelerate the scaling out process of the new technology.

Table 3. Rice yield in three different topo-sequences of rainfed drought-prone area in Indramayu under site-specific nutrient management (SSNM) and farmer nutrient management (FNM) during the 2012-2013 wet season (CURE WG1 Indonesia, unpublished data).

Topo-sequences	Treatment	Farmer 1 (tons/ha)	Farmer 2 (tons/ha)	Farmer 3 (tons/ha)	Average	% yield increase
Upper	SSNM	5.23	4.87	6.23	5.44	11
	FNM	4.38	4.31	6.04	4.91	
Lower	SSNM	4.94	6.49	6.92	6.12	4
	FNM	4.58	6.54	6.53	5.88	
Bottom	SSNM	6.2	6.96	6.19	6.45	6
	FNM	6.98	5.25	6.07	6.1	

Table 4. Rice yield in drought-prone rainfed lowland in two districts of West Nusa Tenggara under site specific nutrient management (SSNM) and farmer nutrient management (FNM) during 2014-2015 wet season (CURE WG1 Indonesia, unpublished data).

Location	No of farmers	SSNM (tons/ha)	FNM (tons/ha)	Yield increase (%)
Central Lombok	12	6.55	5.83	12.4
Sumbawa	5	5.62	4.58	22.5

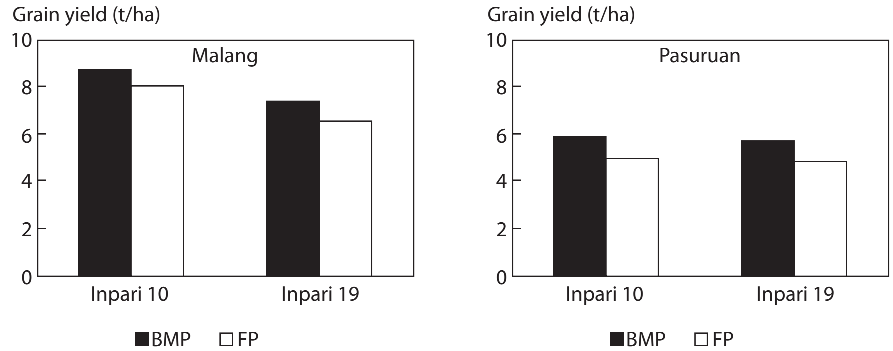


Fig. 3. Grain yield of rice varieties Inpari 10 and Inpari 19 cultivated under best management practices (BMP) and farmers' practices (FP) in Malang and Pasuruan during 2014/2015 wet season (CURE WG1 Indonesia, unpublished data).

To assist the scaling out process of the BMP technology, knowledge management is one of the important processes that needs to be improved. Through the CURE-IFAD project, information materials to disseminate the technology have been developed. The final draft of three posters and fact sheets on BMPs for drought-prone rainfed lowland area have been developed (Fig. 4). The materials will be given to extension workers and farmers in rainfed lowland rice areas.

The implementation of BMPs in drought-prone rainfed lowland rice areas aims to increase rice production in this unfavorable rice ecosystem through the best combination of stress-tolerant varieties and management options to support the national rice production and to increase farmers' income.

The scaling out process of BMPs is targeted to be shared to as many farmers as possible in the drought-prone rainfed lowland rice ecosystem. This ecosystem is estimated to cover 2.08 million hectares in the country. Several provinces with significant rainfed lowland areas include North Sumatra, South Sumatra, Lampung, West Java, Central Java, East Java, West Kalimantan, South Kalimantan, South Sulawesi, West Nusa Tenggara and East Nusa Tenggara (Table 4). West Java, Central Java, and East Java are the most frequent provinces experiencing drought (Fig. 3, Table 5). More importantly, these three provinces account for 60% of national rice production. Other provinces that are prone to drought include Aceh, Lampung, South Kalimantan, South Sulawesi, and West Nusatenggara (Fig. 3, Table 5).

The BMPs would be widely promoted to all 34 provinces of Indonesia, especially to provinces with pronounced areas of drought-prone rainfed lowland areas. The presence of the Assessment Institute of Agricultural Technologies (AIAT) under IAARD in 34 provinces offers great potential to disseminate the technology. Information materials, which have been developed through the CURE-IFAD project, need to be disseminated through AIAT. Knowledge transfer on this technology from ICRR or IRRI scientist to AIAT scientist if necessary needs to be conducted.

Furthermore, outscaling of the BMPs is expected to be implemented by the Directorate of Food Crops and the Director General of Agricultural Infrastructure and Facilities through their national program on increasing their rice production.

Policy and Financial spaces

Encouraging adoption of technology by giving incentives. The Special Effort (UPSUS) program, launched by the Ministry of Agriculture in 2015, needs support for new rice technologies to accelerate the achievement of rice self-sufficiency in Indonesia.

One of the schemes under the program is to encourage farmers to use ICM in their farming system, referred to as *Gerakan Penerapan (GP)-PTT* (ICM Implementation Action) Program. Through

Fig. 4. Draft posters on BMP for drought-prone rainfed lowland rice guidelines for (a) transplanting, (b) wet direct seeding, and (c) dry direct seeding systems.

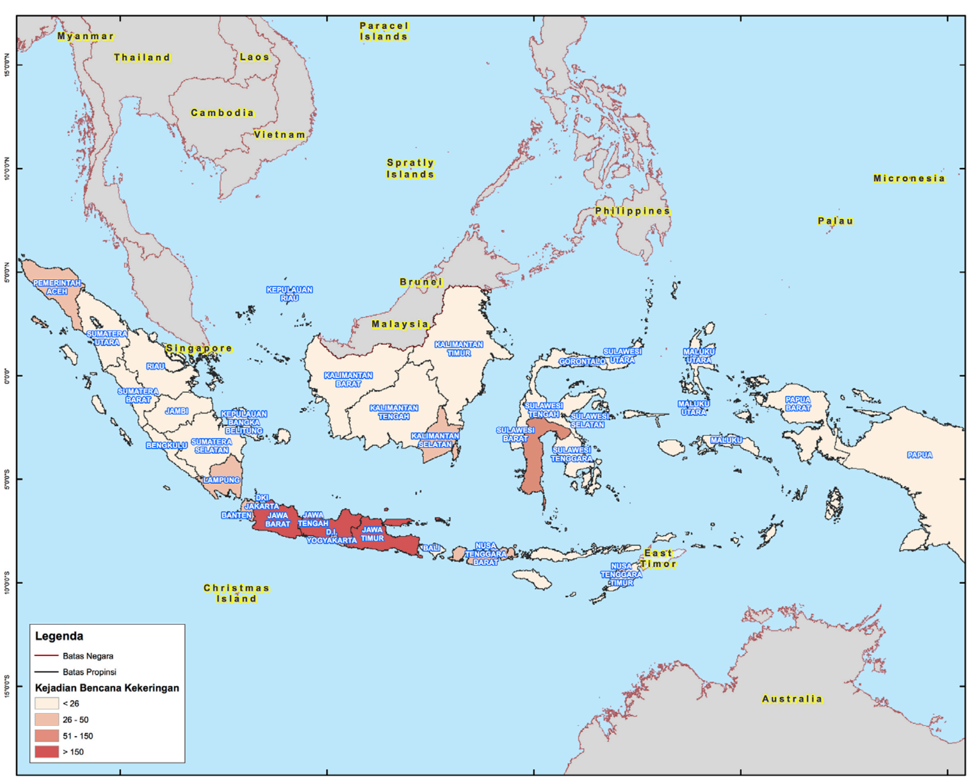


Fig. 5. Map of drought events in provinces of Indonesia from 1979 to 2009 (Source: www.geospasial.bnpb.go.id).

Table 5. Irrigated and non-irrigated rice areas in 34 provinces of Indonesia in 2013.

Provinces	Irrigated (Ha)	Non-irrigated (Ha)	Number of drought events (1979-2009)
1. Aceh	198,438	102,370	43
2. Sumatera Utara	273,052	165,294	20
3. Sumatera Barat	180,628	43,554	9
4. Riau	13,179	80,159	12
5. Jambi	41,232	72,314	24
6. Sumatera Selatan	107,656	504,768	12
7. Bengkulu	66,124	27,258	4
8. Lampung	185,569	174,668	34
9. Kepulauan Bangka Belitung	3,543	1,815	0
10. Kepulauan Riau	283	204	0
11. DKI Jakarta	870	25	0
12. Jawa Barat	744,090	180,952	278
13. Jawa Tengah	683,735	268,790	300
14. D.I.Yogyakarta	46,165	9,171	33
15. Jawa Timur	862,590	240,273	156
16. Banten	104,385	90,331	49
17. Bali	78,163	262	16
18. NusaTenggara Barat	204,590	48,431	50
19. NusaTenggara Timur	104,084	64,979	7
20. Kalimantan Barat	87,750	243,133	11
21. Kalimantan Tengah	23,219	187,588	3
22. Kalimantan Selatan	40,534	399,895	40
23. Kalimantan Timur	14,472	48,834	8
24. Kalimantan Utara	6,567	15,195	Na
25. Sulawesi Utara	46,379	9,778	5
26. Sulawesi Tengah	133,839	12,882	5
27. Sulawesi Selatan	364,573	238,155	108
28. Sulawesi Tenggara	79,971	15,407	6
29. Gorontalo	25,442	6,797	8
30. Sulawesi Barat	34,188	26,882	Na
31. Maluku-	12,845		3
32. Maluku Utara	8,644	1,866	0
33. Papua Barat	6,456	2,271	0
34. Papua	36,270	6,080	0
Indonesia (Total)	4,819,525	3,292,578	

The data on rice areas are from MOA, 2014 and the data on drought events are from www.geospasial.bnpb.go.id

this program, the government gives incentives to farmers who fulfill several requirements:

- Farmers must use certified seeds (proven by showing seed certificate or label).
- Farmers must use recommended fertilizer (the dose approved by local government/ extension workers).
- Farmers must use certain planting system (use alternate row system or *Jajar Legowo.*)

Institutional space

Quality monitoring through institutionalized body. IAARD has set up AIATs in the 34 provinces of Indonesia, which have rules in the assessment and dissemination of new technologies developed by IAARD to the local community. This opportunity should be optimized to deploy the BMP technology parallel to the national extension programs carried out by technical directorate including Directorate of Food Crops and the Director General of Agricultural Infrastructure and Facilities under the Ministry of Agriculture.

Learning space

Going digital for faster technology dissemination. The release of the Internet-based tool, Rice Agro-advisory Service, (*Layanan Konsultasi Padi* in Bahasa or LKP) in Indonesia in early 2015 should help accelerate the implementation of BMP. Currently, LKP has a feature for rainfed lowland areas that can be used by farmers. Through the advancement in information technology, almost all extension workers and farmers in Indonesia now have access to the Internet-based application (see Fig. 6).

Challenges and recommendation

The major challenge in the implementation of the BMP in unfavorable environments is providing the guidance to the farmers in following the technical recommendations. This is mainly caused by the limited number of extension officers in the country. Thus, capacity building and knowledge management of the new technologies must be prioritized.

REFERENCES

Abdulrachman, S., Makarim, A.K., Las, I. (2005). Proceedings of the International Rice Conference: *Integrated crop management experiences on lowland rice in Indonesia*. BBPadi, Sukamandi.

Alam, M.M., Karim, M.R., Ladha, J.K. (2013). Integrating best management practices for rice with farmers' crop management techniques: A potential option for minimizing rice yield gap. *Field Crops Research 144: 62-68.*

Forshee, J. (2006). *Culture and customs of Indonesia.* USA: Greenwood Press.

Dobermann, A., Witt, C., Dawe, D., Abdulrachman, S., Gines, H.C., Nagarajan, R., Satawathananont, S., Son, T.T., Tan, P.S., Wang, G.H, Chien, N.V., Thoa, V.T.K., Phung, C.V., Stalin, P., Muthukrishnan, P., Ravi, V., Babu, M., Chatuporn, S., Sookthongsa, J., Sun, Q., Fu, R., Simbahan, G.C., & Adviento, M.A.A. (2002). Site-specific nutrient management for intensive rice cropping systems in Asia. *Field Crops Research 74: 37-66.*

International Rice Research Institute. (2015). *Rice is key to Indonesia's food security, officials say*. Retrieved from irri.org/news/media-releases/rice-is-key-to-indonesia-s-food-security-officials-say.

Kaneko, S., & Kawanishi, M., editors. (2016). Climate change policies and challenges in Indonesia. Japan: Springer. 297 p.

Fig. 6. The web-based tool, Rice Agro-advisory Service, (Layanan Konsultasi Padi), which was released in Indonesia provides service for drought-prone rainfed lowland areas (tadah hujan) (marked red circle).

Ministry of Agriculture. (2013). Agricultural Statistics 2013. Center for Agricultural Data and Information System, Ministry of Agriculture, Jakarta.

Ministry of Agriculture. (2014). Statistics of Agricultural Land 2009-2013. Center for Agricultural Data and Information System, Ministry of Agriculture, Jakarta.

Ministry of Agriculture. (2015). Strategic Planning of Ministry of Agriculture Year 2015-2019. Republic of Indonesia, Ministry of Agriculture, Jakarta.

Nursyamsi, D, et al. (2014). Pengelolaan Lahan Rawa Lebak untuk Pertanian Berkelanjutan (Management of Lebak Area for Sustainable Agriculture). IAARD Press, Jakarta.

Osorio, C.G., Abriningrum, D.E., Armas, E.B., & Firdaus, M. (2011). Who is benefiting from fertilizer subsidies in Indonesia? Policy Research Working Paper 5758. The Poverty Reduction and Economic Management Division, East Asia and Pacific Region WHO.

Parlina, I., & Salim, T. (2015, February 13). Jokowi confident on food security in 3 years. The Jakarta Post. Retrieved from thejakartapost.com/ news/2015/02/13/ jokowi-confident-foodsecurity-3-years. html.

Pimentel, D.C., Harvey, P., Resosudarmo, K., Sinclair, D., Kurtz, M., McNair, S., Crist, L., Spritz, L., Fitton, R., Saffouri, & Blair, R. (1995). Environmental and economic costs of soil erosion and conservation benefits. Science 267 (24 February): 1117–1123 p.

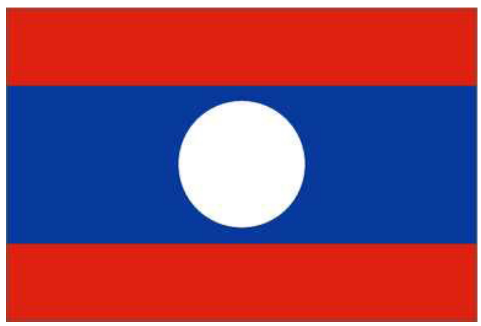
United Nations Convention to Combat Desertification. (2015). Indonesia-land degradation neutrality national report. Retrieved from www.unccd.int/ en/ programmes/RioConventions/ RioPlus20/ Documents/LDN%20 Project%20 Country%20Reports/ indonesia_ldn_ country_report.pdf

Sembiring, H. (2015). Scenario of rice production 2015-2019. 16 February 2015. Paper presented in IAARD-IRRI Meeting, Jakarta.

Statistical Bureau. (2010). Statistics of Indonesia. BPS. Jakarta.

Toha HM, Pane H, Samaullah MY, Kadir TS, Guswara A. 2008. Petunjuk Teknis

Lapang Pengelolaan Tanaman Terpadu Padi Sawah Tadah Hujan (Technical Field Guide of Integrated Crop Management for Rainfed Lowland Rice). IAARD. Jakarta



Lao PDR

Submergence-prone environments

Flood-tolerant rice varieties save farmers from food insecurity in Lao PDR

Phetmanyseng Xangsayasane

To attain the ultimate goal of sustaining farmers with sufficient yield despite environmental stresses in their fields, climate-smart varieties such as TDK1-Sub1 cannot remain in the labs and testing fields. This is where the involvement of other sectors, such as the private sector, in research proves to be advantageous.

From popular to flood-tolerant: The emergence of TDK1-Sub1

Lao PDR largely depends on agriculture for food security and economic growth. However, the production system of the country's staple crop, i.e., rice, remained traditional until the 1990s (Paavo et al., 2012). Despite the recent successes in the adoption of irrigation and high-yielding varieties, the country continues to suffer from uncertainties in rice production due to extreme climatic events such as severe droughts and floods that occur consecutively.[1] Historical flood patterns gathered by the United Nations International Strategy for Disaster Reduction (UNISDR) indicated that, from 1980-2010, the annual probability of flood occurrence in the country is 65%. These floods generally affected the central and southern regions of the country where most of the rice crops are cultivated (Schiller et al., 2006).

In search of measures and strategies to mitigate the effects of floods in rice areas, the International Rice Research Institute (IRRI) developed rice cultivars for submergence conditions. The search started in the mid-1970s when IRRI made crosses between the flood-tolerant donor FR13A and high-yielding varieties such as IR48 and IR36. However, it was not until the early 1990s when the submergence-tolerant lines with high-yielding potential were developed. Although the varietal prototypes provided hope to those living in flood-prone rice areas in Asia, farmers were not enthusiastic about adopting the varieties due to poor grain quality and the absence of agronomic traits that are important to them (Mackill et al., 1993 as cited in Septiningsih et al., 2009). The challenge, therefore, was to develop rice cultivars that have tolerance to submergence while possessing characteristics and traits that match the farmers' needs.

The new millennium sparked new hope for flood-prone countries such as Lao PDR when IRRI initiated collaborative researches to isolate the flood-resistant gene in rice. Using a technique known as marker-assisted backcrossing (MAB), scientists transferred the trait of flood tolerance into commercially valuable local rice varieties that retain the characteristics important to farmers.

Thadokkham 1 (or TDK1), the most popular rice variety in Lao PDR, was subjected to MAB. TDK1 belongs to the Lao-IRRI modern rice varieties (LMVs) released in 1993 through the country's National Rice Research Program. It is an improved, glutinous rice variety that is widely grown and consumed in Lao PDR. It has a high nitrogen response with good tillering characteristic. TDK1 has a high yield potential, good eating quality, and is resistant to most biotypes of brown plant-hopper (BPH) and rice leaf diseases.

[1] Lao PDR is highly vulnerable to extreme climatic conditions. For example, severe drought was experienced in 1977 followed by serious flooding in 1978. This created a famine-like situation in the country. The situation was repeated in 1988 and 1989 (Schiller et al., 2006).

After the successful development of the flood-tolerant variety for Lao PDR in 2006, TDK1-Sub1 was immediately disseminated for adoption trials. Research activities to evaluate the extent of adoption in the country were undertaken as early as 2007. In 2008, farmers' preference for TDK1-Sub1, in terms of major plant characteristics, was determined using research-managed trials and participatory varietal selection (PVS) trials.

With support from the Japan Ministry of Foreign Affairs (MOFA), IRRI funded an umbrella program for the participatory evaluation and dissemination of the Sub-1 mega rice varieties in Southeast Asian countries, including Lao PDR, under the *Dissemination of Submergence-tolerant rice varieties and associated management practices in Southeast Asia* project. The study showed that farmers often prefer rice cultivars that are flood-tolerant, have early to medium maturity relative to commonly grown varieties, and are resistant to pests, diseases, and lodging (Manzanilla et al., 2011). In the same year, seed multiplication of TDK1-Sub1 started in Khammouane Province for dissemination in the coming wet season. About 65 kg of seeds were produced and distributed to the first generation of adopter-farmers (Mackill, 2009).

In the 2010 wet season, the longest-lasting flooding was observed in Dang village, which persisted for 17 days at a depth of 2.5 meters. Results of the trial, demonstration, and use of submergence-tolerant rice in this experimental site showed 100% survival rate of TDK1-Sub1 whereas the local check variety only had 30%. Interestingly, two episodes of flooding were observed in Tonhean Village: the first lasted nine days with water depth of 2 meters while the second lasted seven days with water depth of 2 meters. Under these flooding conditions, the survival rates of TDK1-Sub1 were 95% and 100%, respectively. In contrast, the survival rates of the local check were 50% and 75%, respectively. These data proved that TDK1-Sub1 has a much better tolerance for submergence than the local check variety. Furthermore, results of the experiment in the wet season 2010 confirmed the tolerance of TDK1-Sub1 previously observed in the 2009 wet season. The grain yield of TDK1-Sub1 in the 2010 wet season varied from 1.4 to 4.8 tons/hectare with an average of 2.7 tons/hectare. Experimental data from 2009 and 2010 showed that grain yield of TDK1-Sub1 was higher than that of TDK1 under submergence condition and similar to TDK1 under non-flooded condition (Fig. 1).

Powering seed dissemination

By 2009, the seed multiplication project for TDK1-Sub1 was expanded to include Champasak and Khammouane Provinces. About 3.7 metric tons of seeds were produced in the dry season, and were distributed to 290 farmer-adopters in

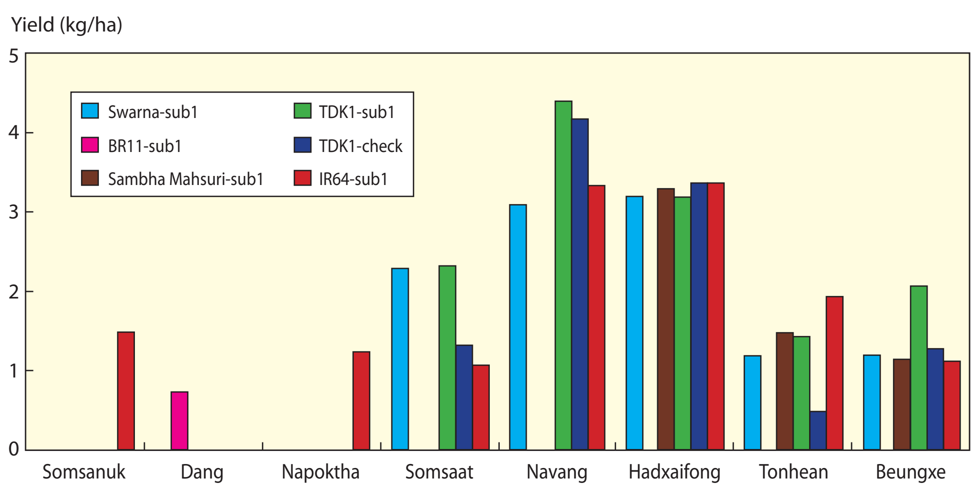


Fig.1. Yield of TDK1-Sub1 vs TDK1 under flooded condition in Somsanouk, Dang, Napoktha, Somsaat, Tonhean, and Bungxe and nonflooded condition in Navang and Hadxaifong.

the wet season. The amount of seeds of TDK1-Sub1 in the country grew from 2 to 49 tons in 2010, while the number of adopters grew from 301 in 2010 to 1,791 in 2011. Farmers' groups significantly contributed to the high level of seed multiplication activities, especially in Khammouane. In 2011, although the seed production was slightly reduced to 43 tons, the project was able to extend its distribution to cover more provinces including Vientiane, Savannakhet, and Bolikhamsai. However, despite the high production of TDK1-Sub1 in these provinces, only 5% of the total demand for certified seeds (18,832 tons) were distributed to farmers, covering 313,861 hectares.

In 2012, a total of 76,035 tons of TDK1-Sub1 seeds were formally disseminated by four organizations, namely, Namthurn 2 Power Company (NT2), Restatement Management Unit (RMU), Theun Hinboun Power Company (THB), and a farmer seed production group (Fig. 2). After 2013, the Khammouane Development Project Component 3 (KDPC3), working under the Provincial Agriculture and Forestry Office (PAFO), promoted the use of TDK1-Sub1 in Xe Bang Fai flood plain in Khammouane. However, the amount of seeds distributed to farmers decreased due to (1) increase in the price of the seeds, (2) several commercial varieties promoted by rice miller association for export, and (3) the inconsistent or unstable performance of TDK1-Sub1 after several growing seasons that caused some farmers to stop using the variety.

Mitigating losses from floods and droughts

Recognizing the importance of food security in the country, the Lao government implemented a five-year national program on food security in 10 provinces along the Mekong River. Fig. 3 identifies the rice varieties to be grown in each of the target province. The rice production areas in these provinces span a total of almost 700,000 hectares where 597,959 hectares are rainfed lowland rice areas. These lowland rice areas are characterized into four main sub-ecosystems: the favorable areas (59,796 hectares or 10%), the drought-prone areas (358,775 hectares or 60%), the drought- and submergence-prone areas (119,592 hectares or 20%), and the submergence-prone areas (59,796 hectares or 10%). These areas are expected to produce 2.5 million tons of rice by 2020, of which 2.1 million tons are for home consumption and 0.4 million tons are for buffer stocking and sharing with other ASEAN countries.

However, droughts, floods, and low soil fertility are the main stresses that cause production losses in the central

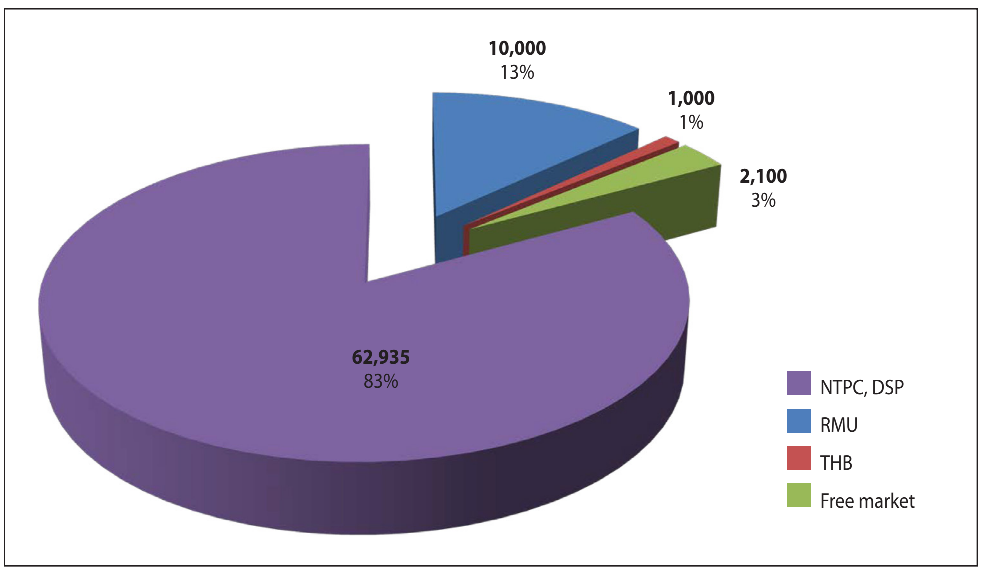


Fig. 2. Percentage of TDK1-Sub1 seeds disseminated by four organizations in 2012.

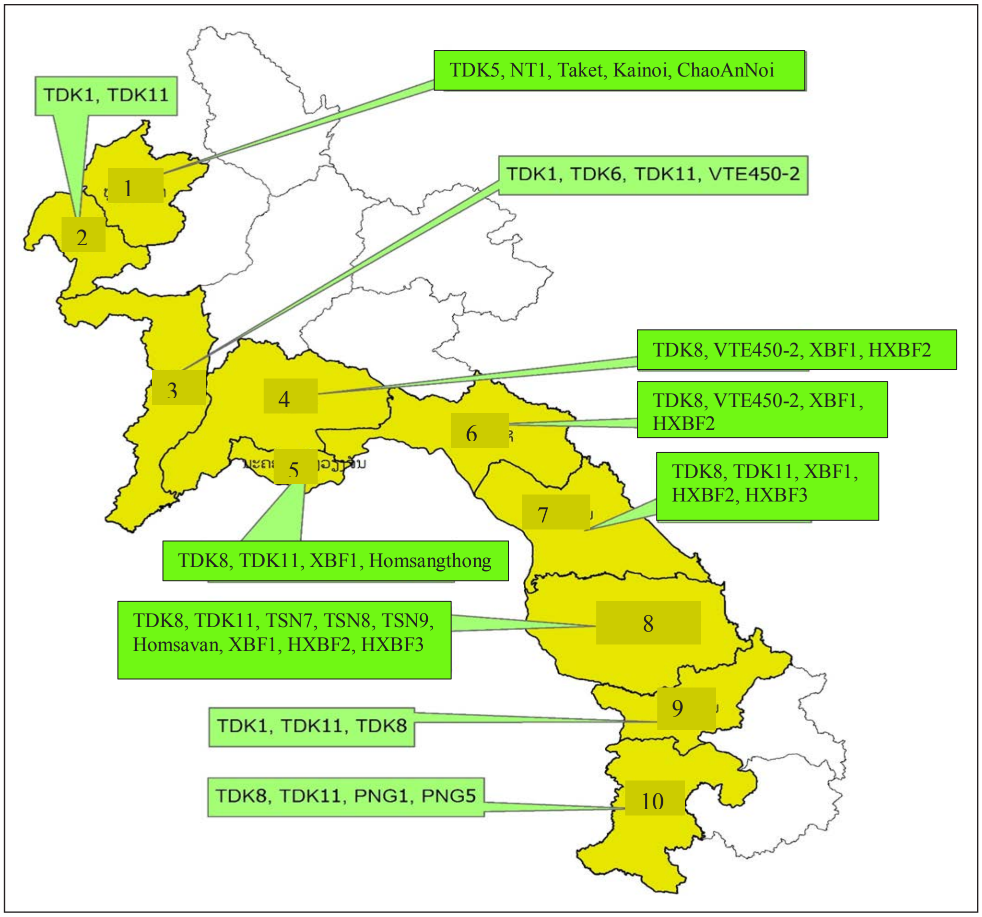


Fig. 3. Ten target rice production areas.
Luang Namtha, Bokeo, Xayaburi, Vientiane Province, Vientiane City, Bolikhamsai, Khammouane, Savannakhet, Salavan, Champasak

part of the country, which may reach up to 20%. These losses consequently trigger fluctuations in the rice production of Lao PDR yearly.

In 2011, about 37,000 hectares of rice fields in the north and 41,200 hectares in the Xe Bang Fai plains (a total of 78,200 hectares) were destroyed by floods. In 2013, over 15,000 hectares of rice fields were damaged by floods (Lao PDR: Floods–Aug 2013, http://reliefweb.int/disaster/fl-2013-000101-lao). Aside from floods, drought is also considered a major constraint in rice production. It usually occurs before or after flooding. Drought can reduce rice yields by 13% (intermittent drought) to as much as 30% (terminal drought) (Xangsayasane et al., 2014).

Farmers living in flood-prone areas continue to grow rice despite the high risk of production losses. Growing season patterns are affected by climate change. Transplanting rice is frequently delayed or sometimes abandoned when early droughts occur.

To reduce production losses in the flood- and drought-prone plains, the use of submergence- and drought-tolerant rice varieties was promoted to help farmers secure their food. In 2013, TDK1-Sub1 was released as XeBangfai1 (XBF1) through the collaboration between Agriculture Research Center (ARC), National Agriculture Forestry Institute (NAFRI), and IRRI. Research collaboration between ARC-NAFRI and Rice Science Center, Kasetsart University, Thailand, and Khammouane Development Project, Khammouane Agriculture and Forestry Office dating back to 2009 was able to release two aromatic non-glutinous, flood- and drought-tolerant rice varieties: HomXeBangFai2 (HXBF2) and HomXeBangFai3 (HXBF3). These were released in 2015. Table 1 presents a short history of the development of these varieties.

Table 1. History of the development of HomXeBangFai2 (HXBF2) and HomXeBangFai3 (HXBF3).

Variety	Year							
	2008	2009	2010	2011	2012	2013	2014	2015
XBF1	Introduction and conducting trials	Trials and demonstration in Khammouane, Savannakhet and Champasak	Trials and demonstration in Khammouane, Savannakhet and Champasak	Trials and demonstration in Khammouane, Savannakhet and Champasak	Seed production and dissemination	Formal release	Recommended in flood-prone areas	Recommended in flood- prone areas
HXBF2		Introduce and conducting trial in ARC	Trials and demonstration ARC, Khammouane and Savannakhet	Trials and demonstration ARC, Khammouane and Savannakhet	Trials and demonstration ARC, Khammouane and Savannakhet	Seed production and dissemination	Seed production and dissemination	Formal release
HXBF3		Introduce and conducting trial in ARC	Trials and demonstration ARC, Khammouane and Savannakhet	Trials and demonstration ARC, Khammouane and Savannakhet	Trials and demonstration ARC, Khammouane and Savannakhet	Seed production and dissemination	Seed production and dissemination	Formal release

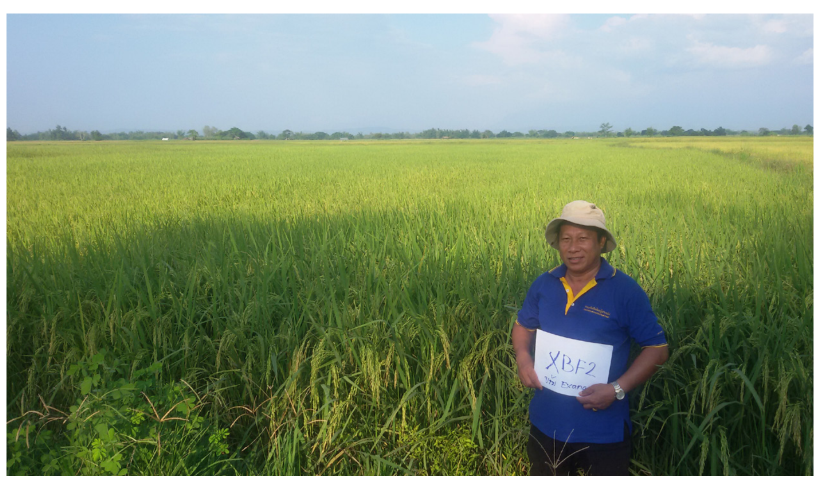
In line with the National Food Security Program, the three stress-tolerant rice varieties are now promoted in the unfavorable rice environments of the central region of Lao PDR. The characteristics of these three varieties are presented in Table 2.

Collaborative research with CURE

Beginning in 2014, the Consortium for Unfavorable Rice Environments (CURE) partnered with Climate Change, Agriculture, and Food Security (CCAFS) to identify new flood-tolerant elite line developed from the breeding line of IRRI, demonstrate and disseminate promising breeding lines in flooded areas, test management options for submergence-tolerant varieties in flooded areas, and provide training on Good Agriculture Practice (GAP). This is a research collaboration between ARC, NFRI, and IRRI-CURE.

Seeds of XBF1, HXBF2 and HXBF3 were demonstrated under farmer's field condition with best management practices in central and southern part of Lao PDR. In 2015, the activity was conducted by CURE and CCAFS in nine demonstration trial sites with the participation of a total of 76 farmers (Table 3):

- 15 farmers in Philom Village, Outhoumphone, District, Savannakhet (CCAFS)
- 13 farmers in Nakua Village, Pakading District, Bolikhamsai Province (CURE)
- 12 farmers in Hatkhamhien Village, Xe Bang Fai District, Khammouane (CURE)



- 7 farmers in Paketue Village, Nong Bok District, Khammouane (CURE)
- 7 farmers in Navangthong Village, Nong Bok District, Khammouane (CCAFS)
- 6 farmers in Ekxang Village, Phonhong District, Vientiane Province (CCAFS)
- 6 farmers NavangYi Village, Nong Bok District, Khammouane (CURE)
- 5 farmers in Nong Bok District, Khammouane (CURE)
- 5 farmers in Tung Village, Xe Bang Fai District, Khammouane (CURE)

Another 176 farmers were trained on seed production technique and rice production technology through CURE and CCAFS. A key benefit of using the certified seeds of Sub1 rice varieties is an increase of up to 35% in rice yield compared with other local varieties. Moreover, the use of XBF1 could ensure rice production in the event of a flood, while growing HXBF2 and HXBF3 could increase farmer's income from 2,500,000 LAK or USD 308.1 per ton (price of glutinous rice) to 3,000,000 LAK or USD 369.7 per ton (price of non-glutinous rice).

Seed production and dissemination system

In Lao PDR, seeds are produced under the formal and informal systems. The formal seed production system, under the NAFRI, farmer seed production groups, and private seed companies, supplies 10% of the total seed requirement in the country. In the informal seed production system, the seeds are produced by the farmers and accounts for 90% of the total seeds produced (Fig. 4).

Seeds produced in the formal seed production begin with the breeder's seed, then foundation seeds (R1), stock seeds (R2), and, finally, extension seeds (R3). Breeder's seeds and foundation seeds (R1) are produced by ARC and NAFRI in Vientiane, while stock seeds (R2) are produced by ARC and PAFO. The extension seeds (R3) are produced by PAFO, private companies, and farmer seed production groups. These seeds are certified by the Department of Agriculture (DOA).

The good seeds produced by farmers through the informal system do not have the certification from DOA. These are usually produced from stock seeds (R2) by farmers for their own use, and are often exchanged among the communities with technical assistance from international organizations and NGOs (Fig. 4).

Table 2. Characteristics of flood- and drought-tolerant rice varieties

	Name of variety		
	XBF1	HXBF2	HXBF3
Grain yield (tons/hectare)	3–6	3–5	3–4
Flood tolerance	10–14 days	10–14 days	10–14 days
Drought tolerance	Yes	Yes	Yes
Days to maturity	140–145	125–135	
Length of milled rice (mm)	7.19	7.17	7.31
Head rice return (%)	45.1	44.5	49.2
Amylose content (%)	0	16–18	16–18
Aroma	No	Yes	Yes
1,000 grain weight (g)	30	27.5	29.2

Table 3. Number of farmers who received seeds and training on rice seed production technology

Year	Province	District	Villages	Seed received (kg) XBF1, HXBF2, HXBF3	Number of farmers participating in seed production, purification, and other technology demonstrations	Training on rice seed production and rice production technology
2014	Khammouane	Nong Bok	Paketue	90	7	22
		Xebangfai	Tung	60	6	15
			Hatkhamhien	120	12	25
	Total			**270**	**25**	**62**
2015	Khammouane	Nong Bok	Paketue	120	7	
			Navangthong	90	7	36
			NavangYi	90	6	28
		Nong Bok			5	
		Xe Bang Fai	Tung	60	5	
			Hatkhamhien	150	12	
	Vientiane	Phonhong	Ekxang	180	6	30
	Savannakhet	Philom	Outhoumphone	180	15	50
	Bolikhamsai	Pakading	Nakua		13	
	Total			**870**	**76**	**144**

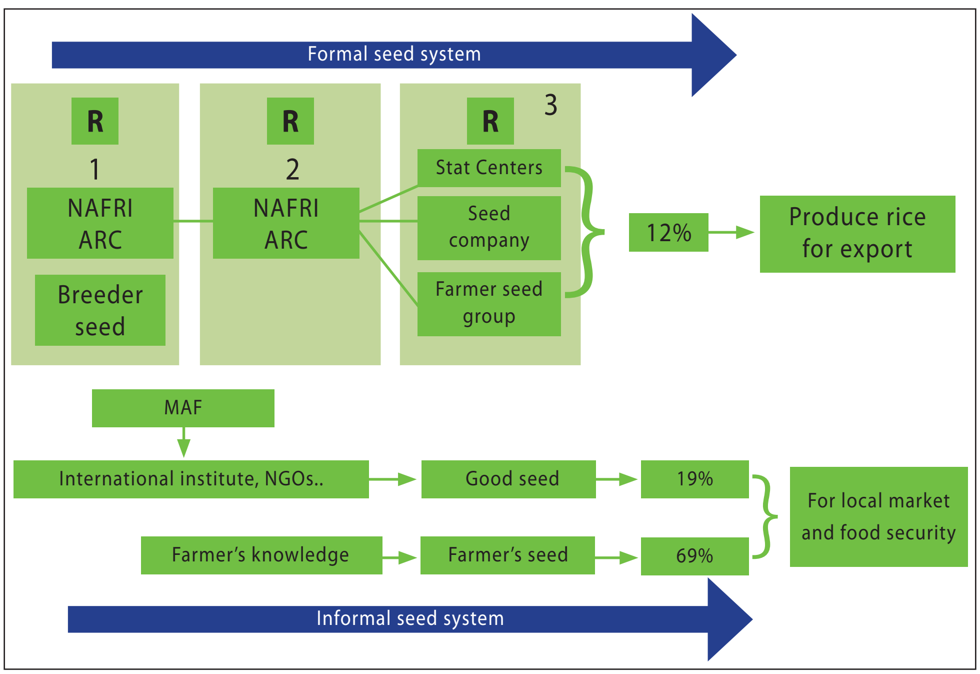


Fig. 4. Seed production and supply in the country.

DRIVERS OF CHANGE

National government banking on food security and capacity development

The Lao PDR government, through its five-year national program on food security, is instrumental in pushing for collaborative researches such as the development and dissemination of stress-tolerant rice varieties to boost the rice production of certain areas in the country.

To achieve this goal, the government is targeting to produce 10,763 tons of extension seeds (R3) to cover 30% rice areas in 2020, and 21,527 tons to cover 60% in 2025.

While 1,794 tons (5%) of the total seed need will be reserved, 35,878 tons will be used to cover 597,959 hectares of the country's rice production areas during the wet season. In the dry season, the total number of seeds expected to be produced is 3,662 tons, which would cover 60% of rice production areas in 2020 and 6,104 tons by 2025 to cover 101,730 hectares.

The total number of extension seeds (R3) needed for the national food security program is 16,220 tons in 2020, which would cover 30% in the wet season and 60% in the dry season. In 2025, 29,425 tons of extension seeds (R3) would be needed to cover 60% in wet season and 100% in dry season. This means that, before 2020, farmers need to produce about 25,114 tons (70%) of seeds in the wet season and 2,442 tons (40%) in the dry season for themselves. By 2025, farmers will need to produce about 14,351 tons (40%) of seeds in the wet season.

The food security program will fund the improvements in facilities and infrastructures of 10 research rice and seed production centers in 10 provinces (Fig. 3) and will strengthen and equip government staff in 10 research centers, 13 private companies and 59 farmer rice seed production groups on rice seed production technology.

The production of foundation and stock seeds is expected to come from 10 research centers, while the extension seeds are expected to be produced by the private sector. The government plans to allot USD 2 million to establish about 1,000 seed production groups in 10 provinces for producing certified seeds in the areas of about 10,000 hectares to produce 30,000 tons of extension seeds (R3) by 2025. The remaining 11,981 tons are expected to be produced by the farmers themselves with the support from international agencies and NGOs.

NGOs and INGOs boosting innovations, raising livelihood in rural Lao PDR.

Aside from the National Food Security Program, several stakeholders such as IRRI, CURE, CCAFS, and NGOs including Democratize Agriculture Research and Extension (DARE), Seed for Need, The Agrobiodiversity Initiative Project (TABI), Smallholder development project, KDPC3, TheunHinboun Power Company (TH), Nam Theun2 Power Company (NT2), Tri Angle, and World Vision, among others, are working on strengthening community seed production, support, and dissemination. These stakeholders play important roles in improving livelihood and food security in the rural areas of Laos.

CURE, in particular, provides the funds for the development and evaluation of rice germplasm as well as integrated crop management options, and the development of decision support tools for technology assessment, training, and production of knowledge products. It also aims to catalyze national governments to fund the multiplication and dissemination of the farmer-preferred varieties.

Environmental space

Climate-change management through climate-ready rice varieties. Climate change has badly affected agricultural production. Thus, climate-ready rice varieties, particularly XBF1, HXBF2, and HXBF3, are expected to significantly contribute to the national food security program in the country. Farmers are assured of harvest despite damages caused by floods during the wet season. These varieties can produce better yields even if subjected to up to 14 days of flooding compared to commercial non-flood tolerant rice.

Flooding and drought are the main constraints in rice production in Laos, and so far, only one glutinous flood-tolerant rice variety (XBF1), and two nonglutinous aromatic flood-tolerant rice varieties (HXBF2 and HXBF3) are available to farmers. XBF1 plays a pivotal role in the flood-prone areas, where rice is produced for home consumption. In non-flooded areas, farmers prefer to grow TDK8 and TDK11 for commercial use because these have high milling recovery compared with XBF1. Moreover, the performance of XBF1 is not consistent after one to two growing seasons. Farmers have to segregate the seeds after one season or buy a new batch of extension seeds from state institutes. To improve and ensure the variety's consistent performance, ARC-NAFRI has conducted a single genotype production of XBF1.

Meanwhile, HXBF2 and HXBF3 varieties are recommended for growing rice for household consumption and commercial purposes in flood-prone areas. However, these varieties are not well-known to farmers and rice miller associations. Thus, the local government needs to increase dissemination and promotion of these varieties.

Policy and financial spaces

Strategies for modernizing the rice sector and achieving food security. Rice production in Lao PDR is an essential part of the livelihoods of around 724,000 producers. The Political Report recognizes the importance of agriculture and forestry as "a fundamental sector of our national economic structure." It calls for a transformation of the rice industry in the country to modernize the sector, making it more productive and market-oriented. The National Socio-Economic Development Plan (NSEDP) seeks to achieve sustainable economic growth and reduce poverty. The Agricultural Development Strategy (ADS) has set, as its primary goal by 2015, to achieve food security in order to meet the calorie intake requirements, especially in remote rice-deficit areas.

To achieve these goals, there is no one rice policy but rather a number of policies that use various instruments that have intricate implications for the rice sector. A group of policies that do not require budget transfers are mainly trade-related and include policies on export bans. To some extent these also include tax concessions as agriculture is not subject to the same level of direct taxes as other sectors of the economy. The policies that do require budget allocation regard those directly benefiting individual farmers (seed, electricity, subsidized credit, extension support). Policies which benefit agricultural producers collectively cover research in rice seed and rice nutrient management.

Meanwhile, the National Rice Food Security Program aims to produce 2.5 million tons of rice in 10 provinces by 2020. However, problems on abiotic stresses need to be addressed in some areas: 60% of the total rice production areas (728,635 hectares) is drought-prone, and 30% is flood-prone. Therefore, the flood- and drought-tolerant rice varieties are crucial in reducing production losses in these stress-prone areas. The three climate-smart varieties have been proposed to be included in the seed production program to support the program.

There are some points that still need to be addressed based on the feedback from farmers such as the seed purification of XBF1 variety to ensure that farmers will have good quality seed. The single genotype selection to purify XBF1 variety will be done at ARC to ensure that the performance of this variety will be uniform.

Institutional space

NGOs producing seeds. In Lao PDR, the formal seed production system can only supply 10% of the total seed requirement in the country. The rest should come from the informal system such as from the farmers who produce seeds for commercial purposes, and preserve them for their own consumption. NAFRI, alone cannot produce seeds to meet the demand of rice production in the country, so seed production and distribution are handled by many NGOs.

Partnership space

Breeding key collaborations. Since 2015, ARC-NAFRI has been collaborating with IRRI on breeding for unfavorable rice environments. These institutes have been working on developing rice varieties suited for aerobic and alternative wet and dry conditions to ensure sufficient harvests even under water-limited condition. IRRI and the BIOTECH Center at Kasetsart University also collaborated in breeding flood-tolerant rice varieties.

Learning space

Knowledge-sharing to researchers, technology transfer to farmers. Studies and articles on XBF1, HXBF2, and HXBF3 were published in the CURE newsletter and NAFRI's journal, respectively, and distributed to all district and provincial agriculture and forestry offices in Lao PDR. A leaflet on recommended planting techniques for each variety was also published and distributed to farmers in target villages. In 2016, seed dissemination of the flood-tolerant rice varieties and demonstration on rice production with best management practice will be organized in the target villages.

REFERENCES

Paavo, E., Santos, N., Pravongviengkham, PP. (2012). *Lao People's Democratic Republic Rice Policy Study*. Retrieved from www.fao.org/fileadmin/user_upload/tci/docs/1_Laos20document20low20resolution.pdf.

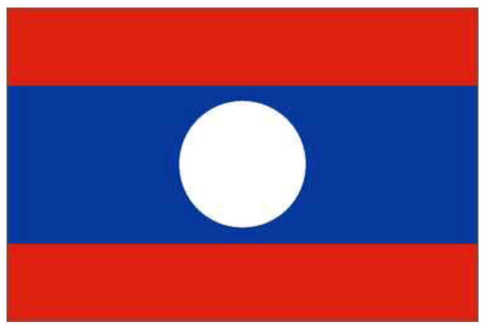
Schiller, J.M., Chanphengxay, M.B., Linquist, B., Appa Rao S. eds. (2006). *Rice in Laos*. Retrieved from http://books.irri.org/9789712202117_content.pdf.

Septiningsih, E.M., Pamplona, A.M., Sanchez, D.L., Neeraja, C.N., Vergara, G.V., Heuer, S., Ismail, A.M., & Mackill, D.J. (2009). Development of submergence-tolerant rice cultivars: the Sub1 locus and beyond. *Annals of Botany 103: 151-160*.

Mackill, D. (2009). *Sub1 Rice News*. Laos.

Manzanilla, D.O., et al. (2011). Submergence risks and farmers' preferences: Implications for breeding Sub1 rice in Southeast Asia. *Agricultural Systems 104, 335-347*.

Xangsayasane, P., et al. (2014). Lao PDR: Floods Aug 2013. Retrieved from http://reliefweb.int/disaster/fl-2013-000101-lao.



Lao PDR

Upland systems

Preserving culture, securing food: Community-based seed system, improved varieties, and rice intensification in Northern Laos

Khamla Phanthaboun and Annette Tobias

Upland rice farmers are hugely at risk of food insecurity, which is why among the improved farming technologies and innovations tested in rural development, the establishment of community-based seed systems that will provide a systematic way of producing and distributing purified seeds of rice varieties traditionally grown in the uplands, introduction of crop management practices and crop intensification are huge steps towards sustainability and food security.

In the upland areas of northern Laos, the rice ecosystem accounts for about half of the total rice area (National Statistical Center, 2004). In these areas where slash-and-burn agriculture system is commonly practiced, extreme poverty is most common. Majority of the country's indigenous people live in the uplands wherein the poverty rate is as high as 43%, compared to about 28% in the lowlands. The poorest groups in the lowlands are those that have been resettled from mountain regions (IFAD, 2014). As a result, rice deficiency in northern Laos has not improved since 1975, or is getting worse (ADB, 2001).

Furthermore, rice farmers in Laos are highly vulnerable to the negative effects of climate change such as prolonged drought. Variability in the climate disrupts sowing time and affects rice production and availability of seeds for farmers. Among those who are susceptible to climate change are upland rice farmers, who mostly belong to minority ethnic groups including Lao, Khmu, and Hmong. These farmers in the drought-prone upland rice areas live in unfavorable environments that are exacerbated by climate change.

As early as 2001, a number of drought-tolerant rice varieties have been

made available for upland areas. However, seeds of these varieties are not readily available to the farmers. Only 10% to 15 % of the rice seed requirement for the uplands is produced by the government through the Upland Agricultural Research Center (UARC). In 2014, around 80 tons of seeds, or 12.5% of the required seeds for around 118,000 hectares of upland rice area were produced by the government.

To ease these problems, alternative agricultural solutions are being developed. These include community-based seed systems, stress-tolerant rice varieties, best management practices, intensification of upland rice-based systems, and introduction of alternative cash crops that allow for income generation and cash to buy rice.

Seeds reach the uplands: Technological interventions by CURE

In 2011, the International Rice Research Institute (IRRI) and the National Agriculture and Forestry Research Institute (NAFRI) through the Consortium for Unfavorable Rice Environments (CURE) came together to address the problem on seed insufficiency of upland farmers by introducing the community-based seed system (CBSS), or also known as "community seed banks." The CBSS is an informal arrangement wherein members of a farming community follow a collective system of producing, exchanging, or selling good-quality seeds, especially in times of disasters and shortages of seeds. Inspired by the success of CBSS established in Arakan Valley in the Philippines as a model, CURE conducted a training session in Lao PDR on how to establish CBSS for the production of quality seeds, and maintenance of seed health. Seventeen trainees participated in the activity, including rice researchers, extension agents, and development workers from UARC, Provincial Agricultural and Forestry Office (PAFO), District Agricultural and Forestry Office (DAFO), and World Vision, an international nongovernmental organization.

By 2012, a year after the training on CBSS, UARC followed through the activity by teaching 104 farmers from four villages how to monitor and maintain seed health. The farmers came from the villages of Pak Keng, Napho, Hat Houy, and Hat Sam in Pak Seng District, Luang Prabang Province, which were identified and targeted for development by the local government because these were among the poorest villages in the district.

Armed with the knowledge on seed selection, crop management, pests and diseases management, and postharvest technologies, the farmers have become confident on establishing CBSS by themselves. As a result, farmers now have access to their preferred traditional rice varieties such as Nok, Makhinsoung, None, and Laboun, which were selected and purified to maintain their grain characteristics.

Local upland rice varieties made anew through Lao PDR-IRRI collaboration

From 1995 to 2000, through the Lao PDR-IRRI collaboration, traditional

rice varieties had been collected and preserved. To date, there are over 13,000 accessions in the Lao PDR gene bank, about half of which are upland rice varieties. These were screened to identify early- and medium-duration varieties that are suited to short fallow period. Early-duration varieties are ready to be harvested after 100 to 120 days, while medium-duration varieties can be harvested after 121 to 140 days. These varieties were finally evaluated through participatory varietal selection (PVS) trials in farmers' fields in the northern provinces, in which four upland rice varieties were selected, namely, Nok, Makhinsoung, None, and Laboun.

Nok is an early-duration variety that yields 1.8 to 2.3 tons per hectare, performs well in poor soil, has large seed and panicle, and has high grain cooking qualities such as in terms of aroma and softness. Makhinsoung, a medium-duration variety, yields 1.7 to 2.2 tons per hectare, is soft when cooked, and is also preferred by farmers although it is not as aromatic as Nok. Both Makhinsong and Nok are japonica varieties. None, a medium-duration variety, which yields 1.7 to 3.1 tons per hectare, and Laboun, an early yielding variety, which yields 1.8 to 2.2 tons per hectare, are both indica varieties. These varieties were preferred by farmers because of their yield advantage of 0.3 to 0.5 tons per hectare, which is 18–27% increase in yield compared with that of the local check varieties.

Purified seeds reach more farmers' fields

To help develop a CBSS, UARC distributed seeds of the four upland rice varieties in 2010 to 2014. A total of 5,074 kilograms of Makhinsoung seeds, 5,487 kilograms of None seeds, 10,600 kilograms of Laboun seeds, and 17,878 kilograms of Nok seeds were distributed to 368 farmers in 27 villages in Luang Prabang Province, several government institutions through Lao PDR Upland Food Security Improvement Projects and Northern Uplands Development Programme, and to non-government organizations such as CARE, Norwegian Church Aid (NCA), Medisch Comité Nederland-Vietnam (MCNV), Service Fraternel ď Entraide (SFE) or Fraternal Mutual Aid Service, and World Vision.

The seeds were distributed primarily for seed multiplication to target upland areas in the provinces of Luang Namtha, Phongsaly, Houa Pham, Xieng Khoung, Bokeo, Savannaket, Sekhong, and Attapue.

With technical assistance from UARC, each farmer who received 10 to 30 kilograms of seeds grew and multiplied the farmer-preferred varieties. UARC bought the seeds produced from the multiplication plots at harvest time. The farmers produced around 184 tons of seeds with an average yield of 1.5 to 2.4 tons per hectare.

In 2015, seeds of the four upland rice varieties were again distributed to farmers in Luang Prabang Province, government institutions, and non-governmental organizations, this time, by UARC. A total of 960 kilograms of Makhinsoung seeds, 1,815 kilograms of None seeds, 7,842 kilograms of Laboun seeds, and 2,885 kilograms of Nok seeds were disseminated (Table 1). Seeds were distributed to government institutions through Lao PDR Eco-Friendly Identification Climate Arrant and Agriculture Systems Project (EFICAS) and Provincial Agriculture and

Table 1. Upland rice seed distributed to government institutions, and non-government organizations.

Recipient	Makhinsoung (kg)	Nok (kg)	None (kg)	Laboun (kg)
Theun-Hinboun Power Company Limited (THPC)	-	645	545	362
Medisch Comité Nederland-Vietnam (MCNV)	800	-	-	5,100
CARE	150	-	-	500
Service Fraternel d'Entraide [SFE (ATP)]	-	-	1200	600
SFE (XK)	-	-	60	940
Khammoun	-	730	-	330

Forestry Office (PAFO) in Khammoun Province. Meanwhile, NGOs including CARE, MCNV, SFE, Theun-Hinboun Power Company Limited (THPC), and Namtheun Power Company Limited (NTPC 2) received seeds of upland rice varieties for seed multiplication in their respective target areas—Phongsaly, Khammouane, Savannaket, Sekong, and Attapue provinces.

The Northern Agriculture and Forestry Research Center (NAFReC) also multiplied upland rice varieties Nok, Makhinsoung, Laboun, and None in their research station and farmer's fields to produce uniform and reliable seeds for dissemination to farmers and for research. Fifty farmers from two districts and six villages (four villages in Pak Xeng district and two villages in Xieng Ngeun district in Luang Prabang Province) participated in the 2014 trials. Researchers bought the seeds produced from the multiplication plots.

A total of 120 kilograms of seeds (19 kilograms of Nok, 30 kilograms of Makhinsoung, 31 kilograms of Laboun, and 40 kilograms of None) were produced at NAFReC (Table 2), with the None variety having the highest number of panicles per hill and grain yield.

At the Pak Xeng and Xieng Ngeun districts in Luang Prabang, a total of 22,591 kilograms of seeds were produced from 50 farmer's fields with a total area of 20 hectares. Farmers used their crop for home consumption and for use in the next cropping season. Out of this volume, a total of 13,215 kg were distributed to 441 resource-poor farmers who were not able to save their seeds for the next season (Table 3).

Improved rice varieties developed by partners

Varieties were continuously developed and tested by CURE partners to produce improved seeds that will tolerate the different stresses in the uplands. In 2012-13, NAFReC evaluated the performance of rice lines for the uplands. Three lines, IR 82635-B-B-59-2, IR 82589-B-B-149-4, and IR 83928-B-B-81-2, were considered the best because they were high-yielding and drought-tolerant.

NAFReC also conducted field trials to identify the best varieties and cropping systems for the uplands in partnership with CURE. Nine upland rice varieties with local check B6144 (nonglutinous) were evaluated in the station. IR82589-B-B-2-3, IR82589-B-B-149-4, IR83928-B-B-81-2, IR82635-B-B-47-1, IR82635-B-B-59-2, and IR82639-B-B-118-3 were selected based on grain size, panicle length, and grain yield for further testing in the 2013 wet season.

Two glutinous entries, Naxang and Oppok, and a local check cultivar were used in the baby trials conducted at nine farmers' fields in Mai Village. Grain yield ranging from 3.16 to 3.53 tons per hectare did not significantly differ from that of

Table 2. Grain yield (kg/ha) and agronomic characters of varieties Nok, Makhinsoung, Laboun, and None multiplied for seeds in UARC, Lao PDR, wet season 2014.

Cultivars	Frequency	Number of days to flowering	Panicle number/hill	Number of hills/row	Harvest area/ row (m2)	Grain yield (kg/ha)
Nok	Average	91	3	41	2.54	1,860
	Max		4	48	3.00	2,369
	Min		3	32	2.00	1,364
Laboun	Average	95	6	38	2.38	2,578
	Max		8	44	2.75	4,159
	Min		5	33	2.06	1,630
Mak hin soung	Average	98	3	40	2.49	2,440
	Max		4	48	3.00	2,909
	Min		3	28	1.75	1,788
None	Average	103	8	36	2.28	4,261
	Max		9	44	2.75	5,350
	Min		6	28	1.75	3,403

Table 3. Amount of seeds distributed and number of farmers who received the seeds for upland rice areas, Lao PDR project sites.

Title of activity	Year	Variety and amount of seeds distributed	Total amount of seeds (kg)	Number of famer-recipients	Funding source, or as part of CBSS, TIS, government, NGOs
Seed distribution	2014	Makhinsoung 200 kg Nok 1000 kg Non 1000 kg Laboun1000 kg	3,200	80	Lao Upland Food Security Improvement Project
Seed distribution	2014	Nok 300 kg Non 240 kg	540	27	Northern Upland Development Program
Seed distribution	2014	Laboun 1300 kg, Makhinsoung 100 kg	1,400	50	MCNV in Lao (Medical Committee Netherlands-Viet Nam) NGO.
Seed distribution	2014	Makhinsoung 70 kg	70	5	NCA in Lao
Seed distribution	2014	Nok 250 kg None 550 kg	800	70	SFE in Lao, NGO
Community Seed Banks: for distribution to farmers directly or through TIS	2014	Makhinsoung 145 kg Non 150 kg Laboun 470 kg Nok 700 kg	1,465	50	CBSS, TIS
Community Seed Banks: seed production for distribution to farmers directly or through TIS	2014	Naxang 670 kg	670	6	CBSS, TIS
Seed distribution	2014	Naxang 50 kg	50	2	World Vision
Seed distribution	2015	Naxang 20 kg (Dry season)	20	1	Loan IFAD project in Xayabuly province
Seed distribution	2015	Laboun 4500 kg, Makhinsoung 500 kg	5,000	150	MCNV in Lao (Medical Committee Netherlands- Viet Nam) NGO.
Total			13,215	441	

the local check variety. Oppok produced about 367 kilograms more grain than did the local check in the trial (3.53 tons per hectare).

Farmers preferred Naxang and Oppok cultivars because of their high yield and good quality grains. Upland rice variety Nok was multiplied by 96 farmers from four villages (Pak Kheng, Had Houy, Na Pho and Had Sam villages) in Pak Xeng District, Luang Prabang Province. Training on seed production was conducted in each village in August 2012. A total production of 63 tons per hectare of Nok seeds was achieved with an average grain yield of 1.5–2.4 tons per hectare.

Farmers' preferred rice varieties

To include farmers' desired traits in developing rice varieties, participatory varietal selection (PVS) was conducted by CURE partners in Lao PDR. In 2014, PVS trials (using the IRRI protocol for PVS) were undertaken by partners in three villages each in the provinces of Luang Prabang, Oudomxay, and Luang Namtha using four non-glutinous entries and a local check cultivar. The mean grain yield

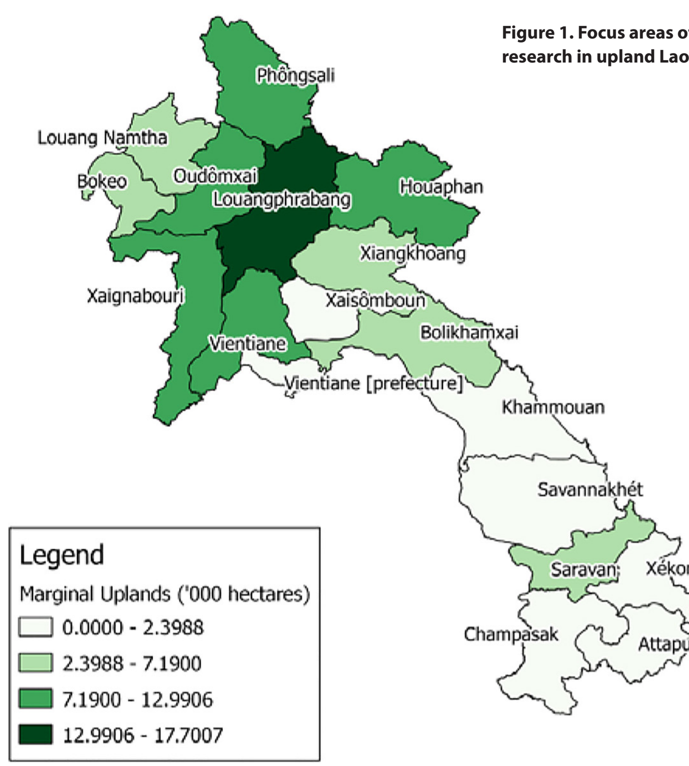


Figure 1. Focus areas of CURE research in upland Lao PDR.

achieved in these trials ranged from 3,411 to 4,218 kilograms per hectare (Table 4). IR82635-B-B-59-2 was the highest yielding entry with a yield of 4,218 kilograms per hectare. Among the three provinces, yield in Luang Prabang was lowest due to losses from rat infestation at the booting and flowering stages. A preference analysis showed that farmers preferred long panicles, big grains, and a high percentage of filled grains, all of which were characteristics of IR82635-B-B-59-2.

Varieties resistant to gall midge were also developed by CURE with partners. In lowland rice areas, gall midge causes 30–35% damage. To select lines for gall midge resistance, seven populations were evaluated from the crosses of varieties Meuang Nga, a local variety that is resistant to gall midge but photoperiod-sensitive, and TDK 7, an improved high-yielding variety that is medium maturing, has good grain quality, and is photoperiod-sensitive (CURE 2015) (Table 5). Although there was gall midge infestation in all rice varieties, losses were lowest at about 8.1% in the Meuang Nga variety. The flowering date in three sites ranged from 109 to 119 days, with most populations having medium maturity. Plant height ranged from 74 to 123 centimeters, but majority of the entries were semi-dwarf type. The number of panicles per hill varied from 5 to 6 panicles. Grain yield ranged from 3,017 to 3,748 kilograms per hectare, with yields being highest in population 3 (V3) and lowest in TDK 7. Populations 3 (V3) and 7 (V7) gave yields higher than parent materials.

Research on cropping systems and management practices

Deficiencies in N, phosphorus, and other micronutrients in the soil are common in Laos. Thus, to identify N fertilization rates for upland rice production, nine

Table 4. Average grain yield, farmers' preference and score for planting in next crop, 2014 wet season in three provinces of Luang Prabang, Oudomxay, and Luang Namtha, Lao PDR.

Entries	Grain yield (kg/ha)	Farmers' preference (%)			Score for planting in next crop
		Total	Women	Men	
IR82589-B-B-2-3	3,876	15.2	4.3	10.8	0
IR82589-B-B-149-4	3,842	38.1	14.5	23.5	0.33
IR82635-B-B-47-1	3,411	0	0	0	0
IR82635-B-B-59-2	4,218	63.8	23.7	40.1	0.5
Local varieties	3,996	13.2	9.0	4.2	1
LSD0.05	438.7	27.26	11.09	18.13	0.41

Table 5. Yield, agronomic characters, and gall midge infestation (%) of seven populations derived from Meuang Nga x TDK7 cross, Lao PDR.

Genotype	Tillering per hill	Gall midge infestation (%)	Panicle number per hill	Plant height (cm)	Panicle length (cm)	Number of days to flowering	Grain yield (kg-ha)	SEEDW
V1	10	11.6	6	95	23.2	107	3632	38.1
V2	11	9.9	6	81	23.3	106	3320	34.2
V3	10	12.4	6	85	22.7	105	3748	32.5
V4	10	9.8	5	118	21.3	109	3559	35.6
V5	13	9.9	6	83	22.6	109	3316	35.6
V6	11	12.8	6	74	22.7	106	3637	32.7
V7	11	12.2	6	79	23.8	113	3718	36.6
Meung Nga	9	8.1	5	123	22.0	116	3693	38.6
TDK 7	11	12.0	6	74	23.0	114	3017	31.3
LSD0.05	2.173	0.405	0.749	8.079	0.656	2.175	383.495	4.05
Pro	0.1ns	0.25ns	0.016*	0.000**	0.000**	0.000**	0.003**	0.000**
CV (%)	21.6	36.6	13.9	3.1	9.5	2.1	11.6	7.4

improved nonglutinous cultivars — IR82635-B-B-145-1, IR 83928-B-B-28-3, IR82589-B-B-2-3, IR83928-B-B-81-2, IR82589-B-B-149-4, IR82635-B-B-47-1, IR82635-B-B-59-2, IR82639-B-B-118-3, and IR82589-B-B-7-3 —and check B6144F-MR-6 were tested at NAFReC. Grain yield was significantly higher at 60 and 90 kilograms of N per hectare.

CURE aimed to introduce more sustainable agricultural production practices in the upland areas by evaluating appropriate methods and best crops for intercropping. To identify the best legumes for intercropping with rice under continuous upland rice cultivation, Laboun, a traditional upland rice variety, was intercropped with soybean, cowpea, and mungbean. Rice grain yield was highest in upland rice alone (1,034 kilograms per hectare), while the lowest yield was observed in the upland rice and cowpea intercrop. Intercropping upland rice with legume crops provided more income than growing upland rice alone. Mungbean with upland rice generated USD1,590 per hectare and soybean with upland rice generated USD1,230 per hectare, which were higher than the income from upland rice alone (US$320). Although grain yield of legume species was higher for mungbean (1.35 kilograms per hectare) than soybean (CM60 = 970 kilograms per hectare), farmers preferred upland rice and soybean intercrop.

CURE likewise assessed appropriate methods of intercropping between legume and maize for continuous upland cultivation in 2014. The trial was conducted at UARC, Xieng Ngeun District, in Luang Prabang. Results showed that maize grain yield (2,363 kilograms per hectare) was highest when planted as a monocrop and lowest when maize was intercropped with rice (Figure 2). However, the intercropping maize and rice generated more income than planting maize alone, with the former earning at about 1,105 USD per hectare while the latter earned 443 USD only. Maize with "stylow" (*Stylosanthes guianensis*) generated an income of about 227 USD per hectare (Figure 3).

Intensification of rice based

DRIVERS OF CHANGE

Consortium for Unfavorable Rice Environments (CURE). CURE's work in upland-based rice ecosystems paved the way of testing new varieties and management options appropriate in diverse rice environments. In food-insecure and disadvantaged ecosystems, cropping system enhancement is highly desirable, which is an integral part of the CURE approach. With shorter-duration varieties and time-saving crop establishment, it becomes possible to grow non-rice crops which bring cash and employment (Castillo, G.T., 2008).

District Agricultural and Forestry Office (DAFO). This acts as the implementing body under PAFO, and is responsible for demonstrating through adaptive research of upland varieties in the farmers' field.

Provincial Agricultural and Forestry Office (PAFO). It coordinates with local government and contributes to the result of implementation of any development project. It is the arm of the agriculture and development extension at the provincial level.

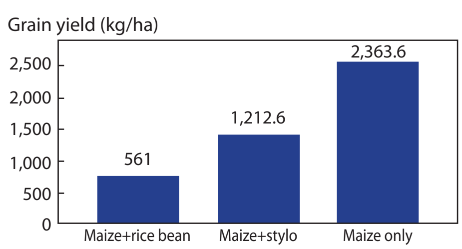


Figure 2. Grain yield of maize intercropped with rice bean and stylow at Upland Agriculture Research Center (UARC), Xieng Ngeun District, Luang Prabang, Lao PDR.

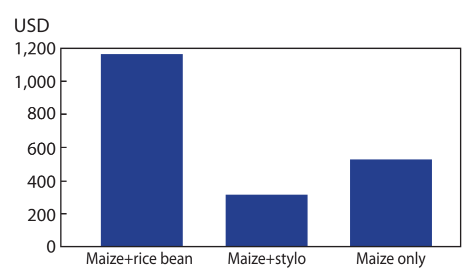


Figure 3. Income generated from intercropping maize with rice bean and stylow at Upland Agriculture Research Center (UARC), Xieng Ngeun District, Luang Prabang, Lao PDR.

Upland Agriculture Research Centre (UARC). As mandated to improve the living conditions of the population in the upland areas in Lao PDR, UARC is a local government institution that coordinates with farmers and other government institutions through Lao PDR Upland Food Security Improvement Projects and Northern Uplands Development Programme; and non-government organizations for seed multiplication to their respective target areas. UARC focuses on implementing sustainable upland agriculture technologies which is demand-driven and responsive to the farmers' needs. The role of the Center is to develop productive and sustainable upland farming systems and land management recommendations related to food security.

Non-government organizations (NGOs). NGOs, which aim to improve the livelihood of food-insecure communities, such as CARE, Norwegian Church Aid (NCA), Medisch Comité Nederland-Vietnam (MCNV), Service Fraternel d' Entraide (SFE) or Fraternal Mutual Aid Service, and World Vision, used their own resources to buy seeds from UARC and provide assistance in distributing rice seeds to upland farmers. CARE distributed seeds of upland seed varieties to farmers in Koua District, Phongsaly Province, while NCA provided seeds to farmers in Long District, Luang Namtha Province and Pha Oudom District, Bokeo Province. MCNV shared seeds in Nong District, Savannaket Province, SFE in Dack Chuet District, Xekong Province and Phouvong district, Attapue Province, and World Vision in Pakseng District, Luang Prabhang Province.

LAO PDR government. The national government, through the National Agriculture and Forestry Institute (NAFRI) and National Rice Research Program, focuses on seed production for rainfed lowland rice and upland rice seed production per year. From 2010-15, it has targeted to produce 10 tons of upland rice per year from eight provinces, namely, Oudomxay, Bokeo, Luang Namtha, Luang Prabhang, Phongsaly, Xieng Khoung, Xabouly, and Houaphan.

Farmer leaders. It continues to support programs and projects that directly benefit IPs and to engage the national government in making policies and programs that will achieve the same goal.

Indigenous people. They are the main inhabitants of the remote, mountainous, and forested areas of Laos and the drivers and main champions of the rice-based intensification approach. The rice-based intensification systems will benefit marginal farmers in the uplands through improved productivity and sustainability in upland rice production.

Financial space

Supporting good causes. The Lao PDR-IRRI collaboration began in the late 1960s and continued in the 1970s with the testing of improved rice breeding material from IRRI's rice breeding and selection work in Lao PDR. Systematic multi-location yield trials, followed by the multiplication and dissemination of several IRRI lines and varieties to farmers, took place in 1973.

IRRI's work in Lao PDR is supported by the International Fund for Agricultural Development (IFAD) under CURE, Swiss Agency for Development and Cooperation (SDC), the Bill & Melinda Gates Foundation (BMGF), the Australian Centre for International Agricultural Research (ACIAR), the Government of Japan, and Germany's Federal Ministry for Economic Cooperation and Development (BMZ).

Partnership space

Upscaling through collaborative effort. Building partnerships with NGOs, cooperatives and international NGOs is an indispensable impetus for upscaling efforts. Strengthened linkages between gene banks (IRRI), plant breeding organizations such as Agricultural Research Center (ARC), NAFRI, and provincial government offices can help develop sustainable rice-based systems.

NAFRI provides the budget to UARC to produce good seeds of upland rice varieties. On the other hand, CURE provides the funds to develop and evaluate rice germplasm and integrated crop management options, and develop decision-support tools for technology assessment. CURE is also supporting seed multiplication and the initiative on CBSS

Meanwhile, projects initiated by government organizations such as Lao Uplands Food Security Improvement Project (LUFSIP) and Northern Uplands Development Programme (NUDP), as well as NGOs, financially support the training activities of PAFO and DAFO officers conducted by UARC in partnership with IRRI. They also buy some seeds from UARC that were produced by the farmers.

Environmental space

Strengthening crop diversity through conservation of traditional rice varieties. CBSS not only promotes biodiversity by preserving on-site conservation of traditional varieties, but it also encourages sustainable use of plant genetic resources. Because of CBSS, local varieties such as Nok, Makhinsoung, None, and Laboun were identified and purified to retain the original traits that farmers primarily preferred in traditional varieties. Thus, CBSS strengthens sustainable use of crop diversity in the community.

Cultural space

Involving the community and more women in the farming process through rice traditions and new technologies. Upland rice is important to many ethnic groups in mountainous areas in the north of Laos. For instance, during harvesting season, Khmuic people see the sun as a symbol of clear sky or a rainless weather, which can also cause damage to rice. When the rice grain ripens and its color becomes yellow or orange, during the time of harvesting, Khmuic people hold small rituals to sacrifice rice souls or spirits on the rice fields, mostly in upland rice fields or swidden fields (slash and burn technique which Khmuic people call "hre hngo"). The rituals of rice soul sacrifices involve hitting a bronze drum, called "yan" or "heurbang greh" (harvest gong), to beg the sun to shine and prevent rain from coming. In case it rains, they also hit the yan and recite sayings to beg for rain to stop. If it rains more than usual during the rainy season, they also hit the yan and recite sayings to beg for rain to ease or stop for a little while. This is why in the Moun Greh Ceremony, Khmuic people hit the yan to thank the sun for shining well during the rice harvesting; and that is why they also refer to the bronze drum as a harvest gong. This kind of practice is rare nowadays.

The involvement of women is encouraged in farming activities even though traditional gender roles still exist among the Hmong communities in the uplands where men remain to be expected as leaders of their households. Women select the seeds one week before harvest to be planted in the next season. They acquire the skills on selecting quality seeds by attending training activities conducted by UARC. Hmong women are responsible for nurturing the children, preparing meals, feeding animals, and sharing in agricultural labor.

Policy Space

Responding to challenges through specific policies. The indigenous communities, who primarily inhabit remote, mountainous and forested areas, practice traditional ways of life such that they experience marginalization. The Lao Government has always kept in mind how to reduce poverty and improve the living standards of ethnic groups, although there is no specific legislation yet in Laos to address the needs of indigenous people. The only national legislation relevant to indigenous peoples is the Ethnic Minority Policy, which upholds the principle that all ethnic groups should have improved access to services and that all discrimination must be eradicated. According to this policy, the government of Lao PDR will make more efforts to improve the living conditions of all ethnic groups. Thus, the indigenous peoples of Laos are encouraged to move down to lowland areas where there are more economic opportunities, productive agriculture, and better access to government services. However, relocation presents a threat to the traditional lifestyles of Lao indigenous communities. Implementation of the principles included in this policy is made difficult due to budget constraints, lack of human resources, and the remoteness of many ethnic minority communities. It is within purview that CURE activities centered on enhancing farmers' access to varieties that are preferred by the farmers and capacitating the local communities to produce their own quality seeds and have surplus to trade or share with farmers, markets, and other projects of the government.

The Lao government is aware of the environmental problems associated with shifting cultivation from the slash-and-burn agricultural system common in these mountainous upland areas, and has thus taken measures to reduce it. The management of upland environment policy was initiated and published in 1995. This policy emphasizes that more productive rice production systems should be developed and adopted through high-yielding varieties, fertilizer inputs, and improved weed and pest management. The development of crop diversification and product intensification is recognized in the Upland Agriculture Policy. Since 1997, the national programs of the Lao government have been working with IRRI in the research support for upland rice production.

In 2012, a policy study was released at the request of the government called the Lao People's Democratic Republic Rice Policy Study. Since the country has moved from rice deficit to sizable surplus, and rice shortages have become more of a localized occurrence, the focus of food security has shifted to addressing nutritional benefits. Improving nutritional outcomes will increasingly be dependent on policies that promote higher household incomes, and education on and awareness of better uses of foodstuff. This report was a support to an evidence-based policy decision regarding the rice sector. It has benefited from the collaboration among the World Bank, the Food and Agriculture Organization of the United Nations (FAO) and IRRI (IRRI, 2015).

Learning Space

Improving knowledge and capacity. At the end of CURE's first phase in 2014, a booklet titled "Best Management Practices for Rainfed Lowland Rice in Laos PDR" was distributed and made available on IRRI's Rice Knowledge Bank Web site: www.knowledgebank.irri.org/BMPlao/index.html. These guidelines were developed based on activities during the first phase of the project. In addition, NARES also produced flyers, brochures, and guides in growing new stress-tolerant varieties for farmers and parters.

Training activities have also been held by CURE for its partners on various topics. The Sustainable Natural Resource Management and Productivity Enhancement Project (SNRMPEP) (2009-16) participated in the CURE-organized training program on establishing community seed banks. It was suggested that SNRMPEP be invited to training programs organized by CURE grant in Lao to enhance the knowledge and skills of the investment's project partners and beneficiaries.

In an action plan approved by CURE and the IFAD-funded investment project in Oudomxay and Xayabuly provinces, a total of 88 participants (67 males and 19 females) were trained on 1 April 2014 to 31 March 2015 on seed production; CBSS; sustainable upland agriculture production; experimental design, data analysis, and report writing; and the management of farmers field' days in Lao PDR. Participants consisted of representatives from four organizations: the Northern Agriculture and Forestry College, the Northern Upland Development Program,MCNV, NCA in Lao, LUFSIP, and the Provincial Agriculture and Forestry Service of Luang Prabang.

The training activities on CBSS were conducted in Nan District, Luang Prabang. The participants, consisting of 12 technicians and 18 farmers, were introduced to the concept of CBSS in rice production systems and the techniques in seed health management, crop management, and various seed-to-seed production system technologies. The training activities on experimental design, data analysis, and report writing were conducted on 2-6 February 2015 in the Northern Agriculture and Forestry College where 35 participants were scheduled to attend.

Recommendations

The capacity of leaders of farmers' groups and communities should be strengthened through training to improve their knowledge of technologies and best management practices. There should also be leadership training for heads of farmers' organizations and leaders of local communities.

Transparency is imperative among farmers' organizations.

Good management and cooperation should exist not only within the organization of the community-based seed system, but also with other organizations.

Local government organizations should monitor the progress of the community to take care of its needs.

There is a need for a marketing plan and a systematic production of rice as grain and seed. Marketing strategies should be incorporated in the management and outscaling of the CBSS. One could add value on the four rice varieties (Nok, Makhinsoung, None, and Laboun) by processing them as brown rice and marketing them as organic rice. The production of these traditional rice varieties preserves the cultural tradition and likewise, conserves the traditional varieties in the mountainous areas of northern Laos.

Besides dissemination of select upland rice varieties and best management practices, other technologies, particularly those that can be used or integrated in rice-pigeon pea intercropping systems, should be developed in the uplands. Cultivating pigeon pea has been found to improve soil condition, suppress weed, and reduce nematode in the upland area. Pigeon pea can also be used for stick lac production. Thus, technologies and management practices on pigeon pea should also be part of the package in upscaling the community-based seed system.

REFERENCES

Asian Development Bank. (2001). *Participatory poverty assessment: Lao PDR*. Vientiane, Laos Asian Development Bank.

Castillo, G.T. (2008). Rice crisis and climate risk management: The CURE approach. International Rice Research Institute, Philippines. *Asian Journal of Agriculture and Development, Vol. 5, No. 1*

Consortium for Unfavorable Rice Environments. (2015). *CURE annual report*. International Rice Research Institute (IRRI). Los Baños, Laguna, Philippines.

International Fund for Agricultural Development. (2014). *Investing in rural people in the Lao People's Democratic Republic*. October 2014.

Myanmar

Submergence-prone environments
Salinity-prone environments
Drought-prone environments

Within each farmer's reach: Development and dissemination of stress-tolerant varieties and best management practices in Myanmar

Tin Tin Myint, Cho Cho Aung, Joel D. Janiya, Madonna Casimero, and Romeo V. Labios

The journey of climate change-ready varieties will not begin unless they reach the farmers' fields, and it will not be complete without improved or best management practices. Gathering support and creating linkages between and among organizations and different sectors thus become vital, for which the Consortium for Unfavorable Rice Environments (CURE), as one of the key players of the project, has been instrumental.

Myanmar's rice areas and environments

Primarily an agricultural country, Myanmar is characterized by different rice ecosystems, namely, irrigated lowlands, rainfed lowlands (including late-sown and Mayin area), deepwater, and uplands. The late-sown rainfed lowland ecosystem is the area sown during the monsoon period where Mayin rice is grown. It can be transplanted only after the monsoon when floodwater recedes. Meanwhile, rainfed lowlands, the largest among the ecosystems, and deepwater rice are confined to the delta region and coastal strip of Rakhine State. Nearly 60% of the delta region, including the Ayeyarwady, Bago, and Yangon regions in Lower Myanmar, is cultivated with rainfed rice.

Because of rainfall and hydrologic patterns, irrigation is critical in Myanmar's central dry zone, whereas, in the delta, there is more concern about drainage and flood protection. The country's upland area is mostly in Mandalay, Sagaing, and Shan states. Some upland areas in Shan State occupy sloping land, which becomes cold in the northern winter.

Myanmar has a total of about 7.31 million hectares of rice areas (6.2 million hectares are grown with monsoon rice, and 1.1 million hectares with summer rice) that produce more than 33 million metric tons of rice in 2010 despite some environmental constraints. However, the stress-prone areas in the country are home to about 40,255,000 rural population whose food supply and lives are affected by harsh environmental conditions. Of the country's total rice areas, 201,252 hectares is affected by drought, 505,675 hectares by submergence, and 295,115 hectares by deep water, and 108,963 hectares by salinity (Table 1). If these environmental constraints will be properly addressed, production of rice would be sufficient enough to supply the country's needs, and even demands for export.

CURE's technological strategies: Confronting the problem of productivity in unfavorable environments

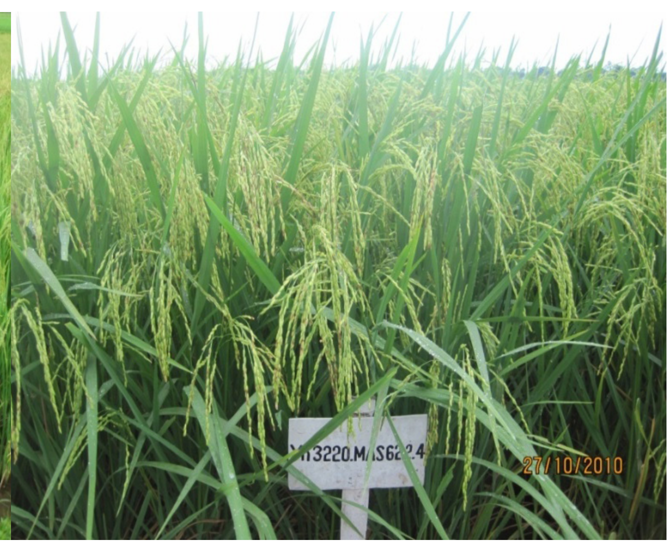
A. "Climate change-ready" rice varieties: Remedy to stress-prone rice areas

Varieties tolerant to environmental stresses such as drought, salinity, and

Table 1. Rice areas in the country affected by stress environments, DoA, 2014

State/Region	Flood-prone area (ha)		Salinity area	Drought-prone area (as of 2005)
	Submerged area	Deepwater area		
Rakhine	22,833		28,600	39,854
Mon	34,865	16,839	5,436	
Kayin	23,396	15,374		
Shan	662			
Kachin	2,890			
Yangon	82,431	16,839	7,346	
Ayeyarwady	214,728	105,792	59,818	
Bago	83,896	131,652		
Bago East				35,985
Bago West				28,956
Sagaing	32,513			45,741
Mandalay	10,068		190	58,482
Tanintharyi	15,621	8,619	7,573	
Magway	2,322			44,868
	506,225	29,5115	108,963	253,886

flooding are significant developments in rice breeding and are dubbed as "climate change-ready varieties." Climate change-ready varieties sprung from IRRI's breeding program which addresses problems in unfavorable rice environments. The innovation is currently adapted in South and Southeast Asia where salinity, flooding, and drought are major concerns. Additional varieties are developed every year to provide farmers with a wide range of options to manage varying conditions in unfavorable environments. One of the strategies developed by the Consortium for Unfavorable Rice Environments (CURE) to address such problems is by using the genetic materials or varieties developed through IRRI's breeding program for problematic rice areas. IRRI's breeding program has produced a series of Sub1 varieties that are tolerant of flash flooding (17 days maximum based on on-farm demonstrations), saline soils with electrical conductivity of 4–6 dS/m, and drought. Several trials have shown overwhelming results in the Philippines, Indonesia, Cambodia, Laos, Vietnam, Myanmar, India, and Bangladesh, where farmers were able to harvest rice in areas that were previously unproductive, if not, left idle. Similarly, previously unplanted



paddies affected by salinity were able to produce a substantial amount of yield where previously nothing can be harvested at all. In many rainfed areas where water availability is unreliable, and drought is a common occurrence, causing farmers to suffer high yield losses, the introduction of drought-tolerant varieties sparked a renewed confidence and hope to farming communities.

However, access to these varieties is limited due to the extent of the areas affected, and the insufficient supply of seeds of these climate change-ready varieties. Moreover, available mechanism and logistical capacity in

the distribution of these varieties is insufficient. To address the problem on submergence, salinity, CURE partnerships will have to reach more farmers. Thus, the intervention needed is to increase access to these stress-tolerant varieties to farmers in the unfavorable rice environments. These varieties have been successfully tested in different locations in the country (Table 2), and have been disseminated by the National Seed Committee to farmers in the aforementioned problem areas.

Beginnings of successful technological intervention through CURE's umbrella mechanism

In 2007, a year after visiting and surveying submergence-prone areas, which was the biggest problem in the Ayeyarwady area in the delta region, Dr. David Mackill, a plant breeder and Dr. Abdelbhagi Ishmail, a plant physiologist, both members of the then CURE Working Group 2, provided a small amount of Swarna and Swarna Sub-1 seeds for testing to compare with the local variety.

In the same year, the CURE Project was introduced to Myanmar through the Department of Agricultural Research (DAR) but did not start formally until 2008. In 2008, DAR received five Sub-1 varieties from IRRI for evaluation at DAR station, which was followed by testing of salinity- and drought-tolerant varieties. From 2011-2012 to date, CURE had been funding DAR for its research activities. Multi-location yield trials for submergence-tolerant rice and stagnant flood-tolerant rice have been conducted since 2008 with materials provided by the IRRI-Japan submergence-tolerant rice project (CURE Report, 2009). But it was not until 2013 when salinity-tolerant rice testing began, and in 2014 for drought-tolerant rice variety under the Drought Project of IFAD (International Fund for Agricultural Development). Myanmar's Ministry of Agriculture, Livestock and Irrigation (MoALI), through DAR, led the development and improvement of breeding materials of stress-tolerant rice together with scientists from the International Rice Research Institute (IRRI). Figure 1 presents the steps involved in the varietal development program employed in the country.

Through the CURE-Myanmar and other IRRI-Myanmar programs, submergence-tolerant rice were released, namely: Yemyoke khan Saba 1 (Swarna-Sub 1) in 2012, and Yemyoke khan Saba 2 (BR 11-Sub 1) in 2014. Salinity-tolerant rice varieties were also successfully released such as SarHnganKan Sin ThweLatt (Saltol Sin Thwe Latt) in 2013, Pyi Myanmar Sein (IR 10 T 107), and Shwe Asean (CSR 36); and drought-tolerant rice varieties, Yeanelo 1 (IR 55423-01) in 2011, Yeanelo 2 (UPLR1-7) in 2013, Yeanelo 3 (WAB 880-SG-6) in 2014, Yeanelo 4 (IR 87707-446-B-B-B) in 2015, Yeanelo 5, 6,

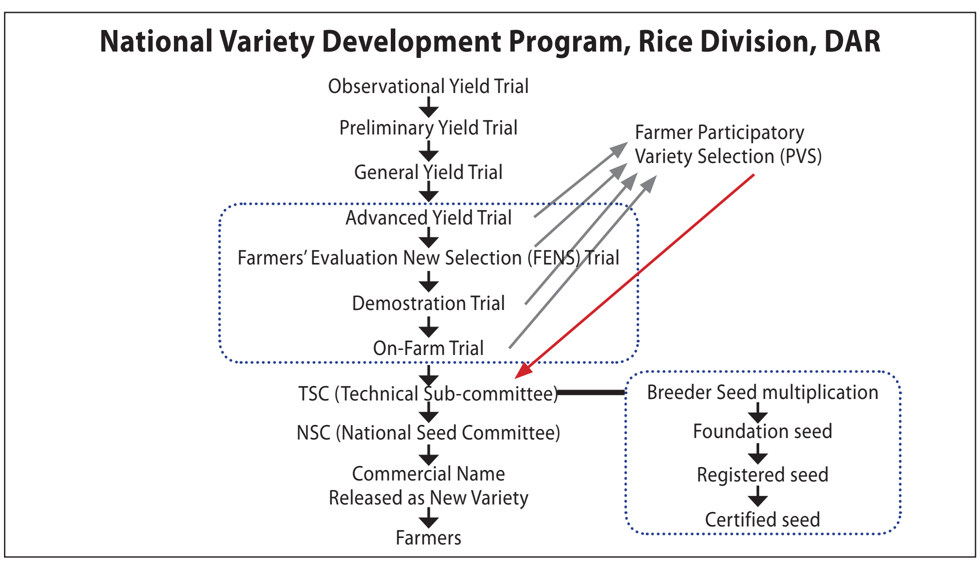


Figure 1. Process of varietal development in Myanmar.

Table 2. Varieties and locations where they were tested for adaptability to specific stress domains and acceptability by farmers.

Varieties	Activity	Locations	Yield (t/ha)
Yemyoke Khan 1 (Swarna-Sub 1)	LIFT A	Ayeyarwady (Bogale) Ayeyarwady (Mawlamyinegyun) Ayeyarwady (Labuta)	4.04 3.90 – No 2.76
	LIFT B		
	ACIAR MyRice	Bago (DaikU)	4.20
		Ayeyarwady (Maubin)	3.50
	On-farm (CURE)	DAR	5.40
		Ayeyarwady (Myaungmya research farm)	5.96
		Ayeyarwady (Kyaungkone)	4.23
		Ayeyarwady (Einmae)	5.32
		Ayeyarwady (Warkhaema)	3.10
		Ayeyarwady (Pantanaw)	3.58
Yemyoke Khan 2 (BR 11-Sub 1)	ACIAR MyRice	Ayeyarwady (Maubin)	3.5
		Bago (Daik U)	3.80
	LIFT (A)	Ayeyarwady (Labutta)	5.40
		Ayeyarwady (Bogale)	4.54
		Ayeyarwady (Mawlamyaingkyun)	3.92
	On-farm (CURE)	DAR (research station)	5.90
		Mandalay	5.80
		Yangon (Htantabin)	4.80
		Yangon (Twintay)	4.70
		Bago (Nyaunglaybin)	3.60
		Bago (Kali)	5.30
		Ayeyarwady	-
		Rakhine (MyaukU)	3.30
		Kayin (Pharean)	3.90
		Taninthari (Longloan)	4.30
		Mon (Kyaikmayaw)	5.40
		Mon (Kyaikhto)	5.80
SarHnganKan Sin ThweLatt (Saltol Sin Thwe Latt)	ACIAR MyRice	Ayeyarwady (Maubin)	5.7
		Bago (DaikU)	3.6
	LIFT (A)	Ayeyarwady (Labutta)	4.32
		Ayeyarwady (Bogale)	4.50
		Ayeyarwady (Mawlamyaingkyun)	4.32
Shwe Asean (CSR 36)	ACIAR MyRice	Ayeyarwady (Maubin)	3.6
	USAID STRIVE	Mrauk Oo	3.4
		Myaung Mya	3.9
		Phoe We Kyi Su	3.9
		Nyaung Pin Gone	4.8
		Yemethin	4.2
		Pyapone	3.4

Continued

Table 2. Continued.

Varieties	Activity	Locations	Yield (t/ha)
Shwe Asean (CSR 36)	ACIAR MyRice	Maubin	3.6
	USAID STRIVE	Mrauk Oo	3.4
		Myaung Mya	3.9
		Phoe We Kyi Su	3.9
		Nyaung Pin Gone	4.8
		Yemethin	4.2
		Pyapone	3.4
	On-farm (CURE/IFAD)	Sagaing	3.8
		Tanintharyi	4.3
		Bago (East)	3.1
		Magway	3.4
		Mandalay	3.1
		Mon	4.2
		Yangon	3.6
		Rakhine	3.8
		Ayeyarwady	4.1
Pyi Myanmar Sein (IR 10T 107)	LIFT (A)	Ayeyarwady (Labutta)	3.31
		Ayeyarwady (Bogale)	1.30
		Ayeyarwady (Mawlamyaingkyun)	2.48
	ACIAR MyRice	Maubin	4.5
	USAID STRIVE	Mrauk Oo	3.7
		Myaung Mya	5.7
		Phoe We Kyi Su	6.4
		Nyaung Pin Gone	5.9
		Yemethin	6.0
		Pyapone	3.5
	On-farm (CURE/IFAD)	Sagaing	4.3
		Tanintharyi	3.5
		Bago (East)	3.5
		Magway	4.0
		Mandalay	4.6
		Mon	4.1
		Yangon	3.4
		Rakhine	4.2
		Ayeyarwady	3.6
Yeanelo 1	On-farm (CURE/IFAD)	DAR	4.20
		Mandalay (Sebin)	3.80
		Mandalay (Pyawbwe)	4.30
		Mandalay (Yemethin)	4.60
		Mandalay (Tharzi)	2.80
		Mandalay (NyaungOo)	3.00
		Magway (Myaing)	4.30
		Magway (Saitphyu)	3.00
		Sagaing (Wetlet)	4.20
		Sagaing (Ye-U)	4.70

Continued

Table 2. Continued.

Varieties	Activity	Locations	Yield (t/ha)
		Ayeyarwady (Myaungmya)	4.30
		Ayeyarwady (Phyarpone)	2.90
		Yangon (Kyisu)	4.90
		Yangon (Nyaungpinkone)	3.70
		Yangon (Htantabin)	4.10
	ACIAR MyRice	Daik U	4.4
		Maubin	3.6
Yeanelo 4	On-farm (CURE/IFAD)	DAR	5.78
		Mandalay (Sebin)	4.05
		Mandalay (Pyawbwe)	6.06
		Mandalay (Yemethin)	5.59
		Mandalay (Tharsi)	3.78
		Mandalay (NyaungOo)	3.99
		Magway (Myaing)	5.53
		Magway (Saitphyu)	3.44
		Sagaing (Wetlet)	4.56
		Sagaing (YeU)	5.00
		Ayeyarwady (Myaungmya)	5.38
		Ayeyarwady (Phyarpone)	3.88
		Yangon (Kyisu)	5.35
		Yangon (Nyaungpinkone)	4.97
		Yangon (Htantabin)	5.36
	ACIAR MyRice	Maubin	3.8
Yeanelo 5	ACIAR MyRice	Maubin	4.9
	USAID STRIVE	Mrauk Oo	3.7
		Myaung Mya	5.4
		Phoe We Kyi Su	6.3
		Nyaung Pin Gone	4.9
		Yemethin	5.5
		Pyapone	4.7
Yeanelo 6	ACIAR MyRice	Maubin	4.4
	USAID STRIVE	Mrauk Oo	3.4
		Myaung Mya	6.5
		Phoe We Kyi Su	5.5
		Nyaung Pin Gone	5.2
		Yemethin	6.4
		Pyapone	3.6
Yeanelo 7	ACIAR MyRice	Maubin	4.3
	USAID STRIVE	Mrauk Oo	1.5
		Myaung Mya	5.1
		Phoe We Kyi Su	4.9
		Nyaung Pin Gone	5.1
		Yemethin	5.0
		Pyapone	3.7

Table 3. Rice varieties released through CURE activities and other IRRI projects and their characteristics.

Local name	Designation	Maturity (days)	Plant height (cm)	Potential Yield (ton ha^{-1})
Submergence-tolerant varieties				
Yemyoke Khan 1	Swarna-Sub1 (Swarna*4/IR49830-7-1-2-2	145	100	4.5-5.0
Yemyoke Khan 2	BR11-Sub1 (IR07F290) (BR11*3 / IR 40931-33-1-3-2)	145	110	5.0-6.6
Shwe Pyi Tan	IRRI 119 (IR43581-57-3-3-6/IR26940-20-3-3-3-1//KHAO DAWKMALI 105)	156	117	5.0-6.5
Salinity-tolerant varieties				
SarNganKhan Sin Thwe Latt	Saltol Sin Thwe Latt (IR53936-60-3-2-3-1/Pokkali)	142	112	4.5-5.0
Pyi Myanmar Sein	IR10T107 (IR 83412-B-B-3-1-1-1)	115	122	5.0-5.5
Shwe ASEAN	CSR 36 (CSR13/Panvel 2/IR36)	115	110	3.5-4.0
Drought-tolerant varieties				
Yeanelo 1	IR 55423-01	115	120	4.0-5.0
Yeanelo 2	UPLRi -7	115	107	4.0-5.0
Yeanelo 3	WAB 880-SG-6	120	111	4.0-5.0
Yeanelo 4	IR 87707-446-B-B-B	117	120	4.5-5.0
Yeanelo 5	IR87705-44-4-B	116	107	5.0-6.0
Yeanelo 6	IR87707-182-B-B-B	111	125	5.0-6.0
Yeanelo 7	IR87705-83-12B	115	108	4.0-4.5

and 7 in 2016 and for freshwater areas are ThiriThuka (12.RMTK-1-UL-16) in 2014 and Pyi Taw Yin (IR77542-90-111-5) in 2015. The characteristics of these released varieties are shown in Table 3.

These released varieties were thoroughly tested in target environments for their adaptability through the combined efforts of DAR, Department of Agriculture (DoA), and IRRI-Myanmar Office in collaboration with grant-funded projects like CURE-IFAD, Australian Centre for International Agricultural Research (ACIAR), United States of America International Aid (USAID), and Livelihoods and Food Security Trust (LIFT) in Myanmar. To ensure acceptability and suitability to farmers' preferences, participatory varietal selection (PVS) was employed (Paris et al., 2011). PVS is a proven method of ensuring that varieties introduced in the field qualify under farmers' scrutiny. Once the farmers selected the variety or varieties, these are then multiplied for wide-scale distribution. The domain of potential application of the stress-tolerant varieties includes about 800,790 hectares for submergence-prone areas, 108,963 for salinity, and 201,252 hectares for drought (see Table 1).

Seed production and distribution

There are two existing seed production and distribution systems currently employed in Myanmar. The first system includes varietal improvement, technical assistance, capacity building, materials and equipment as facilitated by DAR, which produces breeder seeds, foundation seeds, and registered seeds through DAR research center and selected seed production centers under DAR supervision. Meanwhile, seed farms, which produce certified seeds, are established with the support from the DoA to make the seeds readily available to the farmers. On the other hand, seeds in the second system are produced and distributed through village seed banks and farmer seed banks systems, which are widely used in Myanmar. These are formed with technical assistance from DoA (see Figures 2 and 3). Table 4 shows the states where certified seeds of different stress-tolerant varieties are sown, which have covered a total of 77,989.50 acres (31,561.23 hectares) to date.

The DoA and DAR are responsible for the multiplication of the seeds of chosen varieties, which are distributed in collaboration with government and non-government organizations working with farmers in different divisions, districts, and townships. The dissemination of climate change-ready varieties was done to expand the reach of these varieties to areas where farmers are most affected by drought, flooding,

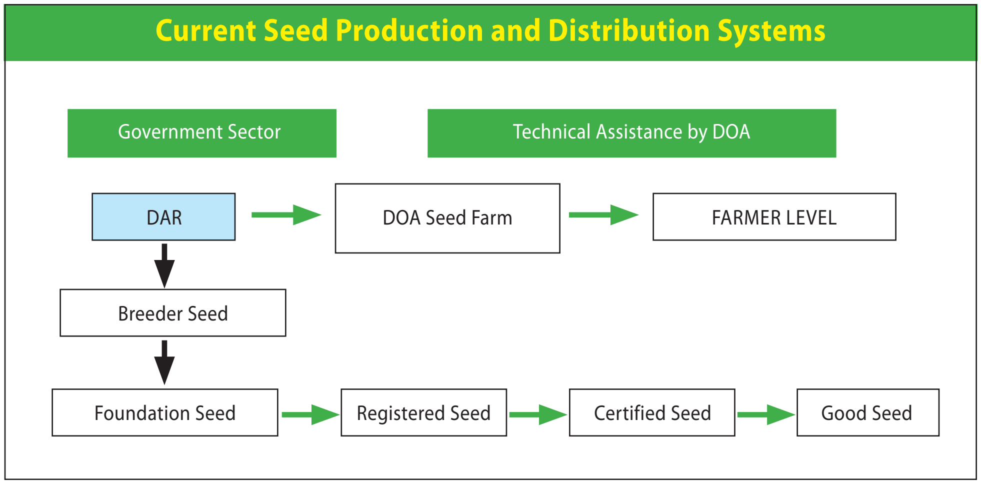


Figure 2. Flow chart of the first seed production and distribution system.

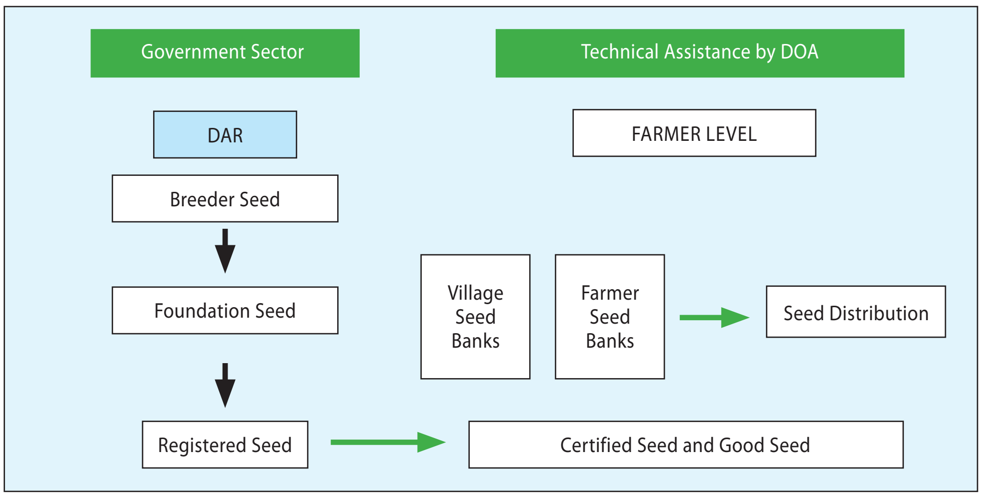


Figure 3. Flow chart of the second seed production and distribution system.

and saline water intrusion into their rice fields. Rapid dissemination of these varieties in the last three years was facilitated through partnership between and among international nongovernment organization (INGO) collaborators [such as Groupe de Recherche et d'Echanges Technologiques (GRET), and Welthungerhilfe (WHH), Mercy Corps], LIFT IRRI (A&B) projects, ACIAR MyRice, USAID STRIVE, and IFAD-drought, submergence and salinity components as shown in Table 5, which provided support, both in terms of manpower and funding for the research activities. Through such collective efforts a total of 2,646 farmers have benefitted from growing stress-tolerant varieties as shown in Table 6.

B. Best management practices go hand in hand with climate-change ready varieties

Research and development of suitable pre- and postharvest crop management options have been lagging behind in Myanmar despite the strong development in rice breeding. Varieties that can tolerate environmental stresses such as drought, flash flooding, stagnant flooding, and salinity have been produced. These climate change-ready varieties are already adapted in South and Southeast Asia where such stresses exist. In addition, new varieties are being developed each year to provide farmers with a wide range of options for different conditions in unfavorable rice environments. And, these varieties need improved management

Table 4. Production of certified seeds for irrigated and rainfed ecosystems, National Certified Seed Production Program, 2015–2016.

Variety	State and Regional	Sown Acre
Shwe Yin Aye	Kayah	520.00
Manaw Thu Kha	Mandalay	1874.00
	Rakhine	310.00
	Sagaing	163.00
	Naypyitaw	515.00
	Magway	2623.00
	Bago	1537.00
	Ayeyarwady	38.00
Ayeyar Min	Mandalay	1001.00
	Sagaing	5014.00
	Magway	720.50
	Yangon	856.00
	Ayeyarwady	1399.50
	Bago	10.00
Shwe Thwe Yin	Mandalay	572.00
Yezin Lone Thwe	Mandalay	653.00
Sin Thwe Latt	Rakhine	2710.00
	Tanintharyi	300.00
	Yangon	858.00
	Bago	6424.00
	Ayeyarwady	659.50
Shwe Wah Htun	Rakhine	1383.00
	Tanintharyi	195.00
	Ayeyarwady	242.00
Paw SanYin	Rakhine	338.00
	Mon	1920.00
	Yangon	72.00
	Ayeyarwady	1230.50
	Kayin	50.00
	Bago	30.00
Paw San Bae Kyar	Ayeyarwady	106.00
	Magway	10.00
Sin Thu Kha	Chin	30.00
	Yangon	3261.00
	Sagaing	590.00
	Naypyitaw	105.00
	Kayin	1500.00
	Bago	9133.00
	Magway	3908.50
	Ayeyarwady	4250.00
Hmawbi – 2	Yangon	144.00
	Sagaing	888.00
	Bago	1009.00
	Kayah	30.00

Continued

Table 4. Continued.

Variety	State and Regional	Sown Acre
	Shan (North)	12.00
	Magway	15.00
	Ayeyarwady	343.50
Thee Htet Yin	Yangon	1033.00
	Bago	100.00
	Ayeyarwady	1037.50
SR- 456	Shan (South)	719.00
Sin Akaryi – 3	Shan (East)	68.00
	Sagaing	740.00
	Shan (North)	110.00
Shwe Bo Paw San	Sagaing	4135.00
	Bago	126.00
Yadanar Toe	Bago	5129.00
	Magway	957.00
	Ayeyarwady	432.00
	Yangon	250.00
Kyaw Zay Ya	Tanintharyi	780.00
	Bago	1156.00
Tayote Hmwe	Kayah	50.00
Shwe Pyi Htay	Magway	14.00
Hmawbi – 7	Yangon	60.00
	Ayeyarwady	27.00
Hnan Khar	Ayeyarwady	425.00
DU-16 (China)	Shan (South)	27.00
	Shan (North)	10.00
201 (China)	Shan (South)	13.00
Hmawbi Kyaut Nyin Hmwe	Shan (North)	3.00
Shwe Myanmar	Bago	500.00
Dagon-1	Bago	50.00
Viet Nam	Bago	103.00
Date-90	Ayeyarwady	300.00
BR-11(Sub-1)	Ayeyarwady	2.00
Sin Shwe Sal	Yangon	5.00
Dagon-1,2,3	Yangon	75.00
Stress Tolerant Varieties		
Salinity Tolerant Sin Thwe Latt	Yangon	3.00
	Ayeyarwady	351.00
Swarna Sub-1	Ayeyarwady	295.00
Total		**77989.50**

Table 5. Seed multiplication and distribution of breeder's seeds, foundation seeds, and registered seeds

Year	Project	Variety	Seed (kg)			Sites
				Production	Distribution	
2008	CURE	Swarna-Sub 1	BS	1050		
			FS			
			RS			
2009	CURE	Swarna-Sub 1	BS	168		
			FS	1045		
			RS	4830		
2010	CURE	Swarna-Sub 1	BS	167		
			FS	1035		
			RS	3348	63	WarKaeMa Township, Ayeyarwady
					63	Amarapura Township, Mandalay
					314	Rakhine
					63	Thonekhwa Township, Yangon
					63	NGO, Ayeyarwady
					2541	Laputta Township, Ayeyarwady
					63	NGO, Yangon
					126	FAO, Ayeyarwady Division
					52	Rice Division (Research), Yezin
2011	CURE	Swarna-Sub 1	BS	157.5	31.5	Ayeyarwady Region
			FS	1564.5	31.5	Laeway Township, Nay Pyi Taw
					630.0	Ayeyarwady Region
					63.0	Myothit Township, Magway Region
					315.0	Yangon Region
					126.0	Yaetarshay Township, Bago Region
					315.0	Nyaungdone Township, Ayeyarwady Region
					10.5	Yae Township, Tanninthari Region
					10.5	Kyaikhto Township, Mon State
					63.0	Seed Division, Myanmar Agriculture Service
			RS			
2012	CURE	Swarna-Sub 1	BS	138	46	Ayeyarwady Region (Seed Farm)
					46	Yangon Region (Seed Farm)
					46	Taninthari Region (Seed Farm)
			FS	3151	138	Bago Region
					46	Mon State
					138	Magway Region
					690	YadanarAyar Company
					2070	Bago (East) Region
					69	Myaungmya Farm
			RS			
2013	CURE	Swarna-Sub 1	BS	84		Pathein, Myaungmya & Latpadan Research Farm (Ayeyarwady and Bago regions)
			FS	2751		Ayeyarwady, Bago, Yangon, Mon, Mandalay, Rakhine, Magway, Taninthari Regions, YadanarAyar Company
			RS	19855		Ayeyarwady, Bago, Yangon, Mon, Mandalay, Rakhine, Magway, Taninthari Regions, YadanarAyar Company
	ACIAR					
2014	CURE		BS			
			FS			
			RS			
	ACIAR					
		Shwe Asean (CSR 36)	FS		660	Bogalay, Latputta,Mawlamyingkyun (Ayeyarwady region)
		Pyi Myanmar Sein (IR 10 T 107)			2670	Bogalay, Laputta, MauBin (Ayeyarwady region), Bago region, Sagaing, Yangon, Mandalay and Magway regions, Rakhine

Table 6. Beneficiaries of stress-tolerant varieties, 2015.

Country	Ecosystem	Varieties	Area (ha)	Number of farmers
Myanmar	Submergence	Yemyoke Khan 2	1.20	2
		Yemyoke Khan 1	1,488.00	64
	Salinity	Shwe ASEAN	267.00	116
		IR-10-7107	1,081.00	470
		Sin Thwe Lat	4,575.00	1,990
	Drought	Yeanelo 1	3.00	1
		Yeanelo 4	7.00	3
	Subtotal		**7,422.20**	**2,646**

practices to reach their potential productivity. [Myanmar Rice Sector Strategy (MRSDS), 2015].

Some crop management recommendations for rice that had been adapted from other countries were brought by IRRI to Myanmar through the Irrigated Rice Research Consortium (IRRC) and CURE. As such, there are limited defined management recommendations for varieties in different growing environments in the country. These are important for farmers to optimize the yield benefits that the new rice varieties offer. Farmers often lack skills and knowledge about proper plant nutrient management. For instance, urea, the most common fertilizer used by farmers, is often applied at low rates and not at the right growth stage of the crop. Fertilizer management through site-specific nutrient management (SSNM) can significantly increase yields by improving nutrient use efficiency as the fertilizer is applied at the right time and at the right amount. The occurrence of major pest problems has, in general, been low in rice fields, except for weeds, but the trend in pesticide use is increasing because farmers have limited knowledge on integrated pest management and the proper use of pesticides (Aung et al., 2012). Thus, improved management practices are greatly needed to help farmers successfully grow rice, improve yields, and gain better income in vulnerable areas (MRSDS, 2015).

Development of Best Management Practices (BMP)

Producing rice is a step-by-step process, which demands careful attention to details to ensure good crop growth and high yield. This step-by-step process uses the best possible and appropriate technologies and practices used to manage and control delivery of technologies at a specified time related to the crop's growth stage for a more efficient use of inputs. These practices bundled up into a single package for ease of use is referred to as Best Management Practices (BMP). Extension workers can use the BMP to guide farmers in the proper use of technologies in producing rice effectively and efficiently. With the use of BMP, farmers can increase their yield and reduce cost of production, and at the same time, minimize pollutants, thereby helping preserve the environment.

BMP resulted from adaptive research, which means technologies were tested along with varieties in specific stress conditions to evaluate if the management practice would complement the variety to achieve maximum yield. Thus, when stress-tolerant varieties are distributed to farmers, they would also go with improved management practices. These management practices are a combination of field experience, farmer knowledge, and results of experimentation to validate observations and current practices. The management practices include all aspect of rice production from seed, variety selection, land preparation, planting, nutrient and pest management, to post-harvest management.

The development of BMP is a tedious task as it involves data gathering, documentation, meetings, and several consultations to come up with one final version agreed upon by all stakeholders. In developing BMP the following steps are involved:

1. Listing down the steps and processes in producing a rice crop (from seed selection to postharvest)
2. Identifying the target rice environment
3. Defining method of crop establishment
4. Scanning and collating technologies from research results and experiences learned from actual use of technologies in the field
5. Filling in the steps with details on how and what should be done in each step
6. Consulting with subject matter experts on the specific steps or technologies
7. Refining information by consulting with concerned partners
8. Consulting with extension workers and end users
9. Refining and printing the final material for distribution to users

The flow of developing BMP is illustrated in Figure 4. This process may be modified to suit local situation and stakeholders' interests.

A generalized BMP was developed and was given to Myanmar partners for them to revise based on their research results and practices in the field. A small group worked on the materials (e.g. BMP in traditional transplanting method of crop establishment [TPR] for drought-prone environments) to localize the content. The material was then submitted to colleagues (i.e., breeders for recommended varieties, pest and disease experts to address pest management, among others). And after a series of consultations and discussions on the materials, a two-day workshop was conducted to discuss, refine, and further revise the content of the materials. The final output was then submitted to higher authorities for approval. The materials were translated into Burmese and approved by the Minister of the Ministry of Agriculture and Irrigation Services. To date, 12,000 pamphlets and 375 posters (4ftx8ft) have been distributed by the MoAI. The following "Integrated Management Practices" (IMP) posters were completed and ready for outscaling:

1. BMP for dry-seeded rice in drought-prone environments-dry zone monsoon
2. BMP for transplanted rice in drought-prone environments-dry zone monsoon
3. BMP for alkaline-prone environments
4. BMP for submergence-prone environments
5. BMP for saline-prone environment of the Ayeyarwady Delta and coastal regions: monsoon rice
6. BMP for brackish water areas in the Ayeyarwady Delta and coastal regions: Summer rice

Major components of integrated management practices for outscaling were made into steps to follow and these were the following:

Step 1. Selection of suitable varieties (See list of varieties in appendix 1).
Step 2. Land preparation
Step 3. Seedling nursery (seedbed) preparation
Step 4. Crop establishment
Step 5. Nutrient management
Step 6. Water management
Step 7. Weed management
Step 8. Pest and disease management
Step 9. Harvest and postharvest operation

Adapting Saltol can increase the yield over farmer's variety by 0.58 tons per hectare. Application of BMP with

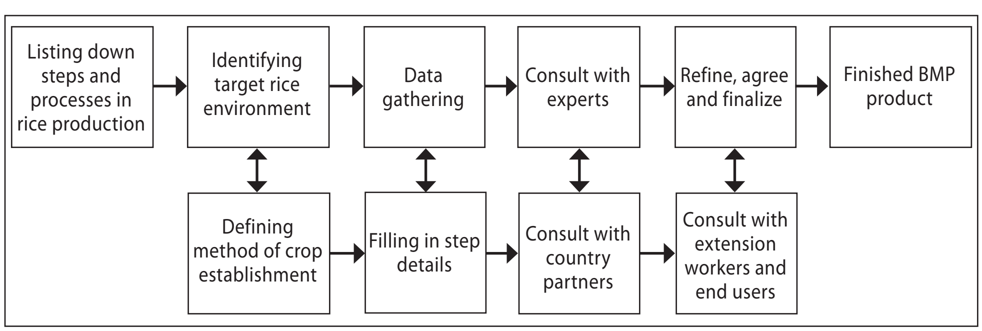


Figure 4. Steps involved in the development of BMP.

farmer's variety increased yield by 0.58 ton per hectare. The effect of agronomic improvement and variety improvement were additive. When saltol varieties were combined with BMP, the increase was 1.18 ton per hectare (34%) compared to farmer's variety and farmer's management (LIFT B Report 2015).

In both the drought-affected and alkaline- and salt-affected sites, varieties and management practices had a positive effect on yield. Effect of agronomic improvement and variety improvement were additive, and integrated BMP yielded higher than farmers' conventional practices (Farmers Variety+Farmer's Practice) by 1.24 tons per hectare (+35%) in the drought-prone areas, and by 1.04 tons per hectare (+79%) in the alkaline (salt-affected) sites. Drought stress was not severe due to supplemental irrigation in the summer season in drought-prone areas, where the effect of variety was larger than that of management (LIFT B Report 2015).

Component technologies of crop management integration developed for best management practice (BMP)

Improved management components that were tested included seedbed management, which involved proper seedbed construction (raised bed), appropriate seed rate and seedling population in the seedbed, and nutrient management; weed control applied at the proper time and rate to manage weeds and nutrient management for specific environmental stresses; rodent management; nutrient management; and postharvest management. These crop management technologies were used in conjunction with varieties bred for the target stress environment such as submergence-prone, drought-prone, and saline-affected soils. For information on these varieties appropriate to target stressed environments, see Appendix.

Nursery bed management

Raised-bed seedling nursery. Farmers in Myanmar generally use flatbed seedling nursery, which often makes managing water level difficult in case of flooding during heavy rains after seeding, which consequently, causes mortality of pre-germinated seeds.

- Seedbed site must be:
  - o an area free from salt stress and tidal water intrusion for saline affected environments
  - o near a fresh water source far from street lights; and
  - o with fertile soil free from disease and weeds.
- Land preparation for a nursery bed should be done 2–3 weeks prior to sowing.
- Use good-quality and pure seeds
- Pre-germinate the seed soaking for 24 hours (h) and incubating for 24–48 hectares.
- For 1 acre (0.40 hectare) of field with a seed rate of 21 kilograms (50 grams seed m^{-2}), 0.1 acre (0.04 hectare) will be needed for a nursery bed area.

Flat bed nursery

Raised-bed nursery

- For every 3-feet interval, one drainage canal should be done.
- Level the seedbeds.
- Some 200 kilograms (one bullock cart) of farmyard manure (FYM)/compost should be applied for the 0.04 hectare at land preparation (5 tons per hectare FYM).
- Apply 1 kilogram of 15:15:15 at land preparation for a 0.04 hectare seedbed (40 kilograms N:40 KgP_2O_5:40 Kg K_2O per hectare).
- Sow the seeds evenly on the seedbed with a density of 50 grams of seed per square meter, and then cover with a thin layer of soil or decomposed FYM or rice hull ash.
- Keep the seedbeds moist and irrigate with shallow water (0.5-1.5 inches with the height of the seedling) 5–6 days after sowing (DAS) and afterwards.
- Control disease and pests if necessary.
- Apply 5 kilograms of urea fertilizer + 1 kilogram of Zifer ($ZnSO_4$. H_2O) for 0.04 hectare of seedbed at 7–10 days before uprooting (40 kilograms N per hectare) (total 80:40:40).
- Nursery beds should be free of weeds to avoid transplanting weed seedlings.
- Manual weeding should be done before transplanting.
- Flood the seedbed to facilitate ease of pulling and avoid seedling injury.
- Pay attention not to damage roots during uprooting as injured roots passively absorb salt.
- Transplant seedlings at 15–21 days old.

Weed management

- Do thorough land preparation to control weeds.
- Remove weeds from puddled field before transplanting.
- Early flooding and closer plant spacing can control weeds.
- If plants were in rows, use rotary weeder after draining the field.
- Do manual weeding and other weed management activities not later than 30–40 days after transplanting (DAT).
- If weeds were a major problem, use registered herbicides for the particular type of weed using the recommended rate and time of application. For instance , if major weeds were likely to be a mix of grasses and sedges, the examples of pre-emergence and post-emergence herbicides to use are shown in Table 6.

Outcome of BMP

The use of BMPs reduced seed rate by two-thirds, and reduced the amount of nitrogen and phosphorus applied. Better yields were obtained when BMP was used. Yields increased by 3% to 10% in the fresh water areas, and by 10% to 52% in the saline-prone areas (Table 7).

In both agro-ecological zones, positive income was generated using farmer's practice and integrated best management practices (IBMPs). In the non-flooded areas, the income in farmer's practice ranged from 217,000 to 607,000 kyats/hectare (185.7 to 519.4 USD/hectare), while in the flooded areas, the income generated ranged from 157,000 to 878,000 kyats/hectare (134.4 to 751.3 USD/hectare) (Table 8). In the non-flooded areas, the income in IBMP was 137,000 to 517,000 kyats/hectare (117.2 to 442.4 USD/hectare), while the income ranged from 179,000 to 900,000 kyats/hectare (153.2 to 770.2 USD/hectare) in the flood-prone areas (Table 9). IBMPs provided higher income to farmers compared to farmer's practice in 7 of the 11 villages.

Table 6. Recommended herbicides for weed control.

Herbicide Name	Rate of application ml /ac	Time of application
Pretilachlor PREE*	500	0–3 DAS
Oxadiazon PREE**	500	0–3 DAS
Bensulfuron methyl PREE	400	7–12 DAE
Bispyribac sodium POSTE**	400	7–12 DAE

*Pre-emergence for wet direct-seeded rice
**Pre-emergence of dry direct-seeded rice
***Post-emergence herbicide should be applied when the weed has 2–3 leaves in all method of crop establishment

Table 7. Grain yield in three fertilizer management practices in freshwater and saline areas in the three townships, summer cropping 2014. LIFT Report 2015.

Township/village	Grain yield (ton ha^{-1})		
	FP	DAR	SSNM
Freshwater areas			
1. Dar Chaung, Bogale (n = 3)	3.8	4.3	4.1
2. Go Nyin Tan, Labutta (n = 3)	4.3	3.8	3.7
Mean	4.0	4.0	3.9
Saline-prone areas			
1. Ah Kal Chaung, Bogale (n = 3)	1.7	2.0	2.1
2. Pa Dae Kaw, Mawlamyinegyun (n = 3)	1.4	1.5	1.3
3. Tin Pone Kwin, Labutta (n = 3)	3.3	3.3	2.8
Mean	2.1	2.3	2.1

Working towards an envisioned future

The development and dissemination of climate change-ready varieties is important to address key problems in rice farming systems, where low and unstable yields are commonplace and where extensive poverty and food insecurity prevail, and to provide adequate supply of quality seeds, and easy access for farmers to these varieties, which would generate substantial yield advantage compared with that of the current varieties that the farmers are using. Moreover, improved management practices using farmers' variety, as adaptive management studies have shown, can improve rice yield (Table 10).

Thus, the CURE project in Myanmar, which provides a venue for partnership among NARES and IRRI researchers, farmers, aims to evaluate the adaptation of submergence-, stagnant-, salinity- and drought-tolerant rice varieties from IRRI, (2) support NARES to develop outscaling systems in the country, (3) improve the existing rice varieties by incorporating novel QTLs (quantitative trait loci) such as *Sub1* gene, *Saltol* gene, and multiple genes through marker-assisted selection in national breeding program, (4) support of packaging of information into knowledge products, and (5) equip partners through capacity-building activities on various topics.

By building and strengthening the partnership between farmer seed producers and the Department of Agriculture through its Seed Division, which is tasked to multiply seeds, and with the support and network of of INGOs in the country, it is expected that the stress-tolerant or climate change-ready varieties can reach at least 75% of the farmers in stress-prone areas in the next three years.

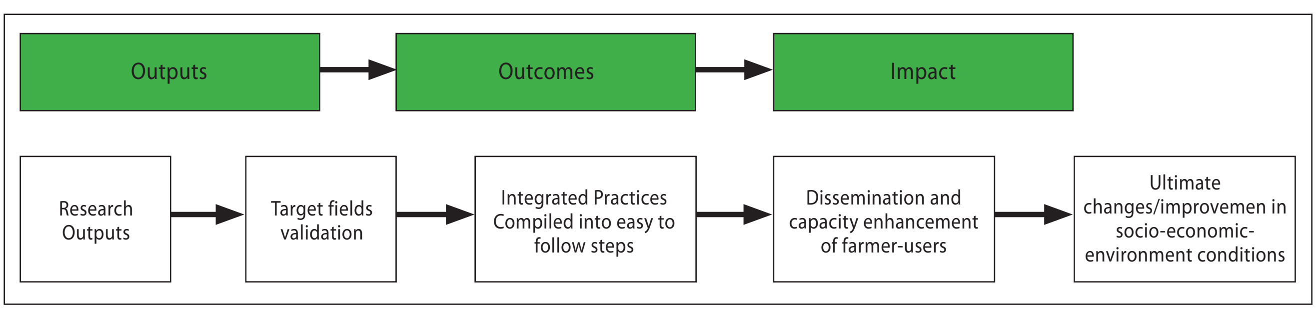


Figure 5. Pathway for disseminating technologies.

Table 8. Comparison in the costs and returns between the farmers' practice and integrated best management practice in freshwater areas, summer cropping 2014. LIFT Report 2015.

Village/profitability parameters	Farmers' practice	IBMP	% Increase in net income
1. Dar Chaung, Bogale			
Yield (ton ha^{-1})	3.7	3.8	
Gross income (kyat/ha)	650,249	666,873	
Gross income (USD/ha)	556.4	570.7	
Total cost (kyat/ha)	470,346	436,558	
Total cost (USD/ha)	402.5	373.6	
Net income (kyat/ha)	179,903	230,315	28
Net income (USD/ha)	154	197.1	
Benefit-cost ratio	1.4	1.5	
2. Kyee Chaung, Mawlamyinegyun			
Yield (ton ha^{-1})	4.8	5.2	
Gross income (kyat/ha)	859,564	934,594	
Gross income (USD/ha)	735.6	799.8	
Total cost (kyat/ha)	564,189	473,092	
Total cost (USD/ha)	482.8	404.8	
Net income (kyat/ha)	295,375	461,502	56
Net income (USD/ha)	252.8	394.9	
Benefit-cost ratio	1.5	2.0	
3. Gone Nyin Tan, Labutta			
Yield (ton ha^{-1})	3.0	3.4	
Gross income (kyat/ha)	570,669	606,899	
Gross income (USD/ha)	488.3	519.4	
Total cost (kyat/ha)	457,938	398,943	
Total cost (USD/ha)	391.9	341.4	
Net income (kyat/ha)	112,731	207,956	84
Net income (USD/ha)	96.5	178	
Benefit-cost ratio	1.2	1.5	
Mean			
Yield	3.8	4.5	
Gross income (kyat/ha)	693,494	800,733	
Gross income (USD/ha)	593.5	685.2	
Total cost (kyat/ha)	517,267	454,825	
Total cost (USD/ha)	442.7	389.2	
Net income (kyat/ha)	176,227	345,908	56
Net income (USD/ha)	150.8	296	
Benefit-cost ratio	1.4	1.8	

Pathways of scaling out and scaling up

The process of scaling out and scaling up began with the adaptation trial and testing of stress-tolerant varieties in the different districts of Myanmar. The process of demonstration followed the PVS approach so that varieties adapted to specific areas were acceptable to farmers. The farmers' selected varieties were multiplied for wider testing and dissemination.

Along with the introduction of stress-tolerant varieties, appropriate crop management practices were also tested in terms of their suitability and refinement, so that the maximum potential of the new stress-tolerant varieties was achieved. From the testing

Table 9. Comparison in the cost and return between the farmer's practice and integrated best management practice in flood-prone areas, monsoon cropping 2014. LIFT Report, 2015.

Village/profitability parameters	FP	IBMPs	% Increase in net income
1. Ah Kal Chaung, Bogale			
Yield (ton ha^{-1})	2.8	4.0	
Gross income (kyat/ha)	555,333	789,667	
Gross income (USD/ha)	476	676	
Total cost (kyat/ha)	355,068	386,961	
Total cost (USD/ha)	304	332	
Net income (kyat/ha)	200,265	402,706	101
Net income (USD/ha)	172	345	
Benefit-cost ratio	1.6	2.0	
2. Ba Wa Thit, Bogale			
Yield (ton ha^{-1})	2.5	2.8	
Gross income (kyat/ha)	816,563	557,000	
Gross income (USD/ha)	699	477	
Total cost (kyat/ha)	412,678	378,004	
Total cost (USD/ha)	354	324	
Net income (kyat/ha)	338,722	178,996	-47
Net income (USD/ha)	290	153	
Benefit-cost ratio	2.0	1.5	
3. Ka Na Sa Chgaung Gyi, Mawlamyinegyun			
Yield (ton ha^{-1})	2.2	3.2	
Gross income (kyat/ha)	484,875	711,000	
Gross income (USD/ha)	415	609	
Total cost (kyat/ha)	328,016	413,231	
Total cost (USD/ha)	281	354	
Net income (kyat/ha)	156,859	297,769	89
Net income (USD/ha)	134	255	
Benefit-cost ratio	1.5	1.7	
4. Pa Dae Kaw, Labutta			
Yield (ton ha^{-1})	3.84	4.68	
Gross income (kyat/ha)	861,667	1,053,000	
Gross income (USD/ha)	738	902	
Total cost (kyat/ha)	328,016	413,231	
Total cost (USD/ha)	281	354	
Net income (kyat/ha)	533,651	728,984	37
Net income (USD/ha)	457	624	
Benefit-cost ratio	2.6	2.6	
5. Kyar Ni Kan, Labutta			
Yield (ton ha^{-1})	3.8	5.6	
Gross income (kyat/ha)	1,143,600	1,260,450	
Gross income (USD/ha)	980	1080	
Total cost (kyat/ha)	264,784	359,696	
Total cost (USD/ha)	227	308	
Net income (kyat/ha)	878,816	900,754	3
Net income (USD/ha)	753	772	
Benefit-cost ratio	4.3	3.5	
6. Taung Kone, Labutta			
Yield (ton ha^{-1})	2.3	3.3	
Gross income	681,000	744,750	
Gross income (USD/ha)	583	638	
Total cost	264,784	359,696	
Total cost (USD/ha)	227	308	
Net income (kyat/ha)	417,000	385,054	-8
Net income (USD/ha)	357	330	
Benefit cost ratio	2.6	2.1	
Mean Yield	3.5	4.7	
Mean Gross income	757,173	852,644	
Mean Gross income (USD)	649	730	
Mean Total cost	325,557	385,136	
Mean Total cost (USD)	279	330	
Mean Net income (kyat/ha)	431,596	467,508	8
Mean Net income (USD/ha)	370	400	
Benefit-cost ratio	2.3	2.2	

Table 10. Mean rice yield of each combination (variety + practice) across three water eco-zones. FV = Farmer variety, FM = Farmer crop management, IV = Improved variety, IM = Improved management practices for rice production. Sing R.K. et al., 2015. LIFT B report 2015.

Water Ecozone	FV + FM	FV + IM	IV1+ FM	IV2 + FM	Mean IV+FM	IV2 + IM	IV1 + IM	Mean IV+IM
Fresh	3.84	4.59	3.6	3.0	3.3	4.5	4.69	4.6
Brackish	2.38	2.98	3.09	3.34	3.26	3.38	3.41	3.40
Saline	3.23	4.1	3.65	2.9	3.28	4.31	4.52	4.42
Mean Yield (t/ha)	3.15	3.89	3.45	3.08	3.27	4.07	4.21	4.14

of existing technologies and introduction of improved technologies, BMP or IBMPs were developed to guide both extension workers and farmers in properly growing and caring for the introduced varieties to achieve their maximum yield.

After the discussions with partners on Myanmar, both government and nongovernment institutions were able to produce a unified "Integrated Management Practices," which is yet to be approved by the Minister, and rolled out to farmers in the different stress areas, particularly in the central dry zone, lower delta, and lower delta coastal areas. To date, translation of the posters from English to Burmese is ongoing. Once the translation is complete, the posters will be reproduced and disseminated to specific stress-prone areas in the country. Table 1 presents potential sites, where the stress-tolerant technologies can be applied or disseminated.

The same government and non-government institutions will work together within their area of operations to disseminate BMPs. DAR along with the MoAI and line agencies, whose efforts are focused at increasing rice export, are lobbying for the implementation of best management practices/integrated management practices to farmers in the lower delta and dry zone areas.

DRIVERS OF CHANGE

Institutionalized support mechanism by the national government and agencies. Myanmar's MoAI is responsible for the provision and production of high-quality seeds, training and education, and research, while the national government provides financial support in the form of credit: Kyats 100,000 (USD 85.6) per acre (0.04 hectare) for rice production for a maximum of 10 acres (4.05 hectares/farmer) with 1% interest for one season. This scheme enables farmers to have additional capital for rice production. Moreover, upon noting the advantages of saline-tolerant varieties, the Deputy Minister of Agriculture and Members of the Parliament from Mon, Kayin State, and Ayeyarwady coastal areas, which are widely affected by salinity, are campaigning for the increase in seed production of these varieties for distribution to their constituents so that these varieties can reach as many farmers as possible, and help them improve their farm yields and livelihood. Rakhine and Ayeyarwady had created central seed farms for seed multiplication to produce foundation and registered seeds to supply the needs of their state and region. Breeder seeds of saline varieties for multiplication were supplied by DAR.

At the same time, the DoA is moving fast to provide the seed demand of stress-tolerant varieties, which will further open opportunities in the development of the seed industry where farmer groups can become important players in seed production. DoA Seed Division is putting up a plan of establishing Regional and District Seed Laboratories to enhance the processing and release of foundation seeds (FS) to farmers.

International organizations and NGOs working for poverty alleviation and farmer emancipation from poverty and food insecurity. The following organizations and programs are keen in ensuring that stress-tolerant varieties reach the farmers.

IFAD (International Fund for Agricultural Development) supports the CURE mechanism in Myanmar by assisting in the development and dissemination of stress-tolerant varieties, capacity enhancement of partners and beneficiaries, and knowledge management.

The Consortium for Unfavorable Rice Environments (CURE) provides a platform for collaboration in seed production and dissemination and information exchange among partners, farmers, NGOs and international organizations. CURE also supports the institution of seed producers to increase production of seeds and enhance distribution to farmers.

LIFT A&B. LIFT (Livelihoods and Food Security Trust Fund) is a multi-donor fund established in 2009 to improve the lives and prospects of poor and vulnerable people in rural Myanmar. LIFT provides technical expertise, targeted research and its position of oversight to improve program design and cohesion for better overall impact. This program supported the testing (PVS) and distribution of stress-tolerant varieties to farmers in stress prone areas.

ACIAR was involved in on-farm participatory adaptive research of rice-based systems, participatory varietal selection (PVS), validation of BMPs, seed production and dissemination of chosen varieties from PVS, post-harvest management, capacity building of partners and farmers, Learning Alliance (LA), and business model in the delta (Maubin township in Ayeyarwady and Daik U township in Bago Regions).

Yadanar Ayar Company, a Bogale-based NGO with business in seed production, is keen in producing and distributing seeds of stress-tolerant varieties.

International NGOs that are partners of DoA and DAR and are supported by LIFT in distributing recommended varieties in the different unfavorable environments.

WHH (Welthungerhilfe) fights against global hunger and for sustainable food security by incorporating the promotion of agriculture suited to local conditions, to campaigns for access to clean water, provision of modern, environment-friendly energy, and the improvement of health and education.

GRET(Professionals for Fair Development) is a French development NGO that has been actively fighting poverty and inequalities on all levels and in a broad range of subjects. Its professionals promote the economic development of rural areas to counter inequalities in accessing the means of production and foster equitable sharing of the benefits of growth.

When food shortages occur due to drought and conflict, Mercy Corps helps prevent hunger and treat malnutrition among the most vulnerable — children, pregnant women, the elderly and the displaced. Mercy Corps helps farmers manage their land, increase their harvests, and diversify crops to produce a larger, more nutritious crops, and stable food supply. It also connects farmers with new markets, and introduce more efficient methods of tending productive livestock, and processing and storing crops to increase income.

USAID (United States Agency for International Aid) World Bank provides support for development of quality rice seeds in Yamethin, Mandalay and Rakhine States. Through the STRIVE project, the USAID aims to improve seed quality and seed health to help farmers establish community seed banks, which will make stress-tolerant varieties accessible to them.

Political space

Prioritizing seed production as noted in Myanmar Rice Sector Development Strategy (MRSDS) 2015. The national government has set four economic policies, one of which is to build Myanmar into a modern industrialized nation through the agricultural development and all-around development of other sectors of the economy. The policies emphasize the production and usage of high-yielding and good quality seeds, training and educational activities on advanced agricultural techniques for farmers and extension staff, implementation of research activities for sustainable agricultural development, awareness to encourage farmers to shift from conventional to mechanized agriculture, production of crops suitable to climate and extension of irrigated area, and amendment of existing agricultural laws and regulations in line with the current situation. These policies directly support the production and use of good quality seeds, which is one of the objectives of releasing new climate change-ready varieties for the unfavorable environments.

The climate change-ready varieties can be disseminated through the formal seed system that starts from DAR, where breeder's seeds are produced. After producing breeder's seeds, the seeds are given to Seed Division farms of DoA for multiplication. Once foundation seeds and registered seeds are produced, these are then given to contract farmers for multiplication of certified seeds with the assistance of extension staff. The certified seeds will be distributed to the farmers, which can only be used in three season cycle. After which, they need to be replaced with a new batch of seeds for planting. The distributions of seeds in townships are supervised by the township staff officer or the district staff officer of DoA.

Financial space

Boosting research activities through continuous funding. DAR has produced seeds of promising varieties for the unfavorable environments (saline-affected, submergence-prone areas and drought-prone areas) with financial support from LIFT-A, which provided the funding (USD 2M) for the adaptation trials and PVS trials in the lower delta, while the LIFT-B program provided the funds (USD 2M) to support the adaptation trials and PVS trials in the dry zone. Although the project of LIFT is not directly connected to CURE program, their activities support and enhance the development of technology and dissemination of the new varieties. These programs helped boost the information dissemination on stress-tolerant varieties, as well as the distribution of these stress-tolerant varieties in both the dry zone and lower delta by the staff from IRRI-Myanmar office. ACIAR and USAID have also greatly contributed in the varietal development of stress-tolerant varieties in the country.

Other than the funding from CURE and IFAD, Myanmar activities in unfavorable areas are also funded by Japan International Cooperation Agency (JICA) through rural development, specifically Pakhangyi Village in Pakhoku Township, Magway Region, especially for rice and rice value-added production. The collaboration between JICA and the local government (MoAI) resulted in the release of Pakhanshwewar rice variety (PSBRc18) in 2009, a short duration, high-yielding variety for drought-affected irrigated areas in the dry zone.

Institutional space

Widening coverage through combined support from farmers' group and potential partners. Seed production is a gargantuan task. The Seed Division of DoA cannot solely meet the demand for registered seeds of these stress-tolerant varieties. Seed production and distribution must then be distributed among stakeholders and seed producers' groups. DAR has created a contract farmers group to handle the production of seeds. Through the supervision of the townships and district staff, seed distribution will be readily facilitated. DoA in collaboration with grant projects are training farmers in quality seed production to provide wider avenue for seed source and distribution.

Moreover, since the LIFT project has ended, the distribution network and partners of LIFT can also be tapped by DAR and DoA to further enhance distribution of stress-tolerant varieties. Taking off from seed distribution model in the LIFT program, the DoA can explore collaborations with LIFT partners like Mercy Corps, GRET, APSI, WHH and Yadanar Ayar in terms of manpower needed for the seed distribution. At the same time, through the financial resources of such partners, the logistics involved to reach all the target farmers and target stress-affected areas will be made possible.

Partnership space

Establishing a systematic process of breeding and dissemination with key stakeholders. The DoA and DAR must take the lead in scaling-up the innovation of stress-tolerant rice varieties through its regular program. The DoA and the INGOs partners, will undertake the distribution, documenting, and monitoring of the seed distribution program. The IFAD may assist in the upscaling of the stress-tolerant varieties with additional financial and training grants.

Also USAID-STRIVE is currently working on training farmers for quality seed production with an intent to transform the farmers' seed producer groups into a community-based seed system. Organizing the farmers will increase their access to quality seeds of stress-tolerant varieties, and will create an opportunity for them to engage with the seed value chain.

REFERENCES

ACIAR Annual Project Report 2014. Diversification and intensification of rice-based cropping systems in lower Myanmar. May 6, 2013-May 12, 2014. Australian Center for International Agricultural Research. Project Number SMCN/2011/046 Pp. 33. Annual Progress CURE Report 2009.

International Rice Research Institute Research findings Optimizing Crop Nutrition (IRRI). 2006. Site-specific nutrient management. http://www.irri.org/irrc/ssnm/. Accessed 23 Oct 2006

International Rice Research Institute. 2013. Annual report of the Project on Improving Livelihoods in Rice-based Rural Households in the Lower Region of Ayeyarwady Delta Myanmar. LIFT A Report 2013.

International Rice Research Institute. 2015. Annual report of the Project on Improving Livelihoods in Rice-based Rural Households in the Lower Region of Ayeyarwady Delta Myanmar. LIFT A Report 2015.

International Rice Research Institute. 2015. Annual report of the project on Reducing risks and improving livelihoods in the rice environments of Myanmar through better targeting of management options. LIFT B Report 2015.

International Rice Research Institute. 2015. Annual report of the project on USAID Stress-Tolerant Rice Varieties in Vulnerable Environments (STRIVE).

Ministry of Agriculture and Irrigation. (2015). Myanmar Rice Sector Development Strategy. PDF e-book. http://books.irri.org/MRSDS_content.pdf

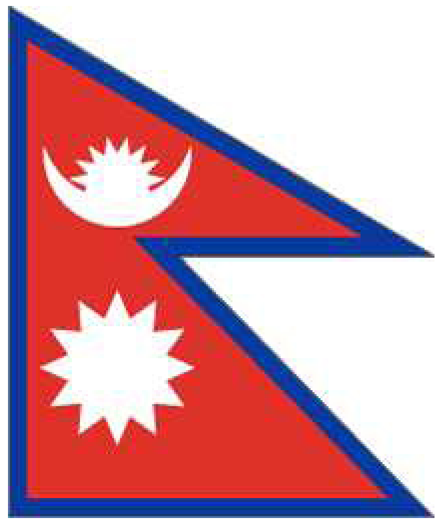
Appendix. Varieties suitable to specific rice environment.

Environment	Local name	Designation	Maturity (days)	Plant height (cm)	Potential Yield (t/ha)
Drought-prone					
Drought (direct-seeded)	Shwe Ma Naw	Taminadu	110	90	4.0-6.0
	Yeanelo 1	IR 55423-01	115	120	4.0-5.0
	Yeanelo 2	UPLRi -7	115	107	4.0-5.0
	Yeanelo 3	WAB 880-SG-6	120	111	4.0-5.0
	Yeanelo 4	IR 87707-446-B-B-B	117	120	4.5-5.0
	Thiri Thuka	RMNTK-1-UL-16 (Reselection of Manaw Thuka)	145	140	4.0-5.0
	Manaw Thukha	Mahsuri-M	135	107	4.5-6.0
	Pyi Taw Yin	IR77542-90-111-5	126	116	4.5-5.5
	Yar 8	Yn 92-17	120	100	3.5-4.0
	Yar 2	Kn 96	125	95-105	4.0
	Yar 2 Tun	Kn 96 Mutant	100	85-90	4.0
	Pyi Myanmar Sein	IR10T107 (IR 83412-B-B-3-1-1-1)	115	122	5.5-6.0
Drought (transplanted)	Sin Thukha	Manawthukha**/IRBB21	140	115	5.0-6.0
	Manawhari	Mahsuri(O)	145	135	4.0-5.0
	Thiri Thukha	RMNTK-1-UL-16	145	140	4.0-5.0
	Khunwar	Local variety	145	140	3.0-3.5
	Pyi Myanmar Sein	IR10T107	115	122	5.5-6.0
	Yeanelo 5	IR87705-44-4-B	110	110	4.5-5.0
	Yeanelo 6	IR87707-182-B-B-B	110	120	5.5-6.0
	Yeanelo 7	IR87705-83-12B	115	108	4.0-4.5
		IR87705-14-11-B	118	125	5.5-6.0
	Shwe Pyi Htay	Yn2841-UL26 (Tethom/KDML105)	127	112	4.5-5.0
	Shwe Pho	Local variety	145	135	2.5-3.0
Alkaline-prone					
	Manaw Hari	Mahsuri (O)	140	140	3.5- 4.5
	Pokali		140	131	2.0-2.5
	Khun War	Local variety	145	131	2.0-2.5
	Pyi Myanmar Sein	IR10T107	115	122	5.5-6.0
	Shwe Asean	CSR 36	115	119	5.0-5.5
Saline-prone					
Delta and coastal monsoon	SarNganKhan Sin Thwe Latt	Saltol Sin Thwe Latt (IR 53936-60-3-2-3-1/ Pokkali)	142	112	4.5-5.0
	Sin Thukha	Manawthukha**/IRBB21	140	115	5.0-6.0
	Shwe Ta Soke	Shwedingar Mutant	162	148	4.0-5.0
	Shwe Pyi Htay	Yn2841-UL26 (Tethom/KDML105)	120	105	4.5-5.0

Continued

Appendix. Continued.

Environment	Local name	Designation	Maturity (days)	Plant height (cm)	Potential Yield (t/ha)
Saline summer	Pyi Myanmar Sein	IR10T107	115	122	5.0-5.5
		IR 10T 108 (IR68144-2B-2-2-3-1/IR 66946- 3R -78-1-1//IR77080-B-4-2-2)	116	122	4.5-5.0
		IR 10T 109 (IR 83414-5-B-9-1-12)	117	94	5.0-5.5
		IR 10T 111 (A 69-1/IR 05A117) (IR 87836-7-1-3-1-3-B)	118	113	3.5-4.0
	Shwe ASEAN	CSR 36 (CSR13/Panvel 2//IR36)	115	110	3.5-4.0
		(IR Salinas 11) 84084-B-B-1-1	116	91	5.5-6.0
		(Salinas 12) IR62700-2B-9-2-3	115	104	4.5-5.0
Submergence-prone					
	Yemyoke Khan 1	Swarna-Sub1 (Swarna*4 / IR 49830-7-1-2-2)	145	100	4.5-5.0
	Yemyoke Khan2	BR11-Sub1	145	110	5.0-6.6
	Shwe Pyi Tan	IRRI 119	140	119	5.0-6.5
	Swe Ta Soke	Shwedingar Mutant	172	148	4.0-5.0
	Hnankar	Local variety	Nov 1st week (flowering)	140	2.5-3.0



Nepal

Upland systems

Seeds grown in Community-based Seed Production (CBSP) in Nepal promise good quality

Bishu Bilas Adhikari and Bhaba P. Tripathi

Seed is the most fundamental and inexpensive input for increasing crop production. The availability of good quality seed in place, time, and adequate quantity is considered to be one of the most significant prerequisites to improve agricultural productivity in Nepal.

Lack of seeds

Farmers in the upland areas in Nepal are food-deficient primarily because of small and fragmented landholdings, a lack of irrigation sources, the absence of mechanization, and poor crop management practices. Farmers suffer from low productivity, low income, and limited economic opportunities. Such prevailing condition in the region resulted from the farmers' lack of access to seed source from both informal and formal seed systems. The seed replacement rate (SRR) has remained very low (8–10%) compared with the desirable seed replacement rate for major food crops, which is 25–30% (Basnyat, 2010).

Most small-scale farmers in unfavorable environments (rainfed lowlands and uplands) primarily retain seeds from their produce with no formal quality control, where only individual selection process and handling skills are involved. In Nepal, only about 7% of the seed requirement is provided by the formal seed sector (Khanal and Maharjan, 2010; Sapkota et al., 2011). But mostly during the "hungry" months, particularly after a period of inadequate rains, farmers tend to consume their seed stocks. As a result, the problem of food insecurity worsens because the lack of seeds means farmers farm less, which results in reduced rice production. But, if high-quality seeds are produced, it could replace excessive imports from neighboring countries—a pivotal role in attaining success in the country's agriculture production. "High-quality seeds" means these seeds are pure (meaning genetically pure or unmixed with other varieties), clean (free from weed seeds and other contaminants, free from insect, and physical damage, and disease-free), and viable (have a uniform and high germination percentage and good seedling vigor). To fulfill the prevailing gap in the country's seed sector, the government of Nepal prepared the National Seed Vision (2013-2015), which is meant to contribute to the production of a wide range of crop seeds for self-reliance and to safeguard seed exports. The principle, "seed security means food security," easily translates to a vision for development in many rice communities. Upon the implementation of the National Seed Vision (2013-2025), the government of Nepal, nongovernment organizations (NGOs), community-based organizations, the private sector, donors, and research institutions have shown a keen interest to work in synergy toward developing a reliable seed system that guarantees the availability of high-quality seeds to farmers.

The beginnings

From 2005 to 2008, the International Fund for Agriculture Development

What are CBSPs?

Community-based seed production (CBSP) programs are community-driven and community-owned efforts to conserve and use both local and improved varieties of crops for food security and to improve the livelihoods of farmers (Sthapit, 2012). These are community-led seed management programs that include production, collection, processing, storage, and marketing of improved as well as local crop varieties of crops under the leadership of a community. As a platform for communities, CBSP strengthens the key roles of the farmer seed systems, which aim to increase crop productivity, raise income, and generate employment opportunities for local people through seed self- sufficiency. In Nepal, the implementation of community seed banks began in the mid-1990s through a USC-Canada coordinated project (Bhandari et al., 2012).

With the establishment of CBSPs, quality seeds can be produced and sold to farmers at the right time, with sufficient quantity, and in a cost-effective way. CBSPs can preserve the seeds of improved and local varieties within the community. They can help increase the income of seed farmers through the sales of seeds with low production cost and can share distribution and marketing knowledge and skills with other farmers. CBSPs can help improve the economic status of rural communities, reduce poverty, and improve food security by empowering farmer organizations while supporting local governance.

In Nepal, formal and informal seed supply systems are practiced in the farming communities. The formal seed supply systems are characterized by a scientifically organized production and distribution of released or registered crop varieties by public or private organizations using quality control mechanism. CBSP programs are intended to produce foundation, certified and improved, or truthfully labeled seeds systematically.

The informal seed supply systems involve farmers producing and preserving their seeds for subsequent planting. Most of the traditional and local land varieties are produced under this system and stored in farmers' houses. Farmers may exchange a small amount of seeds with another farmer by barter system—using seeds with monetary or non-monetary value. The informal seed supply system in the community is not fixed, unpredictable, and unreliable. So, farmers have lesser chances of getting quality seeds during planting season.

CBSP is one of the most important community resources from which smallholder farmers can improve their livelihoods by assuring adequate supply of good quality seeds for farmers. CBSP has been highly valued by local people because they can buy quality seeds at a reasonable price anytime. ■

(IFAD)-funded Technical Assistant Grant 706 (IFAD TAG 706), is a rice research project led by the International Rice Research Institute (IRRI), entitled *Managing Rice Landscapes in the Marginal Uplands for Household Food Security and Environmental Sustainability*. It was launched in Nepal in collaboration with the Nepal Agriculture Research Council (NARC) and the Institute of Agriculture and Animal Science (IAAS). During the duration of the project, more than 30 improved technologies in rice and non-rice crops were validated for the mid-hills and Churia hills of Nepal.

The need for quality seeds

Participatory varietal selection (PVS) activities were conducted on upland rice and rainfed rice at Sundarbazar as a key site. Farmers preferred genotypes from PVS trials, and they even requested seeds for their next planting season. Due to the high demand of seeds, the project team realized that the establishment of community-based seed producers, also generally labeled simply as "seed producer groups" (SPGs), is the cheapest and could be a successful intervention for sustainable seed production. Thus, a seven-member seed producer group named Sundar Seed Producer Group was established in 2007 at Sundarbazar in Lamjung District. Then in 2008, the seed producer group became a cooperative and was named Sundar Seed Producer Agriculture Cooperative Limited. When the rice research team outscaled the CBSP system to neighboring district, Tanahun, another seed producer group was formed in Purkot village. It was called Purkot SPG in 2008 and was renamed as Pragati SPG in 2009.

After the completion of the IFAD-TAG 706 project in 2008, the IFAD-funded Consortium for Unfavorable Rice Environments (CURE) supported the formation of another seed producer group, Bhrikuti SPG, in 2010. It was the first SPG in Gorkha District. With the establishment of these three SPGs, more and more stakeholders became encouraged to participate as farmers' incomes started to increase, and employment opportunities were generated through self-sufficiency, import substitution, and export promotion of quality seeds. To date, a total of 15 SPGs and cooperatives have been established in Lamjung, Tanahun, Gorkha, and Bajhang districts.

Seeds grown in Community-based Seed Production (CBSP) in Nepal promise good quality

CURE supported the validation of appropriate upland agricultural technologies for the poor and marginal farmers living in the uplands to improve their food security and livelihoods. The dissemination of the improved varieties and their improved package of practices (POP) began in three adjacent districts: Lamjung, Tanahun, and Gorkha.

In 2008, another project, *Stress-Tolerant Rice for Africa and South Asia* (STRASA), funded by the Bill & Melinda Gates Foundation (BMGF), provided additional support for the partnership with IAAS. The project aimed to identify drought-tolerant improved rice varieties with good management practices that could be adopted by the farmers and to develop a seed production network. STRASA conducted its activities in Sundarbazar, Purkot, and Bhanu villages. After two years of participatory research and dissemination of validated technologies, the IFAD and STRASA projects produced positive results such as increased yield, improved food security, increased biodiversity, enhanced local secured rice seed availability, and increased farmer's income. (Table 1 shows a list of seed producer groups and cooperatives).

Expanding research activities in the uplands

In 2010, the CURE project continued under the support of IFAD. It became the third IRRI and IAAS collaborative project that spanned four years (2010-2013). Project activities included the development of the Sundarbazar village in Lamjung District as a key site for the major experiments in rainfed lowland rice, while Purkot village in Tanahun District was considered as a key research site for upland rice activities. All the project activities were conducted in collaboration with the concerned District Agriculture Development Offices (DADOs).

Through CURE, six CBSPs or SPGs (including two women SPGs), and one cooperative were established in 2010 in seven villages in Lamjung, Tanahun, and Gorkha districts. Consequently, three SPGs (Rayel SPG, Parakatane SPG, and Bhairabnath SPG) were organized in Bajhang district in Far Western Development Region of Nepal (FWDR). These were formed under the CURE-

Table 1. Community-based seed production (CBSP) groups established in western mid-hill districts of Nepal under IAAS/IRRI projects with women participation, 2006-2014.

Seed producer group (SPG)/ cooperative	Village	District	Year established	Number of members	Percentage of women	Number of executive committee members	Number of women in the executive committee (vital posts in parentheses)
1. Sundar Seed Ag. Coop. Ltd.	Sundarbazar	Lamjung	2007	42	18%	11	2(0)
2. Pragati SPG	Purkot	Tanahun	2008	60	40%	11	4(1)
3. Harrabot Women SPG	Tarkughat	Lamjung	2010	34	100%	11	11 (11)
4. Tarku SPG	Tarku	Lamjung	2010	36	22%	11	3(1)
5. Majhuwa Women SPG	Sundarbazar	Lamjung	2010	21	100%	11	11 (11)
6. Hariyali Seed Coop. Ltd.	Purkot	Tanahun	2010	25	48%	11	4(2)
7. Jaya Buddha SPG	Bhanu	Tanahun	2010	38	32%	11	3 (2)
8. Gaikhur SPG	Gaikhur	Gorkha	2010	46	48%	11	2(1)
9. Bhrikuti SPG	Palungtar	Gorkha	2010	28	21%	11	2(1)
10. Parakatane SPG	Parakatane	Bajhang	2011	15	34	11	3(3)
11. Rayel SPG	Rayel	Bajhang	2011	15	40	11	3(2)
12. Bhairabnath SPG	Bhairabnath	Bajhang	2011	15	34	11	3(2)
13. Pauwatar SPG	Gaikhur	Gorkha	2012	22	50%	11	2(1)
14. Saghan Bali SPG	Archalbot	Lamjung	2012	25	60	11	4(2)
15. Chardi SPG	Ramgha	Lamjung	2014	22	42	11	4(2)

Fig. 1. IAAS research sites in Lamjung, Tanahun, and Gorkha districts in Western Development Region and Bajhang district in Far Western Development Region of Nepal.

Technical Innovation Services (TIS) project in 2011 in collaboration with Western Upland Poverty Alleviation Project (WUPAP), a government loan project also supported by IFAD. Moreover, another seed producer group, the Sagan Bali SPG, was established in 2012, and the Chardi SPG in ChardiRamgha village, Lamjung District in 2014.

The CBSP model

SPGs are essential in raising the seed replacement rate (SRR) and productivity of major food crops in the country (Table 2 shows the steps in creating the CBSP system).

Quality of seeds produced

The recommended varieties were identified by the projects as suitable for Terai, inner Terai, and mid-hill districts of Nepal up to 1,200 meters above sea level (asl) (Table 3).

The seeds of all these varieties were obtained from the National Rice Research Program and were multiplied through SPGs and cooperatives. The adaptability of these varieties (especially Sukhadhan varieties) in high altitude was tested up to 1,600 meters asl. Results from the studies showed that the Sukhadhan series can be adopted up to 1,200 meters asl if transplanted at the right time (before June). All the remaining varieties can be grown up to 1,000 meters asl easily if planted on the second week of June. These varieties as newly verified technology can be planted up to 1,000 meters asl in the eastern and western parts of Nepal with an improved package of practices (POP).

Results of the studies showed that the quality of the seeds produced by the farmers was better in terms of pathological, physical, and physiological qualities. SPGs and cooperatives noted that due to the long duration of cloudiness in the morning and presence of dew for a long time in the plain areas (Terai and inner Terai), the seed crop during maturity and harvesting periods would tend to produce seeds with black color and fungal growth. Because of this, the germination rate of seed was low (80–85%), while the moisture content and physical impurity of seed were high, which might also be due to mechanical threshing and cleaning. The broken seed percentage was also found higher because of less sun exposure during drying. Moreover, the plain areas make use of machines for harvesting, threshing,

Table 2. Steps in organizing a Community-Based Seed Production (CBSP) system.

Process	Steps
1. Initial community preparations	After identifying a project site, a team needs to do the following: 1. Conduct a visioning exercise with the community. 2. Do a rapid rural appraisal. 3. Form a core group of farmers. 4. Assess seeds, validate technologies, and select preferred varieties through participatory varietal selection (PVS). 5. Conduct capacity development/training on good seed quality management and production.
2. Formation of CBSP	1. Trained farmers can start collecting preferred seeds. 2. Sites are selected for the seed-to-seed production. 3. Learnings on seed-to-seed production and seed health management are applied.
3. Foundation for sustained growth	1. The core group is formally organized. 2. Seed quality assurance and links to formal institutions are identified. 3. The CBSP maintains its internal seed quality control system based on a set of practical approaches that approximate the standards of the formal system.

Table 3. Some rice varieties for upland environments and their corresponding traits

Variety	Desirable traits	Undesirable traits
Sukhadhan-1	Early-maturing, high-yielding, attractive and bold grains, medium height, non-lodging, long panicles, blast-resistant, drought- tolerant, good milling recovery (63–65%), highly responsive to fertilizer, yield potential is more than 4.5 tons per hectare under good management practices, recommended for rainfed lowland and upland condition.	Coarse grain, medium taste of rice, non-aromatic
Sukhadhan-2	Highly drought-tolerant, suitable for upland and rainfed lowland conditions, medium panicle, has better yield under upland and lowland, medium height, good milling recovery (65–68%), good response to fertilizer, non-lodging, bold and attractive grains, blast-resistant, yield potential of more than 5.0 tons per hectare .	Less tillering than Ghaiya-1, coarse grain, non-aromatic, medium taste of rice
Sukhadhan-3	Early-maturing, drought-tolerant, suitable for rainfed lowland condition, medium panicle, medium height, good milling recovery (65–66%), good response to fertilizer, non-lodging, bold and attractive grains, amber-colored grains, yield potential of more than 5.0 tons per hectare .	Neck blast susceptible under shady condition, non-aromatic, medium taste
Radha-4	Highly responsive to fertilizer, non-lodging, high yielder, highly drought-tolerant, disease-resistant, high milling recovery (>65%), yield potential of 4.5–5.0 tons per hectare .	Coarse, less tasty, non-aromatic variety
Hardinath-1	Fine grains than other varieties listed, good grain yield under upland and rainfed lowland conditions, drought-tolerant, good response to a high dose of fertilizers, better to grow as spring rice and main season rice, yield potential is 4.5-5.0 tons per hectare .	Semi-dwarf variety, less straw yield than local varieties
Loktantra	Tall, early-maturing, medium fine grains, good milling recovery (68–70%), long panicles, high grain and straw yield, suitable for medium fertile soil and rainfed lowland condition, bold grains, tasteful rice, yield potential is 5.0 -5.5 tons per hectare .	Lodging problem under high fertility conditions
Makwanpur-1	High grain yield, good milling recovery (65-68%), strong and non-lodging under high fertility condition, disease-resistant, very good for rainfed lowland and irrigated lowland condition, potential yield is 5.0-5.5 tons per hectare .	Coarse grains, less tasty, medium straw yield and less palatable straw to cattle
Sabitri	Good grain and straw yield, very good for irrigated and rainfed lowland conditions up to 800 meters asl, no known susceptibility to disease , nonlodging, strong plant, has high milling recovery (65–68%), yield potential of 5.0-5.5 tons per hectare .	Medium coarse grain, less tasty, medium straw yield and less palatable of straw to cattle
Ramdhan	Fine grains, tasteful rice, early-maturing, better grain yield under rainfed conditions, palatable straw to cattle, blast-resistant, good market price, good response to high dose of fertilizers, yield potential is 5.0-5.5 tons per hectare .	Semi-dwarf variety, less straw yield, low milling recovery (58-60%),
Sunaulosugandha	Fine and long grains, aromatic rice, long panicles, better yield under irrigated conditions, medium height, good market price, non-lodging, good response to high dose of fertilizers.	Late tillering, high sterility under moisture stress condition, slightly late maturity, low milling recovery (55–58%).

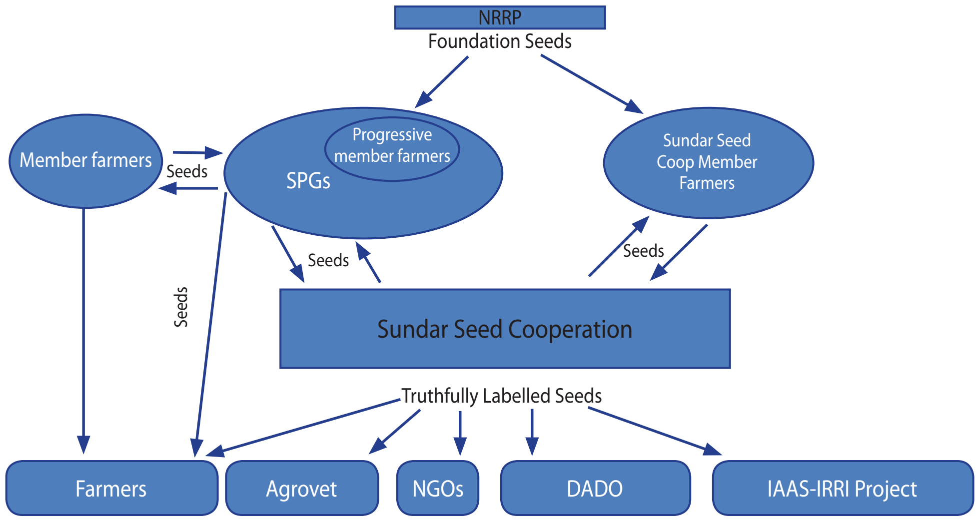


Fig. 2 The CBSP seed distribution process in Nepal.

and grading, which results in broken grains and inert matter (physical impurity is high).

In the case of seeds from the mid-hill areas, they were manually harvested, threshed, and cleaned (using a winnow). The seeds were cleaner or finer, and with high seed purity percentage. Their germination rate was also higher—more than 90% each year.

The role of seed producer groups in Nepal

CBSP programs help farmers maintain site-specific varieties; reduce the import flow of exotic seeds; increase quality seed production; increase seed replacement rate; and enhance processing, storage, and marketing mechanism of seeds. The CBSPs focus on the circulation of locally available improved varieties, which in return will improve food security and nutrition status of farm communities. Moreover, the conservation of endangered traditional varieties and local landraces is an important activity of CBSP.

Variety and site identification

Since the start of the community seed project in 2005, researchers together with the farmers have planted and tested a wide range of rice varieties. In each mother and baby trial, many varieties were closely studied and examined by both researchers and farmers. The varieties were tested under different conditions and as land types such as drought-prone, irrigated, and upland areas.

Both farmers and researchers collected data from the trials. Each participating farmer ranked the varieties

for traits he or she considers important. Traits that have been found significant to farmers in the three districts include high grain yield, high straw yield, drought tolerance, aroma of the grain, short growth duration, and good milling quality. A farmer who has to feed a large family may choose a high-yielding variety with coarse grains as these grains will take longer to digest and help a person feel full longer compared with rice with finer grain.

Results from focus group discussions (FGDs) with the SPGs and cooperatives showed that many attributes that the different varieties offer are vital for wider adoption of the new varieties introduced by the IRRI-IAAS projects. Straw yield is an important characteristic of any variety tested in all the villages. Straw is used as fodder to domestic animals during the lean period of green forages and fodders.

First phase of training of farmers on cultural management (excluding harvesting and processing)

The first series of training activities includes the following topics: introduction to source seed selection, site selection, land preparation, and nursery bed preparation; importance of SPGs in quality seed production, SPGs' responsibility, rules and regulations of seed production; transplanting, insect/pest and weed management; major insects and pests of rice, and ways of managing them; major diseases of rice and ways of managing them; major

Collection of source seed from NRRP

Seed distribution to seed producer farms

First phase of training of farmers on cultural management

plant nutrients and their role in rice seed production; cultivation practices of seasonal and off-season winter vegetable crops for rice-based vegetable farming.

Cultural management (seed-to-seed) including seed plot inspection, and processing, among others

The Sundar Cooperative and other SPGs have quality-control teams that closely supervise and inspect the seed plots of member and nonmember farmers from whom they intend to purchase seeds.

The second phase of farmers' training (before harvesting, processing, storage, and marketing)

The second phase of training was organized in September during the maturity stage of seed crop in the same villages (as the ones in the first phase). The training mainly aims to teach the farmers on quality seed production processes such as seed plot inspection, rouging, maturity judgement, harvesting, drying, threshing, storage and marketing of seeds, and complete establishment of community seed banks (CSBs).

Price determination for collection of seeds

The price of the seeds is determined separately by the Sundar Seed Coop in Lamjung District, the Pragati Seed Producer Group in Tanahun District, and the Bhrikuti SPG in Gorkha District.

Each group or cooperative has invited representatives from respective DADOs, the IRRI research team based in Lamjung campus, local NGOs/INGOs, local government entities, and when available, someone from the local Agrovet to discuss and determine the price, in consultation

Cultural management

The second phase of farmers' training

Price determination for collection of seeds

with leaders of other seed-producing farmers' groups. Based on the agreed price, farmers can earn more if they sell their seeds to the SPGs or cooperatives than in the local market.

Storage of seeds (5–6 months)

Proper seed storage is another crucial step in maintaining and guaranteeing seed quality. The Sundar Seed Cooperative and Bhrikuti SPG have started storing seeds in their storage house. Other funding sources such as the UK-based Department for International Development (DFID) of the British Government, provided support for storage facilities.

Seed groups and cooperatives have taken a piece of land from the local government body (village development committee or VDC) at their locality. To collect the seeds, group members use tractors to pick up the bags of seeds from the side of the road. A seed collection team is formed to check the seed quality of different seed growers from different villages. SPGs hire a tractor and collect the seed from different villages. Farmers collect the seed bags from their home to roadside before reaching the tractor in their village. Members or staff of SPGs or hired labor will collect the seed from the different villages and place the seed in a storage house. A farmer representative from each village comes to weigh the seeds in the storage house and lists the quantity and total price of seeds from each farmers' village. SPGs or cooperatives should have provided the price of seed within 1 or 2 weeks after seed weighing. If some SPGs have a revolving fund to

Storage of seeds

Price calculation for selling seeds

Seed selling

purchase seed, they may provide some amounts before seed collection as advance payment.

Price calculation for selling seeds

The collected seed is kept for five to six months in storage houses. About one month before planting season, price determination by major SPGs and cooperatives take place in each of the three districts (Sundar Seed Coop in Lamjung, Pragati in Tanahun, and Bhrikuti in Gorkha district). During price determination, representatives from feeder SPGs, DADOs, IRRI project, members of SPGs, local agriculture based NGOs, and Agrovets are involved. Before marketing, an SPG determines the price based on the several criteria. These include the current price of grains of respective varieties, price reference of SPGs and cooperatives of Chitwan District (whose seed price is directly influenced by competition at the local market), selling price rate of previous year, grain types (fine and coarse type), storage cost, staff salary, room rent, profit margin-among others are the criteria for the determination of price of rice seed before marketing.

Seed selling

Once the SPG has determined the price, they are ready to sell the seeds to other farmers within and in neighboring districts, to NGOs/INGOs, government institutions (DADOs), Agrovet, among others.

The project on seed production has significantly contributed to the availability of good quality seeds of new and appropriate varieties to the communities (Tables 4 and 5). Stress-tolerant varieties in Nepal have covered 1,479 hectares. A total of 27,813 farmers have benefited from these varieties directly and indirectly. Moreover, a CURE-assisted study assessed the impact of the CBSP program on rice seed security and livelihoods of the seed producer groups in Nepal. Preliminary results of the short study revealed that the seed producer organizations established in the four districts were able to serve more than 20,000 farmer households directly. The farmers were not only able to source out their seeds but were also able to improve their crop productivity from regular seed production training activities, exposure visits, and their regular meetings. Causal effects of adoption suggested yields are higher by 1.94 tons per hectare after using a combination of improved technologies. This has provided an increase in income equivalent to NRs. 45,527 per kilogram. (USD467.10). If the farmers were to adopt the technologies, this would result in at least a 1-ton yield increase. Based on FGDs with more than 30 farmers, with the use of high-quality seeds, the productivity of rice and other non-rice crops was improved by 30–50% (CURE Annual Report, 2013).

According to Mr. Chandra Prasad Pokhrel, president of Sundar Seed Cooperative, before the formation of Sundar SPG in 2007, farmers in Sundarbazar village had used only a few improved rice varieties. But after CURE introduced new varieties under IFAD-IRRI, and STRASA, about 95% rice area has been covered with improved varieties such as Sunaulo sugandha, Ramdhan, Loktantra, Sabitri, Sukhadhan-1, Sukhadhan-2, Radha-4, Sukhadhan-4, Sukhadhan-5, and Sukhadhan-6. Consequently, the rice yield in the village increased by 75–80%. Planting of drought-tolerant rice varieties such as Sukhadhan-1, Sukhadhan-2, and Sukhadhan-5 in drought-prone areas resulted in a 100% increase in yield. In 2013, Megh Raj Paudel, an undergraduate student of IAAS Lamjung campus conducted a survey in Sundarbazar to study the seed production and distribution status of Sundar Seed Cooperative Ltd., Sundarbazar. He reported that the cooperative contributed 11.9% of the total rice seed requirement in Lamjung District.

DRIVERS OF CHANGE

Support from the government. Upon realizing the shortage of high-quality seeds as a major problem, in 2003, the Government of Nepal launched a program called "District Seed Self-Sufficiency Program (DISSPRO)" in 15 districts. The program mainly aimed to strengthen the formal and informal seed multiplication systems within communities. The program covered 63 out of the 75 districts in 2011. At the district level, the program was managed by DADO, which provides technical support and coordination for the production, processing, storage, and marketing of

Table 4. Seeds produced over the eight-year period (2006-2014).

Year	Paddy seed area (ha)	Paddy seed prod. (tons)	Varieties planted (no.)	Upland rice seed area (ha)	Upland rice seed (tons)	Varieties planted	Total area (paddy +upland rice) (ha)	Total (tons produced)	Total varieties used (no)
2006	0.25	0.58	12	0.2	0.54	9	0.45	1.12	21
2007	1.0	3.50	14	0.4	0.89	9	1.4	4.39	23
2008	1.8	7.60	6	0.3	0.52	5	2.1	8.12	11
2009	4.3	20.25	6	0.8	2.10	4	5.1	22.35	10
2010	47.0	155.35	11	5.9	13.97	4	52.9	169.32	11
2011	80	320.0	9	17.0	51.0	4	97	371.0	12
2012	88.8	360.0	12	13.2	46.0	4	102	406	16
2013	61.75	251.0	9	8.0	28.5	4	69.75	279.5	13
2014	52.55	210.7	13	-	-	-	210.7	210.7	13
2015	74.0	296.0	11	-	-	-	296.0	296.0	11

*Estimated production yield (tons) based on crop cut data of respective varieties.

Table 5. Seeds collected and sold by the cooperatives and seed producer groups to farmers (2006-14).

Year	Paddy seed (tons)	Upland rice seed (tons)	Total (paddy + upland rice (tons)	Total area covered (ha)	Seed collected by leader farmers (tons)	Amount of seed kept by producers themselves (tons)
2006	0.58	0.54	1.12	22.4	-	-
2007	3.54	0.89	4.39	87.8	-	-
2008	7.67	0.52	8.12	162.4	-	-
2009	20.25	2.1	22.35	447.0	-	-
2010	94.0	10.11	104.11	2082.2	-	65.21
2011	90.6	16.1	106.7	2134	81.25	183.2
2012	108.5	16.4	124.9	2498	66.2	214.9
2013	124.5	17.5	142.0	2840	37.5	100.0
2014	129.71	-	129.7	2594	26.0	56.1
2015	134.0	-	134.0	2680	62.0	100.0

seeds. The Nepal government encourages the establishment of SPGs and seed cooperatives at the community level towards commercializing of seed production by increasing awareness of the importance of quality seeds, and by providing technical assistance in seed production, and financial incentives. Professionals working in each SPG or cooperative such as retired senior researchers and teachers, and extension workers, who are members of the Executive Committee, contributed to the success of the program.

Support from various organizations. Farmers got some support such as training, visit, seed subsidy, seed plot monitoring, and seed marketing facility from respective DADOs and the Crop Development Directorate (CDD). Seed farmers get technical and physical support through IRRI projects regularly. Seed groups and cooperatives are joined by the national seed network composed of seed enterprises, seed companies, seed processing units, seed testing laboratory, seed quality control center, seed marketing channels, among others. This has made it easy for SPGs to conduct seed activities in a sustainable way. Some seed groups and cooperatives have land obtained from the local government for construction of a building, a storage facility, and a threshing floor. Some SPGs of Lamjung and Tanahun have received grants from national NGOs, the Village Development Committee (VDC) and District Development Committee (DDC) to strengthen their financial, technical, and management capacity. For instance, upon receiving one-fourth hectare of land for building construction from the local government such as Sundarbazar Village Development Cooperative, the Sundar Seed Cooperative Ltd. Lamjung built a storehouse and office building. It received some grant from DDC Lamjung and DADO Lamjung, and a budget of NRs.3300000.00 (USD 33,000) from the Project for Agriculture Commercialization and Trade (PACT) in 2014. In 2015, the DFID project provided for a seed storehouse for Sundar Seed Cooperative, one for Chardi SPG of Lamjung and another for Pragati SPG, Purkot, Tanahun. Similarly, Bhrikuti SPG of Palungtar, Gorkha had two buildings with a budget of about NRs.30,00000 (USD 30,000) from the Irrigation Water Resource Management Project (IWRMP) of Nepal in 2013.Other SPGs and cooperatives are also trying to get financial support from NGOs/INGOs and the Nepal government. Based on the support from the local government and other NGOs, the seed programs of the SPGs seem to be sustainable.

Ability to organize themselves. A key factor to the success of the seed groups and cooperatives lies in the ability of the members to organize themselves with concrete and clear organizational structure, and the capacity to define and perform their roles in the group. Moreover, the participation of more women in these seed groups adds to the capability of the community to produce quality seeds and manage them properly.

Support from seed programs. Different types of seed programs have been launched under various institutions to improve the seed status for increasing food security through seed security. The Crop Development Directorate (CDD) under the Department of Agriculture, Central and Regional Seed Labs, Seed Quality Control Centre (SQCC), National Seed Company (NSC), local NGOs, and INGOs such as IRRI and IAAS projects through CURE and STRASA are directly involved in the seed production process.

The sustainability of the CBSPs depends on the technical and financial support not only from other organizations, NGOs in particular but also from the national government support as well.

Strong sense of ownership. A strong sense of community ownership and belongingness was another important factor of its viability. A local person authorized by the Seed Quality Control Centre (Regional Seed Laboratory) had an oversight function on maintaining the high quality of produced seed, inspecting the seed plot at least twice.

The big SPGs and cooperatives followed quality standards, produced certified seeds, and sold and marketed the seeds with certified tags. If the certified seeds are damaged in the field, the government compensates the farmers. For SPGs with small seed production with less production experience produce truthfully labeled seeds at their own risk. If their crops are damaged, these seed cooperatives and SPGs are accountable to the farmers.

Financial space

Funding source from complementary projects. The IFAD-CURE financially supported the initiative leading to the formation and operation of the CBSPs. Also, the BMGF-funded STRASA project developed and delivered rice varieties tolerant of abiotic stresses to millions of farmers in the unfavorable rice-growing environments. The varieties introduced through the CBSPs can be outscaled for widespread adoption and can be funded by STRASA and by the newly approved USAID project, entitled "*Accelerating the Adoption of Stress-Tolerant Varieties (ASTV)*" that involves smallholder farmers in Nepal. These two projects can complement the upscaling operations of the community-based SPGs through the support of the private sector in the production and dissemination of the seeds of the stress-tolerant varieties.

Political space

From community groups to national institutions working together. At present, different organizations such as the Department of Agriculture (DoA), National Seed Company (NSC), Nepal Agriculture Research Council (NARC), Community Based Seed Production (CBSP) program, Community Seed Bank (CSB), Seed Cooperatives, farmers' seed producer groups (SPG), Agrovets, seed importers, distributors, NGOs and INGOs are involved directly and indirectly in seed production and distribution in Nepal (CDD, 2011a). Seed production, collection, and selling have become a reliable source of income for the seed groups and cooperatives.

Cultural space

Women producing seeds. The CBSP was formed after years of participatory research conducted by IFAD TAG 706, STRASA, and CURE projects. Through these projects, rice seed became available through village-based farmer seed production programs that later on evolved as CBSPs. To date, there are 15 SPGs including two cooperatives in Lamjung district with two female farmer SPGs, namely, the Harrabot Women SPG of Harrabot and Majhuwa Women SPG of Sundarbazar. These two groups mentioned several reasons for forming SPGs exclusively for women, most of them were economically motivated. In 2012, the Nepal government declared that they will support women cooperatives and that female farmers were a priority. For example, women cooperatives are tax-exempted, and women farmers are given access to credit and more training programs.

The Harrabot Women SPG has produced seeds of lowland rice varieties and has been engaged in vegetable production, bee keeping, and livestock-raising. These women are also members of the Fresh Vegetable Coop established in 2005 and have benefited greatly from training activities, visits, and government financial supports. The husbands and children of the members of the Harrabot group expressed their support for the additional role of their wives and mothers as seed producers.

More importantly, the women were happy and proud of the extra income they generated from the added economic activity.

The CBSP concept uses a community-managed seed production approach that applies local knowledge and skills from the household to the community level through collective action and motivation. CBSP has become valuable precisely because its system is governed by the leadership of local people through the rules and regulations developed in the context of a community. It has facilitated building social assets by mobilizing the local community that leads to community empowerment, and has created a platform for community-based management practices. The success and sustainability of CBSPs, therefore, depend on how technical knowledge and management capacity of local champions are enhanced and how local institutions are empowered to make self-directed decision-making.

Policy space

Fundamental principles of mobilization and knowledge-sharing. The success of CBSP should start with farmers' seed systems being substantially improved by introducing scientific knowledge and practices developed by the formal seed system. There is renewed interest in the theory and practices of CBSP for strengthening farmers' seed and food security. At the outset, it is critical that a well-experienced community organizer hails from the community as its local champion who will introduce new ideas and techniques to tackle problems adequately and break down barriers. The key to the success of the CBSP in Lamjung and other communities was both experience in social mobilization and technical competencies of a community organizer.

Community drivers should work with the community in developing teams of local leaders to mobilize the social capital and bring about behavioral and social change.

Learning space

Making knowledge on technologies accessible. Dissemination of information and knowledge on technologies publication of a project completion report, fact sheets on validated technologies, and research outputs and findings, were used as teaching materials in agricultural undergraduate classes at IAAS Lamjung, Sundarbazar.

Training activities for farmers and farmer field days were also organized. These provided farmers a forum for them to discuss their problems related to agriculture production technologies and solutions. Farmers shared their ideas and experiences and assessed the best technologies for them. On the other hand, exposure visits of seed producer farmer groups to successful communities, seed companies, and research farms enabled the farmers from different areas to interact with and learn from each other. These helped strengthen the capacity and competency of SPGs involved in quality seed production and helped establish institutional linkage between seed groups and cooperatives with other GOs, NGOs and seed groups, seed companies, and national research and extension institutes. Village-based seed production and farmer-to-farmer exchange were also implemented as well as the use of dissemination trials with a verified package of practices. Besides dissemination of seeds of validated rice varieties through DADO, NGOs, and the IFAD investment project WUPAP, mini-kit packets of rice were also distributed for free. This is part of the one-kilogram mini-kit distribution activity on rice, which was carried out under the Technology Dissemination Program.

This program is a kind of farmers' participatory informal testing cum extension program. By giving free rice seeds, improved varieties reach its end-users—the farmers—and for farmers to validate these new varieties. Through the mini-kit program, farmers grow improved varieties in small parcels of land using their own practices, and then they compare the performance of the improved variety with local varieties. The mini-kit program helped in the validation and dissemination of drought-tolerant rice as well as non-drought-tolerant lowland rice varieties.

To further circulate information and increase awareness on seed selling, the project team made use of the different forms of mass media. These include local radio and television programs, banners, local newspapers, pamphlets, and posters. Fact sheets and decision-support tools published in local language were crucial in communicating the project activities and technologies to concerned stakeholders including farmers. In 2013, a total of 7,000 copies of pamphlets were published and distributed, while in 2012, 500 copies of the booklet, *Improved cultivation practices of rice*, and 1,000 copies of the leaflet entitled, *Improved cultivation practices of Sukhadhan-2: A success variety for upland* were published. Also, nine pamphlets describing improved cultivation practices of different nine recommended varieties were published in the Nepalese. These pamphlets were given to farmers and extension workers during seed distribution, training activities, and visit programs.

Concluding notes

Majority of the Nepalese farmers obtained the seeds they need through informal sources. From a small but dynamic collaboration between IAAS and DADOs in different mid-hill districts of Nepal through IRRI projects, the CBSPs spread widely among farming communities. The new technologies, which have been validated, became a popular choice especially for upland and rainfed lowland conditions. Thus, the development of new knowledge, skills, and experiences in technology validation, transformation, and adoption were useful in increasing productivity, which consequently helped raise the livelihood of poor farmers. The PVS and the establishment of CBSP have increased community participation and enabled the poor, women farmers, and the disadvantaged groups to gain new technologies and quality seeds as basic inputs for crop production. The integration of technology validation, upscaling, seed production and seed marketing became an effective and sustainable model to the farm communities in the mid-hills of Nepal.

To achieve the same or even greater success in implementing the same model, one should consider some key points. One, awareness of the technology by the local community is pivotal to gaining positive results. Establishing a CBSP can only begin once the members of a community are convinced about their roles in seed and food security. Second, establishing a regular savings fund and mobilizing for income generation is an important strategy to sustain CBSPs. Third, linkage of SPGs and cooperatives with national seed network is highly significant in the coordination among seed groups and cooperatives, and the marketing of their high-quality seeds. Fourth, women participation is key because women are more involved than male farmers in maintaining the seed quality (from roguing, uprooting of weeds, to winnowing and cleaning and storage operations). Finally, regular training activities and exposure visits are necessary for newly established CBSP groups and cooperatives in different districts.

REFERENCES

Agriculture Development Strategy. (2014). Ministry of Agricultural Development Singhdurbar, Kathmandu, Nepal.

Asian Development Bank. (2011). Economic policy network (ADB TA 7042-NEP) Final report. Infrastructure Professionals. Enterprise (P) Ltd. 2nd Floor, C-2, Green Park Extension New Delhi-110016, India.

Basnyat, B. (2010). Improving seed security through the expansion of seed multiplication farms in the public, private, and cooperative sectors in Nepal. Economic Policy Network II, MOF/ADB, Kathmandu, Nepal.

Bhandari, B., Hamal, M., Rai, J. Sapkota, D. Sangel, K. Joshi, B. K., & Shrestha, P. (2012). Proceedings of a National Workshop: Establishment and present status of Dalchoki community seed bank in Lalitpur, Nepal. In: Community Seed Banks in Nepal Past, Present, Future, 14-15 June 2012, Pokhara, Nepal.

Central Bureau of Statistics. (2003). National sample census of agriculture (Nepal, 2001-02: Highlights). National Planning Commission Secretariat, Thapathali, Kathmandu, Nepal.

Central Bureau of Statistics. (2013). National sample census of agriculture (Nepal, 2011/012: Highlights). National Planning Commission Secretariat, Thapathali, Kathmandu, Nepal.

CURE Annual Report 2013.
FAOSTAT. (2012). Crop information 2011 [Data file]. Retrieved from http://faostat.fao.org/ site/567/DesktopDefault.aspx? Page ID=567#ancor.
FAOSTAT, 2014. Crop information 2014 [Data file]. Retrieved from http://faostat.fao. org/site/567/DesktopDefault.aspx?PageID=567#ancor.
Khanal, N.P., & Maharjan, K.L. (2010). Sustainability of community-based seed production enterprises in Nepal: Institutional issues. Nepal Agric. Res. J. 10:34-41.
Ministry of Agriculture and Cooperatives. (2010). Statistical Information on Nepalese Agriculture (Annual Report). Singha Durbar, Nepal.
Nepal Economic Forum. (2015). Economic Impact of Earthquake—Agriculture [Data file]. Retrieved from http:// nepaleconomicforum.org/blog/ neftake/ detail.ph?blog_id=24#sthash.beKKWItE.dpuf.
Nepal Food Security Monitoring System. (2010). Framework Document [Data file]. Prepared by the Government of Nepal, the UN World Food Program, and the Food and Agriculture Organization Joint Mission. Retrieved from http://documents.wfp.org/stellent/ groups/public/documents/ena/wfp224722.pdf.
Paudel, M. R., Adhikari, B. B., Dhakal, C. K., & Shrestha, K. (2014). Role of Sundar Seed Cooperative for rice (Oryza sativa L.) seed supply in Lamjung: A case study at SundarbazarLamjung. Proceedings. IAAS Lamjung Campus, Lamjung, Nepal.
Sapkota, S., Regmi, P.P., Pandey, S., Tripathi, B., & Sah, SK. 2011. Prospects and constraints of formal rice seed systems in Nepal. Agron. J. Nepal. 2:157-167.
Seed Quality Control Centre. (2013). Seed balance sheet 2013 [Data file]. Retrieved from http://sqcc.gov.np/.
Sthapit, B. (2012). Emerging theory and practice: Community seed banks, seed system resilience, and food security. In: Community seed banks in Nepal: Past, present, future. Proceedings of a National Workshop, 14-15 June 2012, Pokhara, Nepal. UNDP. 2009. UNDAF Theme Group on Sustainable Livelihoods, Year-End Report 2008 (Draft), Kathmandu, Nepal.

Philippines

Submergence-prone environments
Drought-prone environments

Participatory selection of climate-ready varieties and farmers' adoption of technologies for stress-prone rice areas

Nenita V. Desamero, Daisy D. Pablero, Aurora M. Corales, Royette C. Santos

In the Philippines, rice is grown widely across the country. However, the diverse nature and wide geographical spread of the rainfed environments make it essential that research is carried out in partnership with national agricultural research and extension systems (NARES) drawing on local scientific expertise and farmers' indigenous knowledge to develop information and technologies that can tolerate stresses in rice production. These include producing improved varieties, establishing community-based seed systems or seed banks, and conducting participatory technology demonstration (PTD).

Background

Drought-prone ecosystems

Irrigated lowlands share 62.5% (1.75 million hectares) of the 2.80 million hectares of physical area for rice production in the Philippines, while 2.8% (0.08 million hectares) is occupied by the rainfed rice areas. The drought-prone rice areas are estimated to be 585,259 hectares as shown in Figure 1 (DA-AgriPinoy Program, 2012; DENR, 2016). In 2010, 30.2% (107,476 hectares) of the estimated 355,984 hectares affected by drought was totally damaged, resulting in a production loss of 507,843 metric tons, valued at PhP7,667,259,000 (USD 153,345) (BAS, 2010; PhilRice 2010).

The drought-prone rainfed lowland rice areas are associated with a number of production constraints such as biotic, abiotic, and socioeconomic factors. Scarcity in water for irrigation results in low rice yields, contributing to the high poverty incidence among farming households that are dependent on rice grown in these areas. With rice as the major staple food crop and source of income of the farming households, addressing production constraints to increase rice productivity and profitability with technologies available is vital.

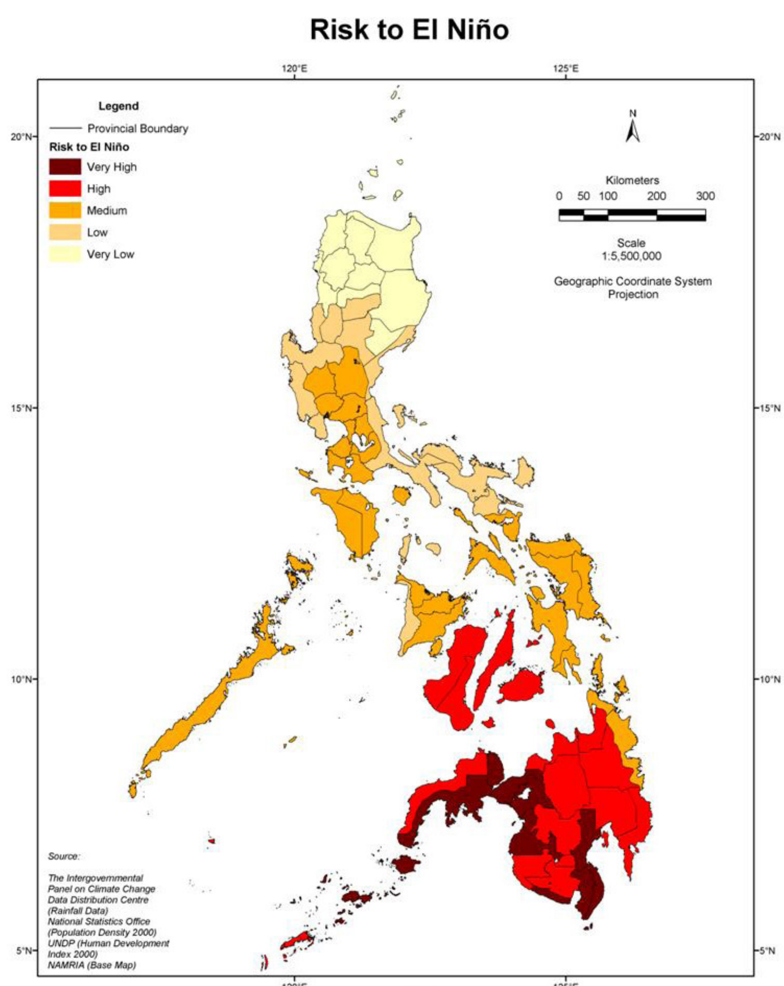


Figure 1. Drought-affected areas in the Philippines.

Variety development for water-scarce rice environment

The use of drought-tolerant rice varieties is an economical and sustainable strategy to minimize production losses attributed to scarcity in irrigation water, as well as a viable adaptation strategy to climate change. The formal variety release system in the Philippines requires the conduct of the multi-location, multi-season field performance trials of elite breeding lines of rice developed by various breeding institutions such as the International Rice Research Institute (IRRI), Philippine Rice Research Institute (PhilRice), the University of the Philippines Los Baños (UPLB), and private companies. The elite breeding lines are entered in the National Cooperative Testing (NCT) for multi-trait evaluations, implemented by the Rice Technical Working Group (RTWG) and regulated by the National Seed Industry Council (NSIC). The lines which passed the NCT standards are recommended by the RTWG to the NSIC Secretariat, which then endorses approval of its registration to the NSIC. The NSIC designates a registration number and commercial name to the elite line approved for commercial cultivation in a specific rice production ecosystem.

In 2009, NSIC approved the release of the first sahod ulan variety, NSIC Rc192.

Eleven rice varieties were approved in 2011-2013 for commercial cultivation in drought-prone rainfed lowland for dry direct seeding. An additional 13 varieties were registered for commercial release in 2015-2016. In total, there were 25 varieties with commercial names Sahod Ulan 1 to Sahod Ulan 25 available for farmers' use in drought-prone rainfed lowland rice areas (Tables 1a and 1b).

The adoption of a rice variety in farmers' fields is the measure of ultimate success in varietal development (Launio et. al, 2008). A short period between variety release and farmer adoption would often lead to rapid variety replacement in the farmers' fields, resulting in higher return to public plant breeding research (Brennan and Byerlee, 1991 as cited by Launio et al., 2008).

Prior to 2014, the activities to promote adoption of the Sahod Ulan varieties such as demonstration, deployment, and diffusion at the national and regional level were very minimal, if not lacking, resulting in end-users having a lack of or limited access to the technology. The farmers' lack of or low awareness of the Sahod Ulan varieties and non-availability or inadequate seed supply for the local farmers were, likewise, constraints and bottlenecks to the immediate adoption and diffusion of the newly released climate-ready varieties.

Demonstration and selection for adoption of new varieties

The challenges and differences of the growing conditions in the rainfed rice ecosystem, as well as the varied preferences of farmers and consumers, emphasize the importance and the need to allocate resources to develop and demonstrate new and suitable varieties for selection and subsequent adoption by the target end-users. It is crucial that varieties be developed according to the characteristics of the rice environment. Rainfed lowland farmers grow mostly varieties released for the irrigated lowlands as these are readily available (Launio et al, 2008). Farmers' lack of access and information about the seeds of new varieties add to the non-adoption of suitable varieties for the drought-prone rainfed lowland ecosystem.

PTD in relation to participatory variety selection (PVS) is a rapid and effective strategy to identify the better performing and acceptable varieties for adoption by the target end-users. This is an effective approach in creating awareness and promoting the adoption of new varieties by encouraging farmers to test the varieties themselves in their own fields. Farmers can test the crop varieties' yield and yield stability across seasons.

On the other hand, in PVS, farmers help in identifying lines which have better yield performance and stability. The detailed account of how to conduct PVS which focused on submergence-tolerant rice variety was described by Paris et al. (2011). Meanwhile, the potential impact of PVS in enhancing breeding programs to develop appropriate varieties for increased production in the marginalized rainfed rice areas was reported by Manzanilla et al. (2011).

The described PVS protocols were adopted with some modifications for the Sahod Ulan varieties released for

Table 1a. Rainfed Lowland-Dry Seeded Released Varieties, 2009-2016: Agronomic traits. (National Cooperative Testing/National Seed Industry Council)

NSIC Registry name	Commercial name	Year approved	Breeding institution	Yield (t ha^{-1})		Maturity DAS	Plant Height (cm)	Productive tiller per linear meter no.
				Ave	Max			
NSIC Rc192	Sahod Ulan 1	2009	IRRI	3.7	5.5	106	109	91
NSIC 2011 Rc272	Sahod Ulan 2	2011	PhilRice	3.0	6.4	110	88	94
NSIC 2011 Rc274	Sahod Ulan 3	2011	IRRI	3.0	6.7	116	92	69
NSIC 2011 Rc276	Sahod Ulan 4	2011	UPLB	2.6	5.5	119	100	81
NSIC 2011 Rc278	Sahod Ulan 5	2011	IRRI	2.4	5.3	110	122	86
NSIC 2011 Rc280	Sahod Ulan 6	2011	IRRI	2.5	5.6	123	104	81
NSIC 2011 Rc282	Sahod Ulan 7	2011	UPLB	2.9	6.4	120	115	68
NSIC 2011 Rc284	Sahod Ulan 8	2011	IRRI	3.7	5.7	114	98	91
NSIC 2011 Rc286	Sahod Ulan 9	2011	UPLB	3.5	5.0	115	94	97
NSIC 2011 Rc288	Sahod Ulan 10	2011	PhilRice	3.6	6.6	118	127	60
NSIC 2013 Rc346	Sahod Ulan 11	2013	PhilRice	3.3	6.2	105	97	111
NSIC 2013 Rc348	Sahod Ulan 12	2013	IRRI	3.0	5.0	103	119	74
NSIC 2015 Rc416	Sahod Ulan 13	2015	PhilRice	3.4	5.0	116	87	110
NSIC 2015 Rc418	Sahod Ulan 14	2015	UPLB	3.8	5.7	113	101	99
NSIC 2015 Rc420	Sahod Ulan 15	2015	IRRI	3.7	6.0	108	104	107
NSIC 2015 Rc422	Sahod Ulan 16	2015	PhilRice	3.4	5.3	112	89	104
NSIC 2015 Rc424	Sahod Ulan 17	2015	PhilRice	3.6	5.4	110	94	85
NSIC 2015 Rc426	Sahod Ulan 18	2015	PhilRice	3.7	5.8	110	94	107
NSIC 2015 Rc428	Sahod Ulan 19	2015	IRRI	3.5	4.9	107	97	84
NSIC 2015 Rc430	Sahod Ulan 20	2015	PhilRice	3.5	5.4	111	92	101
NSIC 2015 Rc434	Sahod Ulan 21	2016	IRRI	3.4	4.6	105	94	108
NSIC 2015 Rc472	Sahod Ulan 22	2016	PhilRice	3.3	4.3	117	86	88
NSIC 2015 Rc474	Sahod Ulan 23	2016	IRRI	3.2	4.5	116	89	92
NSIC 2015 Rc476	Sahod Ulan 24	2016	UPLB	3.6	4.7	113	93	93
NSIC 2015 Rc478	Sahod Ulan 25	2016	IRRI	3.8	5.8	113	97	100

the drought-prone rainfed lowland rice ecosystem. The approach requires the active participation of the rice industry stakeholders, namely, the researchers, extension workers, local government officials, farmers, seed growers, consumers, and traders in various activities for validation, adaptation, development, and promotion of the varieties in the target rice-growing areas.

Implementing PTD and PVS

PhilRice and IRRI in partnership with the local government units (LGUs) implemented an International Fund for Agricultural Development (IFAD)-funded collaborative project titled, "Improving livelihoods and overcoming poverty in the drought-prone lowlands of Southeast Asia," from 2011 to 2014. Increasing farm productivity and farmers' income through adoption of improved varieties for the drought-prone rainfed lowland was a main objective of the project. To fast-track the adoption of the Sahod Ulan varieties, the farmer clienteles and LGUs were strategically involved as active partners in the conduct of the on-farm PTD, followed by PVS.

The farmer-partners allotted a portion of their fields to grow the crop and serve as a demonstration area, while agricultural extension workers from the LGUs assisted in monitoring the trials. PhilRice and IRRI provided the seeds of the varieties tested, the necessary inputs and technical expertise, and were responsible in establishing the trials and collecting data. Varieties that were most suitable, acceptable, and preferred by the farmers in the trial sites were identified and selected for subsequent dissemination and promotion in specific locations or growing areas.

Table 1 b. Rainfed Lowland-Dry Seeded Released Varieties, 2009-2016: Grain quality traits. (National Cooperative Testing/National Seed Industry Council)

Variety	Physico-chemical Characteristic			Milling Potential				Physical Attribute			Acceptability	
	% Amylose	% Protein	G.T. Score	% Brown Rice	% Milling Recovery	% Head Rice	% Chalky Grains	% Immature Grains	Grain Length (Size)	Grain Shape	Cooked	Raw
Sahod Ulan 1	23.5 I	6.6	6.5 I/L	78.0 F	70.1 Pr	44.1 G2	13.9 G3	0.1 Pr	6.2 M	2.6 1	-	-
Sahod Ulan 2	25.0 I	7.3	6.7 L/I/HI	75.6 F	66.6 G1	32.3 G1	7.8 G2	2.9 G1	6.0 M	2.4 I	43.3	80.0
Sahod Ulan 3	18.7 L	7.4	4.4 I/L	76.2 F	67.5 G1	35.8 G3	5.2 G2	1.5 Pr	7.3 L	3.2 S	86.7	86.7
Sahod Ulan 4	26.0 H	5.7	4.6 I	78.0 F	69.0 G1	53.9 G1	16.3 aa	3.0 G1	7.2 L	3.2 S	73.3	86.7
Sahod Ulan 5	20.4 I	7.1	6.9 L/I	76.5 F	68.5 G1	40.0 G2	7.3 G2	2.6 G1	6.8 L	2.9 I	76.7	93.3
Sahod Ulan 6	22.3 I	7.5	6.9 L/I	75.7 F	65.4 G1	38.3 G3	8.0 G2	5.1 G1	7.6 EL	3.9 S	96.7	86.7
Sahod Ulan 7	27.2 H	5.8	4.9 I	77.4 F	69.3 G1	53.8 G1	11.3 G3	1.9 Pr	7.0 L	3.2 S	63.3	86.7
Sahod Ulan 8	22.2 I	6.4	5.0 I/L	77.9 F	68.2 G1	41.2 G2	7.2 G2	0.1 Pr	7.6 EL	3.5 S	78.4	80.0
Sahod Ulan 9	26.9 H	6.0	5.1 I/L	79.5 F	70.9 Pr	48.9 G1	18.7 aa	0.0 Pr	7.3 L	3.1 S	70.0	98.3
Sahod Ulan 10	19.7 L	8.3	6.9 L	77.7 F	69.7 G1	56.9 G1	7.8 G2	0.4 Pr	5.7 M	2.4 I	-	-
Sahod Ulan 11	21.5 I	8.7	3.5 HI/I	77.0 F	68.6 G1	44.3 G2	8.2 G2	2.6 G1	6.8 L	3.2 S	78.3	79.8
Sahod Ulan 12	22.1 I	8.2	6.7 L	76.7 F	68.4 G1	44.7 G2	43.6 aa	5.9 G2	7.3 L	3.0 I	83.3	85.3
Sahod Ulan 13	19.5 I	7.8	4.0 L/I	78.7 F	71.2 Pr	48.2 G2	38.5 aa	0.2 Pr	6.3 M	2.8 I	83.3	60.0
Sahod Ulan 14	21.1 I	-	3.5 HI	77.0 F	70.0 G1	51.0 G1	12.3 G3	6.0 G2	7.2 L	3.4 S	85.0	85.0
Sahod Ulan 15	21.0 I	-	5.5 L/I	77.5 F	69.1 G1	49.6 G1	11.3 G3	5.3 G2	7.3 L	3.4 S	83.0	78.3
Sahod Ulan 16	19.9 I	-	3.1 HI	78.2 F	70.5 Pr	57.4 Pr	4.0 G1	6.8 G2	6.8 L	3.3 S	96.7	86.7
Sahod Ulan 17	20.8 I	-	3.5 HI/I	78.1 F	71.4 Pr	57.4 Pr	9.2 G2	6.2 G2	6.7 L	3.0 S	88.2	85.0
Sahod Ulan 18	19.1 I	-	3.5 HI/I	78.2 F	71.0 Pr	42.3 G2	9.7 G2	5.6 G2	7.0 L	3.1 S	81.7	85.0
Sahod Ulan 19	18.9 I	-	3.3 HI/I	76.8F	69.9 G1	50.8 G1	9.6 G2	9.2 G2	6.9 L	3.1 S	85.0	66.7
Sahod Ulan 20	19.0 I	-	3.6 HI/I	77.9 F	70.5 Pr	58.7 Pr	8.6 G2	7.2 G2	6.7 L	3.1 S	90.0	86.7
Sahod Ulan 21	19.4 I	-	4.3 HI/I	78.2 F	70.7 Pr	48.1 G1	13.9 G3	5.7 G2	7.2 L	3.3 S	83.3	76.7
Sahod Ulan 22	22.1 H	8.2	6.9 L	79.9 F	74.5 Pr	59.6 Pr	22.8 aa	5.6 G2	5.9 M	2.6 I	51.7	75.0
Sahod Ulan 23	2.4 VL	7.9	6.0 L	77.2 F	69.8 Pr	54.6 G1	5.3 G2	4.9 G1	6.1 M	2.9 I	90.0	90.0
Sahod Ulan 24	19.1 I	6.6	3.4 HI	79.1 I	72.3 Pr	50.1 G1	26.7 aa	8.3 G2	6.6 L	3.0 I	81.7	51.7
Sahod Ulan 25	20.1 I	-	6.4 L	78.4 F	71.1 Pr	49.8 G1	9.6 G2	4.1 G1	7.3 L	3.5 S	76.7	91.7

In 2011 to 2014, 11 PTD and PVS trials were established in six pilot sites (Tarlac, Pangasinan, Nueva Ecija, Zambales, Cagayan, Ilocos Norte).The drought-tolerant varieties Sahod Ulan 1 to 12 were evaluated for adaptation, acceptability, and preference on the basis of agro-morphological traits. Participants of the participatory sensory evaluation selected their preferred varieties based on eating quality. Sahod Ulan 4 and 7 were identified as stable, high-yielding varieties across trial sites, while Sahod Ulan 6 and 10 were identified as varieties of high-eating quality with superior acceptability by farmers over the local varieties. Moreover, varieties most adaptive in specific pilot sites (location-specific adaptation) were identified. The short-duration varieties maturing in 110 or less days from sowing were Sahod Ulan 1 (106 days), 2 (110 days), 5 (110 days), 11 (105 days), and 12 (103 days). These were the best candidates to escape drought occurring at the late reproductive stage of the crop (terminal drought).

PTD impact on Sahod Ulan 7 adoption and diffusion

The very first PTD trial conducted during the 2011 wet season at a farm in Nilasin 1st, Pura, Tarlac, identified Sahod Ulan 7 (NSIC 2011 Rc282) as the most preferred variety in the locality. This variety yielded the highest in both weeded (3.98 tons per hectare) and unweeded (3.32 tons per hectare) trials, producing more than the farmer's variety by 0.52 ton per hectare

(13%) under weeded and by 1.153 tons per hectare (35%) under unweeded condition. The adoption of Sahod Ulan 7 after the conduct of PTD-PVS in the 2011 wet season started with 1.5 kilograms of basic seeds provided to the agricultural technician, and planted by an early farmer innovator on 500 square meters of land in Sta. Barbara, Victoria, Tarlac, for good seed production in the 2012 dry season (Table 2). By end of the fifth cropping season in the 2014 wet season, the variety was grown in 7.4 hectares (148 times larger than the initial area of production), producing 800 kilograms of good seeds, equivalent to 533 times more than the starting amount. The farmer-to-farmer diffusion (Figure 2) of the most preferred variety Sahod Ulan 7 was tracked for five cropping seasons from 2012 to 2014 through interviews in partnership and with assistance from the LGUs. Sahod Ulan was diffused in four barangays with farmer adopters producing good seeds, which were either shared with relatives or sold to other farmers. A total of 18 farmer-adopters grew Sahod Ulan 7 for 1 to 3 seasons.

Variety diffusion in the drought-prone rainfed lowlands is constrained by seed availability and access to the technology. As an offshoot of the PTD-PVS, local demand for the seeds of the preferred variety was created. With this opportunity, a local seed grower was motivated to produce high-quality seeds of the preferred variety in the locality. Usually, when rainfed lowland farmers are

Table 2. Sahod Ulan 7 good seed production, adoption, and diffusion immediately after the conduct of the first PTD-PVS in 2011 wet season in Victoria, Tarlac, Philippines, 2012 dry season to 2014 wet season.

Particular		2012 DS	2012WS	2013DS	2013WS	2014WS
Amount of seeds (kg)		1.5	372.5	220	640	800
Area planted (ha)		0.05	4.96	2.80	6.33	7.40
Seed yield, fresh weight (ton/area planted)		0.38	26.09	17.41	32.72	33.65
Seed yield, fresh weight (tha^{-1})		6.89	4.59	5.71	4.51	3.97
No. of farmer-adopters		1	4	3	6	8
Location of farm:	Sta. Barbara	1	4	2	5	7
	Balayang			1		
	Sta. Cruz				1	
	San Gavino					1

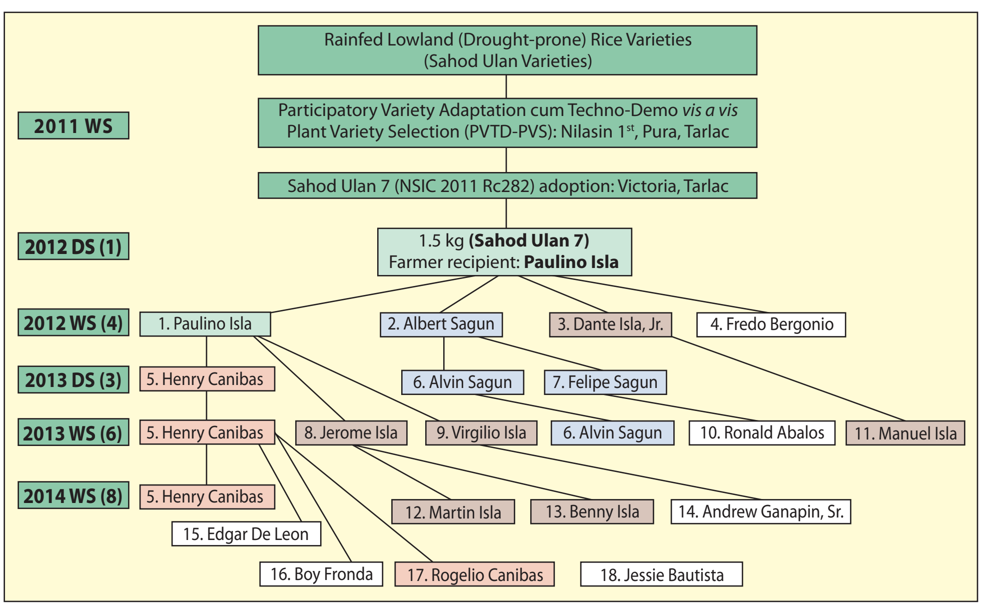


Figure 2. Farmer-to-farmer diffusion of Sahod Ulan 7 rice variety for five growing seasons (2012-2014), triggered by PTD-PVS conducted in 2011 wet season at Pura, Tarlac. (Note: Values in parenthesis denote number of farmer adopters).

asked if they have grown or are willing to grow the Sahod Ulan varieties, their usual response is either they have not heard of the varieties or there are no seeds available in the market. On the other hand, if a seed grower is asked whether they produce or are willing to produce seeds of varieties for rainfed areas, his usual response is "it is not profitable to venture in those varieties as there is no demand for the seeds." With PTD-PVS out- and upscaled, the cycle of "no seeds available-no seed demand" will eventually be broken, resulting in the use, adoption, and diffusion of varieties developed for drought-prone rainfed areas. Similar scenarios are common and seen in other stress-prone rice environments such as the saline- and submergence-prone areas.

The CURE2 Project started the adaptability testing and adoption of drought-tolerant rice varieties in partnership with LGUs in Tarlac and Pangasinan with only four farmer cooperators—three in Tarlac and one in Pangasinan. They were given seeds of 2–10 kilograms each due to limited availability of seeds. In view of the lack of seeds and seed growers as well, the project supported the training of four farmers so that they will become accredited seed growers who can provide assistance in the seed production of Sahod Ulan varieties.

In the 2015 wet season, a farmers' field day and forum was held to showcase the drought-tolerant varieties Sahod Ulan 1, 4, 6, 7,10 (Fig. 3). Fifty farmers evaluated the varieties, and the Sahod Ulan 7 emerged as the most preferred. Sahod Ulan 7, according to the farmer-evaluators, had more tillers, long panicles, and less grain shattering, and showed tolerance to drought.

Starting in the 2016 wet season, dissemination, validation, and testing were intensified in Region 3 (Tarlac and Nueva Ecija), then introduced as well in Region 1 (Pangasinan, La Union, Ilocos Sur, and Ilocos Norte) to increase

Figure 3. Activities conducted: (a) Farmers' Field day and Forum (b) Mini-kits distribution (c) Techno-demo field in Tarlac (d) Farmer's presentation of final data.

the area planted to drought-tolerant varieties (Fig. 4). Variety adaptation was focused on four varieties, namely Sahod Ulan 6,7,11, and 12 because these were proven to be popular among farmers in the project sites. Mini-kits were prepared for testing in Regions 1 and 3. More than 180 farmers and farmer-groups have benefitted from the seed distribution scheme through "Lakbay Binhi" or seed caravan (Fig. 3).

Consistent with the results of the 2015 wet season farmers' evaluation in Tarlac, Sahod Ulan 7 also emerged as the most preferred variety in Region 1. Meanwhile, Sahod Ulan 11 and 12 were the most preferred varieties in Ilocos Sur and Ilocos Norte because of their early maturity.

In the 2016 dry season expansion, 3860 kilograms of seeds were distributed to 182 farmers in Regions 1 and 3 covering 6 provinces for testing cum seed multiplication in the Farmer Field School sites with a total planted area of about 58 hectares (Table 3).

In terms of overall yield performance, Sahod Ulan 7 obtained the highest average yield of 4.99 tons per hectare and 4.83 tons per hectare in both Regions 1 and 3, respectively, while Sahod Ulan 11, which is an early-maturing variety, had lower average yields of 4.77 tons per hectare in Region 1 and 3.73 tons per hectare in Region 3. Sahod Ulan 12 followed with average yields of 4.73 tons per hectare and 2.90 tons per hectare in Regions 1 and 3, respectively. Lastly, Sahod Ulan 6, known for its good eating quality, obtained the lowest average yields of 4.66 tons per hectare in Region 1 and 3.36 tons per hectare in Region 3 (Fig. 5).

Scaling-up PTD-PVS

PTD-PVS Components. The PTD-PVS strategy is a 3-in-1 approach where an on-farm trial addresses (1) evaluation of the

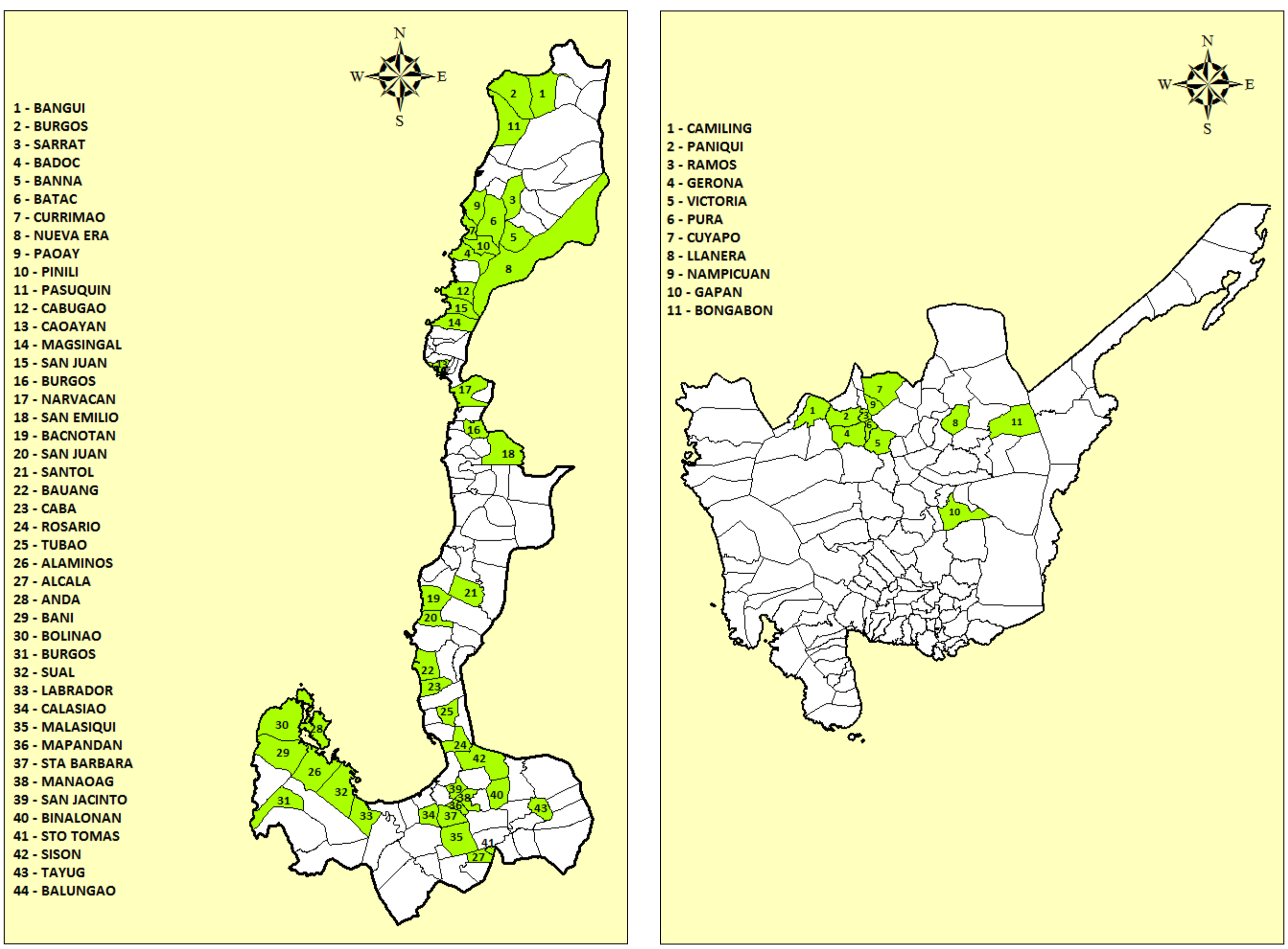


Figure 4. Map of CURE2 project sites in Regions 1 and 3.

Table 3. Areas of implementation in 2015-2016 indicating the number of farmer-cooperators, seeds distributed, and area planted.

Location	Number of farmer-cooperators, amount of seeds distributed, and area planted											
	WS 2015				DS 2016				WS 2016			
	M	F	kg	ha	M	F	kg	ha	M	F	kg	ha
1. Pangasinan	1	-	34	1.16	2	-	50	1	29	9	460	9
2. Nueva Ecija	-	-	142		12	-	552	2.2	63	8	300	19.5
3. Tarlac	2	1	-	2.70	11	2	208	8	13	2	2420	4.5
4. La Union	-	-	-		-	-	-		7	9	260	4
5. Ilocos Sur	-	-	-		-	-	-		13	1	140	4
6. Ilocos Norte	-	-	-		-	-	-		20	8	280	16
Total	3	1	176	3.86	25	2	810	11	145	37	3860	58

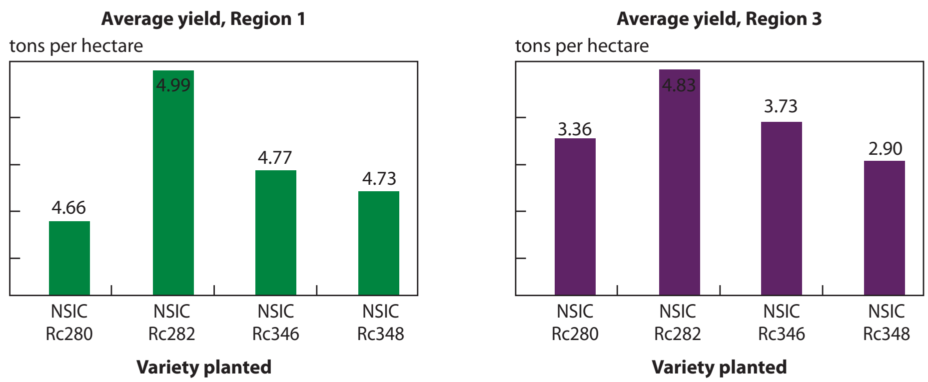


Figure 5. Regional yield performance of Sahod Ulan varieties in Regions 1 and 3.

comparative variety yield performance, (2) technology demonstration for client/stakeholders' awareness and (3) site-specific preferred variety selection. The implementation of PTD-PVS is a two-step process, starting with the researcher-managed on-farm (mother trial) trial. It includes evaluating 10–20 varieties for field performance, engaging active partnership with the farmers, LGUs, other potential partner-stakeholders in identifying and selecting the most acceptable and preferred varieties. This is followed by the farmer-managed evaluation of one to three identified most preferred varieties in a specific location.

With the researcher-managed PTD-PVS, the trial may be replicated to facilitate data collection and analysis for a scientifically sound interpretation of results and drawing of conclusions. The best replicate may serve as the demonstration area where the farm walk is conducted for participatory evaluation and identification of the acceptable, and the most and least preferred varieties by participating farmers, seed growers, extension workers and researchers, among others. An open forum or discussion follows immediately after the farm walk with the presentation of the ranking of the varieties as to the farmers' acceptability and preference. The farmers' impressions of the varieties and selection criteria are discussed.

As for grain quality consideration, a participatory sensory evaluation of the raw and cooked rice is conducted with farmers, housewives, seed growers and preferably with traders and millers as participants. The PVS (Paris et al., 2011) or the NCT (PhilRice, 1997) on-site sensory evaluation protocol for grain quality may be adopted. Women participation in PTD-PVS is underscored.

The strategy of PTD-PVS was successfully adopted in the identification of top varieties for each province. In support of the Next-Gen project under the National Rice Program of the DA Food Staples Sufficiency Program (FSSP), the conduct of the researcher-managed PTD-

PVS is implemented by public breeding institutions such as IRRI, PhilRice, and UPLB in partnership with the DA-RFOs, while the DA-RFOs with farmer partners lead the conduct of the farmer-managed PTD-PVS (baby trial), evaluating the identified 2–3 preferred varieties in a pilot site. High-quality seed (foundation seed, registered seed, or certified seed) are used in the PTD-PVS, so the seed growers and farmer- beneficiaries have quick access to quality seeds of varieties suitable and most- preferred in their areas, which are harvested from the farmer-managed PTD-PVS. The NSQCS is engaged in the activity to address the seed quality regulation concerns. The farmers can also acquire quality seeds through the regional seed coordinators.

As part of the "Agri-Pinoy Rice Seed Component Activities in Support to Next-Gen Project, BPI spearheads and coordinates the PTD-PVS cum seed production conducted by the partner seed growers all over the country and some DA-Research Outreach Stations (ROS). In 2015, from 9 July to 30 August, 115 seed growers from 16 regions, , with an average of 7 seed growers per region, 9 ROS, and 1 institution conducted the PTD-PVS with an average of 6 new rice varieties as entries, per region, in an accumulated area of 117.5 hectares (Palizada et al., 2015b). This activity provides information on the top five performing varieties within a province, which will be the focus of high quality seed production program in the country. The preferred varieties for adverse or stress-prone environments were identified through these PTD-PVS activities.

Partners enhance knowledge and skills on rice science and technology

Capacity building using the Farmers Field School approach

Provision of training and technology updating proved to be effective in increasing farmers' knowledge and awareness to modern technologies and innovations (Taylor, 1998). From the 2016 wet season, a total of 49 season-long Farmers Field Schools *(FFS)* on the PalayCheck system were conducted by 49 local farmer technicians (LFTs) with emphasis on drought-tolerant varieties (Sahod Ulan 6, 7, 11, and 12) and the PalayCheck system. PalayCheck is a dynamic rice crop management system that presents the best key technology and management practices as Key Checks; compares farmer practices with the best practices; and learns through farmers' discussion group to sustain improvement in productivity, profitability, and environment safety (PhilRice, 2009). Intensive promotion of the PalayCheck system is being done to enhance its acceptance because DA believed that farmers will greatly benefit in using this approach (Corales et al., 2014)

In the FFS on PalayCheck, demonstration cum learning fields for variety promotion were used for seed multiplication of drought-tolerant varieties in Region 1. Every FFS site has 25–35 farmer-participants (Fig. 6). The 16-week FFS achieved more than 1,000 participating farmers through the combined efforts of LGU partners, DA-RFO1, LFTs, rice program coordinators in Region 1 and the CURE team at PhilRice. Furthermore, a Rice Science and Technology update was conducted in the 2016 dry season for 52 farmer-leaders and agricultural extension workers in Nueva Ecija. The activity aimed to provide awareness among participants on newly-released, drought-tolerant varieties and to open new partnerships for project expansion in Region 3.

Moreover, four S&T updates were conducted focusing on dry direct-seeding technology and disease diagnosis for 116 LFTs and LGU partners in Pangasinan, Ilocos Sur, Ilocos Norte, and La Union to further enhance their knowledge about insect pest identification and rice disease diagnosis.

Rice varieties for salinity-prone ecosystems

Apart from having areas that are prone to water scarcity, the Philippines also has salt-prone areas due to its narrow and extensive coastal lowlands. Its low-lying coastal areas are also predicted to be affected by rising sea water level. The total rice area affected by salinity in the country is estimated at 27.06 thousand hectares.

Figure 6. Activities conducted: (a) Farmers' field day and forum cum PVS (b) Varietal testing in farmers field(c) Lakbay Binhi (d) Farmers Field School (e) Review and assessment (f) Technology updating.

From 2009 to 2013, the Philippines released 18 salt-tolerant varieties (Table 4). An on-farm technology demonstration of salt-tolerant rice varieties was showcased, and on-station quality seeds for commercialization were produced. The on-farm technology demonstration of salt-tolerant rice varieties (2011-2012) showed grain yields ranging from 3 to 4.14 tons per hectare in four municipalities across nine sites (Table 5).

Seven salt-tolerant varieties were further released in the Philippines from 2013 to 2014 (Table 4). Seed multiplication of new varieties was carried out in 2014 at IRRI to support the local demand and supply the seed requests of all partners and the requirement of the IRRI project in the Philippines. In 2014-2015, 50 new elite lines developed for inland salinity and coastal salinity were distributed to CURE partners. The "two-in-one" varieties that combine salt- and submergence- tolerance were included as an ideal strategy to help farmers' adaptation to coastal salinity (Table 6).

Since 2013, CURE and its Philippine partners have multiplied and distributed 1,661 kilograms of seed of salt-tolerant varieties.

Community-based seed system (CBSS) and other platforms for seed dissemination

Farmer-owned saved seeds, both for modern and traditional varieties, played a significant role in rice production in the past 7 years (2009-2015), contributing 55% of the reported rice seed utilization. Furthermore, it will still substantially contribute to enhance rice production in the next 3 years with its projected 17% average utilization in more than 2 million hectares of harvest area (Palizada et al., 2015b).

Table 4. Salt-tolerant varieties released from 2009 to 2013.

No. of varieties released	Name of varieties	Year released
18	NSIC 2013 Rc324 (Salinas 10)	2013
	NSIC 2013 Rc326 (Salinas 11)	2013
	NSIC 2013 Rc328 (Salinas 12)	2013
	NSIC 2013 Rc330 (Salinas 13)	2013
	NSIC 2013 Rc332 (Salinas 14)	2013
	NSIC 2013 Rc334 (Salinas 15)	2013
	NSIC 2013 Rc336 (Salinas 16)	2013
	NSIC 2013 Rc338 (Salinas 17)	2013
	NSIC 2013 Rc340 (Salinas 18)	2013
	NSIC Rc290 (Salinas 6)	2011
	NSIC Rc292 (Salinas 7)	2011
	NSIC Rc294 (Salinas 8)	2011
	NSIC Rc296 (Salinas 9)	2011
	NSIC Rc182 (Salinas 1)	2009
	NSIC Rc184 (Salinas 2)	2009
	NSIC Rc186 (Salinas 3)	2009
	NSIC Rc188 (Salinas 4)	2009
	NSIC Rc190 (Salinas 5)	2009

Table 5. Grain yield of saline-tolerant varieties in the techno demo in Cagayan, Philippines, 2011-2012.

Cropping season	Municipality	No. of site	Variety	Grain yield ($t\ ha^{-1}$)
2011 WS	Buguey	1	NSIC Rc184 (Salinas 2)	3.00
	Sta. Teresita	1	NSIC Rc184 (Salinas 2)	3.50
2012 DS	Sta. Teresita	1	NSIC Rc184 (Salinas 2)	3.60
	Aparri	1	NSIC Rc184 (Salinas 2)	3.30
2012 WS	Buguey	1	NSIC Rc182 (Salinas 1)	3.67
		1	NSIC Rc184 (Salinas 2)	4.14
		1	NSIC Rc186 (Salinas 3)	3.85
		1	NSIC Rc188 (Salinas 4)	3.55
		1	NSIC Rc190 (Salinas 5)	4.06

Table 6. Seeds produced and distributed to NARES partners, local farmers, state universities, and local government units in the Philippines and other countries.

IR Designation	Official NSIC Registry Number	Vol. of Seeds Produced in 2014 (kg)	Seed Class
IR84048-B-B-1-1	NSIC 2013 Rc326	295	Foundation
IR62700-2B-9-2-3	NSIC 2013 Rc328	200	Nucleus Breeder Seeds
IR83410-6-B-4-1-1-2	NSIC 2013 Rc334	285	Nucleus Breeder Seeds
IR84095-AJY3-8-SD01-B	NSIC 2013 Rc336	340	Nucleus Breeder Seeds
IR84096-AJY4-2-SD04-B	NSIC 2013 Rc340	445	Nucleus Breeder Seeds
IR83140-B-28-B	NSIC 2014 Rc 390	205	Nucleus Breeder Seeds
IR84675-58-4-1-B-B	NSIC 2014 Rc 392	11	Nucleus Breeder Seeds

Community seed banks were instrumental in distributing new tolerant varieties to farmers. The Arakan Community Seed Bank Organization (ACSBO) through the initiative of the LGU Arakan's Office of the Municipal Agriculture forged linkages with Don Bosco, an NGO that has established market outlets in Cotabato and in Manila for organically produced traditional rice varieties by Arakan farmers. These traditional varieties include Dinorado, black rice, and red rice. On their own, the ACSBO members marketed their seeds to farmers in neighboring municipalities.

The concept of the community-based seed systems (CBSS) project of the DA, is somehow influenced by and modified from the community seed bank (CSB) model for the upland rice in Arakan Valley, North Cotabato, developed under CURE through the leadership of Drs. Edwin and Rosafe Honrade of the University of Southern Mindanao (Manzanilla et al., 2014). In the DA Upland Rice Development Program, the CBSS is used to ensure availability of and farmers' access to adequate quality seeds of traditional and modern varieties suited and preferred in the area at any time needed. Keeping quality seeds of preferred varieties and buffer stocking in the CBSS, ensures seed security in case of natural calamities and other factors.

One of the interventions of the proposed Rice Seed System Road Map (2016-2022) to enhance and sustain high-quality seed utilization is to strengthen the implementation of the CSB program in the rainfed and upland ecosystems (Palizada et al., 2015a). The road map targets 13% and 12% share for the CSB-produced and farmers' seeds, respectively, to the estimated 5.2 million hectares to be planted with high-quality seed by 2022. The government targets to provide sufficient funds for the implementation of the activities under the program.

DA-RFO 3 procured seeds from the 2008 dry season produce of the farmer-partners in San Antonio, Nueva Ecija, and multiplied the seeds of IR64-Sub1 and PSB Rc68 (drought- and submergence-tolerant varieties released in 1997) in the 2009 dry season in at least 50 hectares, in support of the GMA Program.

DRIVERS OF CHANGE

With CBSS and PTD-PVS in place and routinely done as part of the technology dissemination and extension activity of the DA for new rice varieties, its mission, as stated in the Philippine Rice Seed System Road Map, of "supporting effectively the objective of increasing the utilization of high-quality seeds by delivering adequate quantity of appropriate and preferred varieties at all times and any place," is deemed achievable. At least a certain portion of the target high-quality seed production will be contributed by the program utilizing the CBSS and PTD-PVS strategies.

With the removal of seed subsidy, utilization of commercial seeds dropped. Some seed growers turned into commercial palay growers, resulting in less high quality seed production. Other seed growers opted to grow good seeds without passing through the process of seed certification, and market their produce directly to the farmers. The CBSS and PTD-PVS under the DA Seed System for Rice Program are somehow regulated, ensuring the production of quality seeds of suitable and preferred varieties, which are made available and accessible for consumption by the target end-users.

Location-specific seed multiplication and utilization of seeds, as targeted, warrant identification of varieties best suited in the target areas. The conduct of PVS provides implementers with a strong basis of prioritizing the most suitable and preferred varieties in a particular area, resulting in enhanced and sustained technology adoption.

The use and promotion of high-quality seeds of varieties for stress-prone environments has gained laudable attention in response to the need for adapting to climate change-related scenarios and its potential contribution in achieving sufficiency in rice.

As the seed industry development act of 1992 (RA 7308) considers the seed industry as a preferred area of investments, the enhanced high-quality seed usage is deemed a profitable investment for the government to increase rice production in the country and achieve sufficiency in rice. BPI, in its rice seed system road map, proposed an average annual budgetary requirement of 11.2 billion pesos for the next seven years, from 2016 to 2022, to produce hybrid and inbred high quality seeds from an average of 3.5 million hectares annually (Palizada et al., 2015b).

External Catalyst

Rice is the one food that Filipinos cannot live without. Besides being a major staple food, it is also an important source of livelihood for more than two million Filipino households. The world rice price crisis in 2007–2008—when exporting countries banned their exports while importing countries lifted their tariffs to avoid shortages—affected mostly the marginalized households who are the main rice consumers in developing countries such as the Philippines. This contributed to the Philippine agricultural input policies which are geared to achieving high agricultural productivity, food staples sufficiency and food security, and sustainability (Galero et al. 2014).

Even before the rice crisis, since 1995, food self-sufficiency has been a desired goal of the Philippine government. The current administration addresses this concern through the FSSP of DA. The national self-sufficiency in food staples, through the Food Staples Sufficiency Program (FSSP), will be achieved by (1) raising productivity, profitability, and competitiveness of Filipino farmers, (2) providing adequate economic incentives and enabling mechanisms, and (3) managing food demand including promoting diversification towards other traditional staples (Galero et al. 2014).

Former Philippine President Benigno Aquino III, in his second State of the Nation Address (SONA) on 25 July 2011, summed up the national policy on food staples sufficiency as follows (FSSP 2012): "*Ang gusto nating mangyari: una, hindi na tayo aangkat ng hindi kailangan. Ikalawa, ayaw na nating umasa sa pag-angkat. Ang isasaing ni Juan de la Cruz, dito ipupunla, dito aanihin, dito bibilhin.*" (What we would like to happen is that first, we don't have to import if it's not needed. Second, we don't have to rely on importation. What Juan de la Cruz cooks, it is planted here, harvested here, and bought here).

FSSP 2011-2016 was launched on 5 July 2012 during the 2nd Agricultural Machinery Exposition or the "Makina-Saka 2012" at the World Trade Center in Pasay City under the Agrikulturang Pilipino (AgriPinoy) framework. The program primarily aims for rice self-sufficiency by enhancing domestic production to satisfy the requirements for food, seeds, processing, and feeds, and promotes consumption of alternative staples, in a way contributory to food security. The program, covering rice, white corn, saba, cassava, and sweet potato, implements projects addressing adoption of yield-enhancing technologies, increasing income, and improving delivery of extension and research services.

Ideas, Vision, Leadership

"Producing more with less to raise productivity" is underscored by the FSSP as a strategy to meet the growing demand for food. While technologies to increase productivity are available, one of the key challenges posed by the program is to make more farmers adopt the available yield-enhancing and cost-reducing technologies.

Yield-enhancing technologies include improved crop varieties. The first step towards rice self-sufficiency ladder is making available and accessible the seeds of the right varieties to the farmers for cultivation in the right growing environment, considering the country's highly variable rice production landscape.

The level and extent of variety adoption by the target farmer-clienteles and utilization by other stakeholders is a significant indicator of the success and impact of a crop breeding program. With the complexity and heterogeneity of the growing conditions in the rainfed lowlands, not all varieties developed for the ecosystem are expected to be suitable and perform well in a specific site or stably across all target locations. Likewise, acceptability and preference of stakeholders for a variety varies with location. The conduct of PTD-PVS with active participation and engagement of relevant stakeholders provides opportunity to address this concern.

Champions

In extending technologies for impact, rice varieties that are appropriate, high-yielding, and acceptable to the farmers in the target growing areas must be identified and selected for eventual dissemination and promotion. A viable strategy to address this is the conduct of PTD-PVS where the farmers and other stakeholders are actively engaged in the process of evaluating and selecting their preferred varieties. It is imperative to note that success in promoting technologies for adoption and diffusion depends largely on the matching or fitting of the technology to a specific growing environment and target end-users. Commitment and partnerships with the LGUs, in particular, the government officials and agricultural extension workers, as well as with other potential partners such as the SUCs, NGOs, local farmer technicians, civil society organizations (CSOs), as well as private sectors are vital in achieving sustained technology promotion and utilization.

Central to the FSSP is the farmer. The plans for the program implementation are anchored on the farmer, and restoring the farmers' trust in the government is the mission. With the PTD-PVS integrated in the national program, our farmers who are the beneficiaries are capacitated as they are also part of the variety trial implementers. The frontliner champions are the farmer partners and the agricultural extension workers from the LGUs (municipal agriculturists, and agricultural technicians) providing technical assistance to the farmer partners and facilitating the component activities of the PTD-PVS.

Incentive

In areas where access to variety information and seed availability is lacking, the PTD-PVS is a strategy where seed demand, hence market for the seeds of new varieties, can be created. Thus, it is crucial to involve local seed growers, as well as traders and millers in the activity to ensure seed supply of the preferred varieties in the locality. Interested participating farmers can be trained to become local seed growers if there are no or very few seed growers.

The benefit of using improved, drought-tolerant varieties is best realized and optimized in rice areas where drought events are commonly experienced. Having the PTD-PVS in place ensures fast adoption and diffusion of varieties most appropriate in the target areas for eventual increase in rice productivity and profitability.

With changing environment, as effected by climate change, aside from the inherent heterogeneity and complexity of the fragile rainfed lowland rice ecosystem, variety improvement and development should be a continuing research and development endeavor because this provides a coping mechanism to climate change. Consequently, PTD-PVS should be routinely conducted as new varieties are released periodically for commercial cultivation. This will shorten the gap between variety release and farmers' adoption, resulting in rapid variety replacement, which indicates higher return to public plant breeding research. Then it can be confirmed that the government can invest in the variety development program.

Institutional and Partnership Spaces

Ensuring access to and availability of high-quality seeds through

PVS. The role of PVS in accelerating dissemination and adoption of new varieties was institutionalized with enhanced partnerships of the public breeding institutions and the DA-RFOs, through the Next-Gen Project of the FSSP program under the country's National Rice Program. The newly released varieties are established in the farmers' fields and distributed in the different agro-ecological zones as PVS- researcher-managed trials (mother trials) for adaptability and preference analysis. These are implemented by the joint-efforts of breeding institutions IRRI, PhilRice, and UPLB, and the DA-RFOs.

Harnessing partnership, strengthening linkages and networking, and directing support through funding are some strategies to accelerate the impacts of benefits from CURE. Scaling up the PTD-PVS system is made possible by integrating and mainstreaming it into the National Rice Program of the Philippines under DA. The country's FSSP under DA, which addresses the goal of enhancing agricultural productivity, profitability, and global competitiveness is an excellent venue for the integration of the benefits from CURE. The FSSP is anchored on a vision of a food-secure society where farmers enjoy decent and rising standards of living.

PhilRice recognizes the importance of local farmer technicians in supporting delivery of agricultural technologies and innovations. As of September 2015, the DA has 1,600 local farmer technicians nationwide who serve as reinforcement of LGU-based agricultural extension delivery. Along this context, a strategic partnership with the Regional Field Office 1 and local farmer technicians was forged to enhance technology reach and at the same provide farmer-partners access to a broad range of resources and expertise.

Figure 8 presents the networking framework for upscaling the PTD-PVS. The framework emphasizes the partnership between IRRI, DA, and PhilRice, as well as their linkage and network with the DA-RFOs and the LGUs, which include the provincial and municipal agricultural offices who have direct links to the farmers, and other relevant stakeholders (NGOs, GOs, CSOs, SUCs, as well as the private sectors).

FSSP is a partnership catalyzing the efforts of the Philippine government and IRRI towards food sufficiency, transforming rice farming from low productivity into sustained growth and

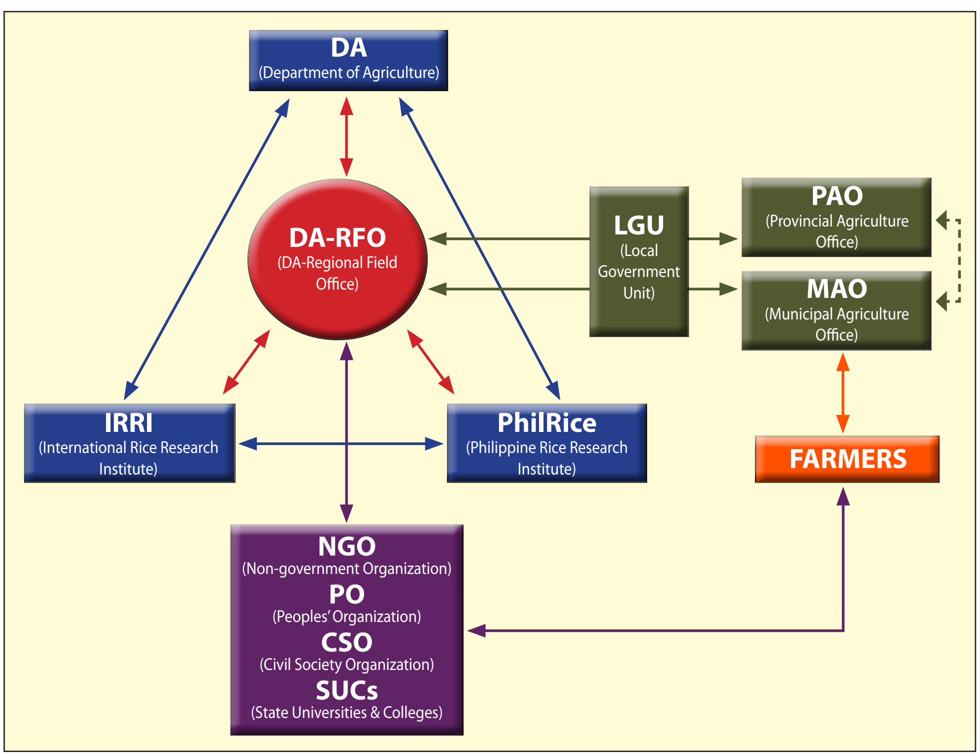


Figure 8. Networking framework for technology out- and upscaling: Partnership, linkaging and networking framework for accelerating impacts of gains from CURE under the Philippine Food Staples Sufficiency Program (FSSP) platform.

higher income. The challenges of the FSSP are addressed by PhilRice, IRRI, and the stakeholders through (1) adoption of yield-enhancing technologies; enhanced economic incentives, (2) improved delivery of extension and research services, and (3) strengthened capacities of public institutions, innovative approaches to deliver farm services.

One of the seven FSSP projects, titled "Accelerating the development and adoption of next-generation rice varieties for major ecosystems in the Philippines," dubbed as Next-Gen, has two components: (1) fast-tracking the development of next-generation high-yielding and climate-change-resilient rice varieties and (2) accelerating the adoption of high-yielding rice varieties through multi-environment testing (MET) and production of high-quality seeds.

The project employs the PTD-PVS approach to address the production of high-quality seeds of new climate-resilient rice varieties and make them available to the Filipino farmers to facilitate and enhance the adoption and utilization of released varieties for the various rice ecosystems such as irrigated and rainfed lowlands, and stress-prone rice environments. DA provides the funds directly to the RFOs, who implement the evaluation of the performance and acceptability of the new varieties. The end result is the identification of the top five most preferred varieties in each of the 16 regions across the country.

The Bureau of Plant Industry (BPI) regulates the quality of the preferred variety seed production through the NSQCS. Alternatively, quality seeds may be made available through the Community Seed Banking System. Seeds are produced for high-quality seed buffer stocking (10% of the total seed requirement) and for farmers' cultivation.

DA-RFOs implement the PTD-PVS activities in partnership with the LGUs, target farmers and other stakeholders, while DA, PhilRice, and IRRI do the oversight coordination, monitoring, and evaluation of the project outputs and impacts.

Learning Space

Production, dissemination, and promotion of high-quality seed of new varieties through PVS. Information and seeds of a new variety should be readily accessible to as many farmers as possible immediately after release to achieve optimum impact and return of government investment on public crop improvement research and development. The PTD and PVS are CURE initiatives that serve as avenues for technology awareness and information campaign on rapid access of farmers to new technologies and for identification and selection of the most adapted and preferred varieties. Information on the traits of the varieties acceptable to the end-users is also generated through PTD and PVS. The farmers' best management practices are extracted and new technologies are shared during the farmers' forum, which is part of the participatory activities. The PVS approach (Paris et al., 2011), as an integral part of a breeding program, has been very useful in the development of appropriate varieties that is adaptable and acceptable for adverse rice environments such as the saline-prone and drought prone rainfed rice areas.

REFERENCES

Bragantini, C. (2004). Formal and informal seed systems: Definitions, perceptions, concepts and prejudices. In: Seed multiplication by resource-limited farmers, FAO Plant Production and Protection Paper 180, Food and Agriculture Organization of the United Nations, Rome, pp. 11-15. (ISBN 92-5-105217-4)

Consortium for Unfavorable Environments. (2015). Reducing risks and raising rice livelihoods in Southeast Asia through the Consortium for Unfavorable Rice Environments (CURE 2). Annual report submitted to the International Fund for Agricultural Development, April 2015: International Rice Research Institute.

Consortium for Unfavorable Environments. (2014). Enabling poor rice farmers to improve livelihoods and overcome poverty in South and Southeast Asia through the Consortium for Unfavorable Rice Environments (CURE). Final report submitted to the International Fund for Agricultural Development, 15 January 2014: International Rice Research Institute.

Corales, A.M, Dizon, J.T., & Cardenas, V.R. (2014). Assessing PalayCheck institutionalization in selected municipalities in the Philippines. Philippine Journal of Science. 143 (2): pages 167-176, December 2014.

Department of Agriculture. (1992). Implementing rules and regulations of Republic Act No. 7308 (otherwise known as the Seed Industry Development Act of 1992). Approved by Roberto S. Sebastian, Secretary, Department of Agriculture.

Department of Agriculture Administrative Order No.10 Series of 1994. Implementing guidelines on seed multiplication, production, and distribution of recommended superior food crop cultivars. Approved 20 August 1994 by Roberto S. Sebastian, Secretary, Department of Agriculture.

Department of Agriculture. (2011, November 1). DA allots P192M for community seeds banks, rice seed production program. Press release from the Department of Agriculture. Retrieved from http://www.gov.ph/2011/11/01/da-allots-p192m-for-community-seeds-banks-rice-seed-production-program/.

Department of Agriculture. (2012). Food Staples Sufficiency Program (FSSP) 2011-2016: Enhancing agricultural productivity and global competitiveness (1st ed.). Published by the, Office of the Secretary, National Rice Program, www.da.gov.ph, ISBN 978-971-704-027-1.

Department of Agriculture. The Philippine Rice Seed Industry Road Map, 2011-2016/2017-2022., Elliptical Road, Diliman, Quezon, City, Philippines

Department of Agriculture. Upland Rice Development Program, 2011-2016. Agri-Pinoy Rice Program.

Desamero, N.V, & Pablero, D.D. (2015). Improving livelihoods and overcoming poverty in the drought-prone lowlands of Southeast Asia [Terminal Report 2011-2014]. Philippine Rice Research Institute, Science City of Muñoz, Nueva Ecija. PhilRice Ref. No. 590 RTF 003 / IRRI Ref. No. DPPC2009-119. Sponsored by International Fund for Agricultural Development (IFAD). 194 p., appendices

Desamero, N.V., & Pablero, D.D. (2015). Participatory adaptation cum techno-demo trial (PVTD) accelerated adoption of rainfed lowland variety Sahod Ulan 7. Paper presented as poster during the 23rd Federation of Crop Science Society of the Philippines (FCSSP) Scientific Conference, 11-16 May 2015, Hotel Stotsenberg, Clark Freeport Zone, Pampanga.

Desamero, N.V., & Bagarra, J.C. (2011). Implementation plans to disseminate submergence tolerant rice varieties and associated new production practices in the Philippines [Terminal Report 2007-2009]. PhilRice Ref. 452 RTF 003, IRRI Ref No. DPPC2007-22. Sponsored by The Ministry of Foreign Affairs of Japan, (Philippine Rice Research Institute, Science City of Muñoz, Nueva Ecija) 194 p., appendices.

Ferrer, R.S. (2014). More rice, less pork: Community seed banks in the rice seed production program. SEARICE Review Volume 7 (issue 1): 1-15.

Gabertan, H.A., Jarilla, F.A., Dayap, F., & Alibuyog, C. (2016). A country-integrated seed sector status paper Philippines. Retrieved from http://q.datakultur.se/~svalofco/wpcontent/uploads/2012/12/Philippines-Seed-Sector-Status-Paper.pdf,

Galero, S., So, S., & Tiongco, M. (2014). Food security versus rice self-sufficiency: Policy lessons from the Philippines. Paper presented at the DLSU Research Congress: Toward rigorous, relevant and socially responsive Lasallian Research, De La Salle University, Manila, Philippines March 6-8, 2014.

Hernandez, J.E. (2013). Strengthening palay seed systems in Southern Tagalog and Bicol regions. Bangko Sentral ng Pilipinas Professorial Chair Lecture presented on 05 March 2013, Crop Science, UPLBCA. Retrieved from http://www.bsp.gov.ph/events/pcls/downloads/2013s2/BSP_6a_hernandez_paper.pdf, retrieved.

International Rice Research Institute. (2015). DA and IRRI Rice research toward food security in the Philippines, FSSP_brochure_IRRI, January 2015

Launio, C.C., Redondo, G.O., Beltran, J.C., & Morooka, Y. (2008). Adoption and spatial diversity of later generation modern rice varieties in the Philippines. Agronomy Journal 100(5):1380-1389.

Manzanilla, D., Tobias, A., & Calumpang, L. (2014). Community-based seed systems: Improving access to quality seeds. In:

Moving up innovations to scale: Lessons from IFAD-Supported Development Interventions in the Philippines. Philippines: IFAD, pp. 53-62.

National Cooperative Testing Manual for Rice: Guidelines and Policies. 1997. Rice Technical Working Group, National Seed Industry Council (NSIC), Bureau of Plant Industry (BPI), Department of Agriculture, Elliptical Road, Diliman, Quezon City, (Philippine Rice Research Institute, Maligaya Science City of Muñoz, Nueva Ecija) 113 p.

National Cooperative Testing (NCT). 1997. Philippine Rice Research Institute (PhilRice), Maligaya Science City of Muñoz, Nueva Ecija; National Seed Industry Council (NSIC), Bureau of Plant Industry (BPI), Elliptical Road, Diliman, Quezon City

Nidoy, MGM. (2015). What we talk about when we talk about food. PhilRice Magazine, Apr-Jun 2015 pp. 5-7.

Obien, S., Fernandez, R., Malabanan, F., Barroga, R. & Dacumos, C. (1996). The Philippine Rice Industry and the National Rice Seed Production Network, Rice Technology Bulletin. No. 6. Department of Agriculture-Philippine Rice Research Institute.

Palizada, S. A., D.V. Fidel, E. Santiago. (2015). Philippine seed systems for rice and the Seed Production Network. Report presented during the "National Rice Program Mid-Year Assessment and Planning Workshop for the Project Accelerating the Development and Adoption of Next-Generation Rice Varieties for the Major Ecosystems in the Philippines (Next-Gen Project) ," 07-11 June 2015, Subic, Zambales.

Palizada, S., Fidel,D., Agcaoili, A., Penus, A., Laot, G., & Abaquita, M.. (2015). Seed information system of BPI and highlights of 2015 rice seed component activities in support to Next- Gen Project. Report presented during the "National Rice Program Year-End Assessment and Planning Workshop for the Project Accelerating the Development and Adoption of Next-Generation Rice Varieties for the Major Ecosystems in the Philippines (Next-Gen Project)", 16-20 November 2015, Bohol.

Paris, T., Manzanilla, D., Tatlonghari, G., Labios, R., Cueno, A., & Villanueva, D. (2011). Guide to participatory varietal selection for submergence-tolerant rice. Los Baños (Philippines): International Rice Research Institute. 11 p.

Republic Act No. 7308 (Seed Industry Development Act of 1992. An Act to promote and develop the seed industry in the Philippines and create a National Seed Industry Council and for other Purposes. Republic of the Philippines, Congress of the Philippines, Metro Manila, Approved/ Enacted March 27, 1992 by Corazon C. Aquino, President of the Philippines.

Thailand

Drought-prone environments

Farming made easy and cost-effective in drought-prone rainfed lowlands in northeastern Thailand

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Stresses in different rice ecosystems such as drought require urgent intervention, especially because of the heightened effects of climate change. Thus, innovative farming technologies can help farmers in drought-prone areas reduce their losses by maximizing rice productivity while keeping their production costs to a minimum.

Crisis in the rice fields of northeastern Thailand

Northeastern (NE) Thailand has about 6.3 million hectares of rainfed lowland rice, with about 5.6 million hectares (89%) dominated by KDML105 and RD6 (an induced mutant of KDML105) varieties. The average rice yield in the region is low, and fluctuates from year to year depending on the rainfall, ranging from 1.5 to 2.2 tons per hectare. There are only about 0.35 million hectares of rice-growing areas during the dry season. Half of the growing areas depend on water from rivers, swamps, or ground for irrigation using electric, gasoline, or diesel pumps. Increasing irrigation areas and facilities are difficult because water resources are limited. Furthermore, the poor soil fertility, due to the mainly sandy soils, and droughts, which occur early or late in the wet season, are the main constraints limiting rice production in northeastern part of the country.

The water crisis is threatening the sustainability of the rice production in the region. Droughts may develop any time during the growing season. Early-season droughts usually occur during transplanting of seedlings and growth of direct-seeded rice. Late-season droughts occur at the end of the rainy season before crop maturation, particularly in paddy rice in a high toposequence position. When drought sets in at different stages of rice growth, farmers experience a significant loss in rice productivity, which is estimated to be as much as 56% in NE Thailand. In terms of the geographic spread of droughts (Fig. 1), the Ministry of Agriculture and Cooperative estimates that droughts affect 2.6 million hectares of farmland in 58 provinces, including 2 million hectares in the NE.

Occurrence of droughts

There are yet no drought-tolerant rice varieties that have been bred and introduced to farmers in the affected areas. Thus, developing cultivars that can withstand drought but still produce higher yields than local cultivars is one of the main objectives of the project. In addition, improvement of germplasm, nutrition management, water-use efficiency, and planting method are also key goals at the project.

Technology development through collaboration

Novel technologies, such as mechanized dry-seeded rice (DSR) technology, site-specific nutrient management (SSNM), and alternate wetting and drying (AWD) approach were developed

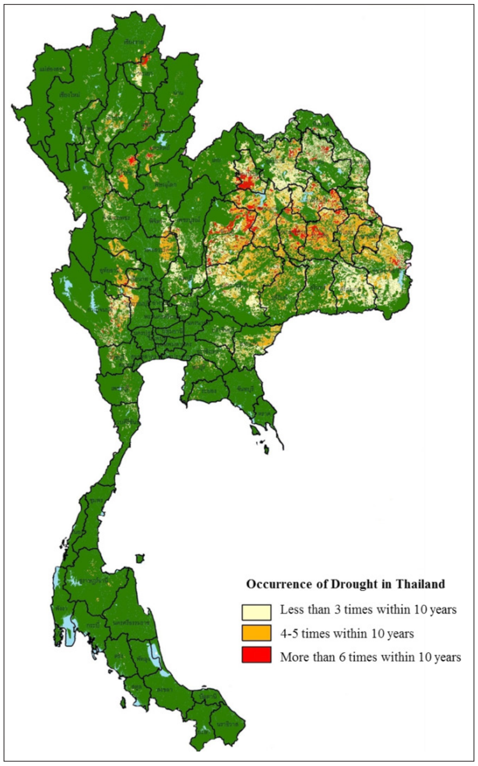

Figure 1. Drought-prone areas in Thailand.
Source: Land Development Department, Thailand (LDD, 2013).

under the Consortium for Unfavorable Rice Environments (CURE) project to help farmers in the NE to increase rice productivity and reduce their production costs.

From 2009 to 2013, the Ubon Ratchathani Rice Research Center (URRC) worked with the CURE Working Group 1 to increase the rice productivity in the drought-prone rainfed lowlands Ubon Ratchathani and Nakhon Ratchasima. One of the outputs of this activity was the development of the nutrient management guideline for rainfed lowland rice.

During the collaboration period, another project, *Improving livelihoods and overcoming poverty in the drought-prone lowlands in South and Southeast Asia* (TAG 1227), was launched in December 2010. Implemented under CURE with the support from the Intenational Fund for Agricultural Development (IFAD), the four-year project operated in NE Thailand with different institutions working together on cultivation and trials of drought-tolerant varieties and validation of developed technologies (Table 1). Four major activities were conducted under the project, namely: (1) identification and validation of drought-tolerant germplasms at Nakhon Ratchasima and Ubon Ratchathani provinces; (2) nutrient management trials to validate the site-specific fertilizer application that had been developed through CURE in Amnat Chareon, Nakhon Ratchasima, Nong Khai, Ubon Ratchathani, Udon Thani, Sisaket, Yasothon and Sakon Nakhon provinces; (3) AWD trial for dry-season rice at Ubon Ratchathani province; and (4) validation of mechanized DSR technology for drought-prone lowlands in Ubon Ratchathani.

Milestones in technological innovations

Farmer-tested participatory varietal selection (PVS)

On-farm PVS trials were conducted in the drought-prone environment of NE Thailand during the wet seasons of 2011 and 2014 to identify and validate drought-tolerant genotypes. In 2011, 16 new drought-tolerant IRRI lines were evaluated under both favorable and drought conditions in the Khong and Phimai Districts in Nakhon Ratchasima Province. Thirty farmers evaluated the agronomic characteristics of the drought-prone rice varieties, while 38 farmers evaluated paddy, milled rice, and cooked rice qualities.

Results show that IR83388-B-B-8-3 produced the highest yield (4.41 tons per hectare) under favorable conditions, while IR82589-B-B-2-2 produced the highest yield (2.70 tons per hectare) under drought (Table 2).

For the standing crops in the field, the farmers preferered sturdy stems, large and compact panicles, and straw colored slender grains. The top three lines were shown in Table 2.

For paddy rice quality, the top three varieties/lines preferred by farmers were RD15 (local check), IR83377-B-B-93-3, and IR83381-B-B-137-1 (Table 3). Farmers preferred straw color grains with slender shape and uniform size and disliked bold grain shape and grains with awn.

For milled rice quality, the top three varieties/lines preferred by farmers were RD15, IR83376-B-B-130-2, and IR83377-B-B-93-3, which the farmers liked because of the long, shiny grains with

Table 1. Timeline of validation and demonstration of developed technologies under CURE IFAD TAG 1227 project in NE Thailand, 2010-2014

Year	2011	2012	2013	2014
Technologies/target sites (province)	SSNM/Amnart Charoen, Nakhon Ratchasima, Nong Khai PVS/Nakhon Ratchasima AWD/Ubon Ratchathani	SSNM/ Ubon Ratchathani, Udon Thani AWD/Ubon Ratchathani	SSNM/Ubon Ratchathani, Udon Thani AWD/Ubon Ratchathani	SSNM/ Sisaket, Yasothon and Sakon Nakhon AWD/Ubon Ratchathani PVS/Ubon Ratchathani DSR/Ubon Ratchathani
Partner institutions	Ubon Ratchathani Rice Research Center, Nakhon Ratchasima Rice Research Center, Nong Khai Rice Research Center, Udon Thani Rice Research Center Sakon Nakhon Rice Research Center	Ubon Ratchathani Rice Research Center, Udon Thani Rice Research Center	Ubon Ratchathani Rice Research Center, Udon Thani Rice Research Center	Ubon Ratchathani Rice Research Center, Sakon Nakhon Rice Research Center

Table 2. Grain yields of the top 3 lines grown under favorable and drought conditions in 2011.

Designation	Grain yield (t/ha)	Days to flowering	Height (cm)
Favorable condition			
IR82589-B-B-84-3	4.06	87	113
IR83377-B-B-93-3	4.31	91	123
IR83388-B-B-8-3	4.41	89	112
Mean	3.67	88	115
Drought condition			
IR82589-B-B-84-3	2.59	86	88
IR82589-B-B-2-2	2.70	90	88
MTU1010	2.62	89	79
Mean	2.17	95	78

Table 3. Preference analysis on agronomic characteristics of the top three lines grown under favorable and drought conditions in 2011.

Designation	No. of persons who like			No. of persons who dislike		
	Male	Female	Total	Male	Female	Total
Favorable condition						
IR83376-B-B-130-2	18	4	22	0	0	0
IR83377-B-B-93-3	18	4	22	0	0	0
IR87707-446-B-B-B	14	1	15	4	3	7
Drought condition						
IR83376-B-B-130-2	13	2	15	0	0	0
IR83377-B-B-93-3	12	2	14	0	1	1
IR83377-B-B-48-3	9	2	11	4	0	4

slender shape but were concerned with the high chalkiness of these lines.

For cooked rice quality, the top three varieties/lines preferred by farmers were RD15, IR83377-B-B-93-3, and IR87707-446-B-B-B based on their soft texture and aroma.

In 2014, four drought-tolerant advanced backcross lines with a Thai variety (Surin1) genetic background and two check varieties KDML105 (a popular rice variety in the region) and IR57514-PMI-5-B-1-2 (a drought-tolerant genotype) were grown in a farmer's field in Ubon Ratchathani. Breeders have long noticed that IR57514-PMI-5-B-1-2 has a good drought-tolerant genotype even before starting its drought-breeding trials. A PVS trial was conducted before harvest, in which 16 farmers were invited to participate.

Results showed that all drought-tolerant lines had higher grain yield than the local variety, KDML105. IRUBN06024-B-1 and IR57514-PMI-5-B-1-2 showed significantly higher grain yield than KDML105 (Table 4), and were the most preferred by farmers (Table 5). These promising lines can be introduced to farmers in drought-prone areas where early- or late-drought episodes frequently occur, especially in areas in high toposequence.

Applying fertilizers using site-specific nutrient management (SSNM)

The majority of soils in the Mekong river basin, including in NE Thailand, are sandy and low in nutrients that, along with drought, results in low rice yields. Improving nutrient management could enhance rice productivity in the region. Although the local government developed a guideline for nutrient management for drought-prone lowlands, it did not consider the toposequential effect in undulating fields. Thus, SSNM was developed, evaluated, and introduced to farmers. The SSNM was developed to help farmers determine the amount of nitrogen, phosphorus, and potassium (NPK) fertilizer based on soil fertility and

Table 4. Grain yield of advanced backcross rice lines with a Thai variety, KDML105 (farmers' variety) and IR57514-PMI-5-B-1-2 (drought-tolerant genotype) in the PVS trial in wet season 2014.

Designation	Grain yield (t/ha)	Height (cm)	Panicles/hill	Days to Flowering
IRUBN06024-B-1	2.72	120	11	109
IRUBN06024-B-3	1.94	126	10	99
IRUBN06024-B-5	2.38	134	10	99
IRUBN06024-B-9	2.29	117	11	101
IR57514-PMI-5-B-1-2	3.03	94	11	108
KDML105	1.76	111	10	111

Table 5. Preference analysis on grain quality of the top three varieties/lines in 2011.

Designation	No. of persons who like			No. of persons who dislike		
	Male	Female	Total	Male	Female	Total
Paddy rice quality						
RD15	10	13	23	0	0	0
IR83377-B-B-93-3	10	12	22	0	1	1
IR83381-B-B-137-1	10	9	19	0	4	4
Milled rice quality						
RD15	10	11	21	0	2	2
IR83376-B-B-130-2	5	10	15	5	3	8
IR83377-B-B-93-3	10	2	12	0	11	11
Cooked rice quality						
RD15	10	13	23	0	0	0
IR83377-B-B-93-3	8	10	18	2	3	5
IR87707-446-B-B-B	7	10	17	3	3	6

Note: RD15 - a non-glutinous rice variety that has short maturity duration than KDML105

toposequence position of the rice field. Toposequence is important because soil characteristics of lower and upper fields are different (i.e., higher soil fertility is typically found in the lower fields).

Before the project, a team from IRRI and URRC developed a new guideline for fertilizer application, i.e., SSNM, based on the initial on-farm trials in 2004-2006. It estimates the required application rate of NPK based on toposequence positions, soil fertility, and soil type within a miniwatersheds. In this project, the SSNM guideline was compared with the farmers'

practice and the local government recommendations (Table 6, Fig. 2).

The SSNM guideline increased rice yield by 10% (2.86 vs. 2.60 tons per hectare) on average for 119 sites in 8 out of 20 provinces from 2009 to 2014. The yield advantage of SSNM over farmers' practice negatively correlated with the yield in the farmers' practice, and the advantage was not observed when yield surpassed 3 tons per hectare.

The SSNM guideline emphasizes yield improvement of low-yielding environments (1–3 tons per hectare), and recommends no fertilizer application in high-yielding environments due to low-yield potential of the current popular varieties (3.5–4.0 tons per hectare).

Although the average yield did not differ between the three guidelines, the net return was slightly different. The SSNM guideline resulted in higher net return than the two government recommendations (soil test-based and soil type-based) by USD 54 to 69 tons per hectare. Furthermore, the net return of the SSNM guideline was more stable and gave higher returns than other methods. The results of a six-year trial showed that the SSNM guideline consistently improves rice yield and net return in low yielding environments. Also, SSNM is a less risky management option than other guidelines for nutrient management in NE Thailand.

Planting smart

Since labor shortage is becoming a serious problem in the region for the last ten years, majority of rice farmers

Table 6. Guideline for nutrient management based on the soil test (Rice Research Institute, 2004). The fertilizer application rate is determined by the amount of organic matter content, available phosphorus, and exchangeable potassium in the soils.

Organic Matter		Available Phosphorus		Exchangeable Potassium	
Analyze (%)	Recommended rate (kg N/ha)	Analyze (ppm)	Recommended rate (kg P_2O_5/ha)	Analyze (ppm)	Recommended rate (kg K_2O/ha)
< 1	56.25	< 5	37.50	< 60	37.50
1–2	37.50	5-10	18.75	60-80	18.75
> 2	18.75	> 10	0	> 80	0

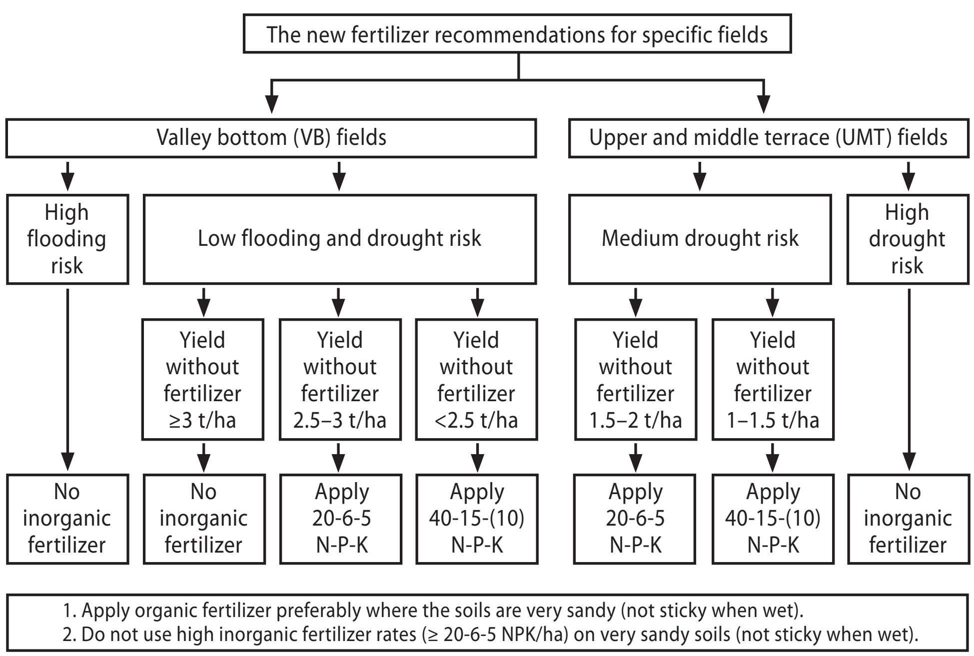

Figure 2: Site-specific nutrient management guideline in northeastern Thailand. The fertilizer application rate is determined by the toposequence positions, soil fertility and soil type (Haefele & Konboon, 2009).

have shifted their planting method from transplanting to dry seed broadcasting. While for harvesting, they opt to use harvesting machines. However, the broadcasting method often limits rice yields due to poor crop establishment and inefficient weed control. So, farmers tend to use more seeds for DSR. To improve DSR technology, this project tested mechanized DSR using a local drill seeder.

A seed drill mounted on a hand tractor was used in row or line seeding to reduce the seeding rate. A demonstration trial was conducted in Khueang Nai District, Ubon Ratchathani during the wet season of 2014. The trial compared the net return over the cost of rice production of three cultivation methods: manual DSR, mechanized DSR, and manual transplanting.

The seeding rate in drilling (20 cm of row spacing, hill-to-hill space around 20 cm, 6–9 seeds per hill) was only 40% of that in broadcasting (50kilogram/hectare vs. 125 kilogram/hectare). The grain yield in drilling was the same as that in transplanting, but significantly higher than that of broadcasting method.

The products from transplanting and drill methods could be sold as certified seeds, which can command a higher price (USD 0.43/kilogram) than that of the broadcasting method (USD 0.38/kilogram), which was sold to millers. Mechanized seeding gave the highest return (USD 367.4/hectare) compared with transplanting (USD 364.2/hectare) and broadcasting methods (USD 200.6/hectare).

As observed from the trials, some factors need to be considered in using and improving this technology. One, using the appropriate grain seeder for DSR may depend on the soil type. The driller used in the project proved suitable for sandy and sandy loam soils. On clay loam soil, land preparation should be improved to use mechanized seeding or a different seeder should be used. Meanwhile, weed management remains a big challenge in DSR. Farmers often delay the spraying of pre-emergence herbicide because of the immediate rainfall after seeding, resulting in delayed rice growth. Lastly, a narrow range in suitable soil moisture for the operation of drill seeder may limit technology dissemination. The machine cannot be operated and pre-emergence herbicide cannot be used if the soil is too moist. A practical solution would be to advance the seeding date by one to two weeks by modifying the land preparation.

Growing dry-season rice while saving water

The demand to save on the cost of irrigation is most pronounced during the dry season because many farmers use diesel pumps to draw water from swamps or, shallow tube wells. Rice production is strictly confined to some areas depending on the availability of water in the village. To reduce the risk to rice production and increase farmers' income, URRC introduced the water-saving AWD technology through the project.

Contrary to continuously flooding the field, AWD water management technique allows farmers to dry out their rice fields for one to several days after the disappearance of ponded water before it is flooded again. A "safe" AWD consists of three key elements (Bouman et al., 2007):

(1) shallow flooding for the first 2 weeks after transplanting to help the plants recover from transplanting shock and suppress weeds (or with a 10-centimeter-tall crop in direct wet-seeded rice); (2) shallow ponding from heading to the end of flowering as this stage is very sensitive to water-deficit stress and the crop has a high growth rate and water requirement; and (3) AWD during all other periods, with irrigation water applied whenever the perched water table falls to about 15 centimeters below the soil surface. The threshold of 15 centimeters will not cause any yield decline since the roots of the rice plants can still take up water from the perched groundwater and the almost saturated soil above the water table. The water table can be easily monitored by installing a simple PVC or bamboo pipe, an improvisation introduced by IRRI through the Water-Saving Workgroup of the Irrigated Rice Research Consortium (Lampayan et. al., 2015).

The initial on-station trials showed that AWD can safely and substantially reduce irrigation cost without sacrificing rice productivity (Table 8). An on-farm demonstration trial further confirmed the result (Table 9). Rice yield was higher in AWD than in full irrigation, while irrigation input decreased by 16–20%. Thus, AWD technology can be incorporated into good agricultural practices (GAP) for dry-season rice in NE Thailand.

Table 7. Guideline for nutrient management based on soil textures (Soil Science Division, 2000).

Soil texture	Basal application (20 DAT)		Top dressing (PI)
	16-16-8%	16-20-0%	Urea
	(N-P2O5-K2O)	(N-P2O5-K2O)	(46-0-0%=N-P2O5-K2O)
Clay	-	156.25 kg/ha	62.5 kg/ha
Sandy loam and sand	156.25 kg/ha	-	62.5 kg/ha

DAT = days after transplanting; PI = panicle initiation.

Table 8. Rice yield (cv. Chai Nat1) and water input in two water management methods. Two fertilizer application rates, 75-37.5-37.5 (F1) and 112.5-37.5-37.5 (F2) kg ha-1 of N-P2O5-K2O at URRC during the dry season of 2012.

Water management	Nutrient management		Average yield (ton ha-1)	Irrigation cost (USD/ha)
	F1	F2		
Full irrigation	3.20	3.40	3.30b	577
Alternate wetting and drying	3.66	3.76	3.71a	286

CV (a) = 3.78*, CV (b) = 8.95NS. 1 THB= 0.030707 USD
FI = full irrigation; AWD = alternate wetting and drying

Table 9. On-farm demonstration of the water-saving technology. Rice yield (cv. RD10) and water input in two water management methods, full irrigation and alternate wetting and drying (AWD), in Ubon Ratchathani province, during the dry season of 2014.

Water management	Grain yield (ton/ha)	Irrigation input (mm)	Irrigation cost (USD/ha)
Full irrigation	3.16±0.89	530	415
Alternate wetting and drying	3.84±0.51	424	339

Disseminating the technologies to greater areas

The novel technologies developed under CURE, namely, mechanized DSR technology, SSNM, and AWD approach, are expected to be acceptable to farmers and distributed to larger areas.

The introduction of a mechanized DSR technology could reduce labor and seed costs, and hence improve farmers' net income in NE Thailand. Only the rice varieties to be used have not changed since most farmers still grow the widespread varieties KDML105 and RD6. The glutinous RD6 is mostly grown for home consumption in lower fields, while the nonglutinous KDML105, preferably grown in upper and middle fields, often serve as a cash crop.

The existing recommendations from the local government based on soil test and soil texture for the entire rainfed lowland rice area, (which do not consider the typical undulating topography of rice environment in rainfed areas in the region), is the only nutrient management reference available for farmers. Moreover, tools for more SSNM such as detailed soil maps, soil testing, or even geo-referenced yield data, are unlikely to be available to farmers. Thus, field-specific management of N, P, and K fertilizers developed under CURE should be a suitable option for improved nutrient management. The recommendations have been validated for large-scale coverage in almost all provinces in the NE region. This new guideline could be used as an alternative nutrient management reference not only in the region, but even in the drought-prone rainfed lowland areas in neighboring countries.

Directing upscaling efforts to specific sites

SSNM technology is targeted to be validated and upscaled in eight provinces, which include Buriram, Chaiyaphum, Khon Kaen, Maha Sarakham, Nakhon Phanom, Roi Et, Sisaket and Surin provinces. About 12–15 farmers in each province will be selected for the technology validation. Researchers at the URRC also plan to introduce this technology to farmers in Lao PDR under a collaboration project as well. Meanwhile, the DSR technology is targeted to be upscaled through seven farmers' groups each in the provinces of Amnat Charoen and Ubon Ratchathani.

Maximizing yield, reducing costs

In the wet season, the combination of SSNM and the use of rice seed drill have been observed to reduce farmers' production cost. SSNM could reduce the cost of fertilizer, while using a rice seed drill could lessen the cost of transplanting. Farmers find the use of dry-seed drill acceptable and expressed their desire to use it again in the next cropping season. Areas that make use of the rice drill are expected to increase in number in the next wet season.

Meanwhile, in the dry season, farmers could reduce the cost of irrigation by approximately 50% from their current practice in AWD testing fields. The farmers used AWD as a guide in deciding when to irrigate their fields. The selected rice lines from the PVS trials that are well-adapted in drought-prone areas and produce higher yield than the existing local variety could be introduced to other farmers whose fields suffer from drought. The promising lines may increase grain yield compared with the existing rice variety when drought occurs in the areas.

Recommendations

The SSNM (wet season) and AWD (dry season) technologies were conducted over the years in rainfed lowland condition that cover several provinces in the NE region. The results from trials indicated that SSNM and AWD could reduce the cost of rice production of farmers in the tested fields. These technologies were considered as the ones that could be extended beyond the tested areas. The following are some observations and feedback on the technologies that were introduced and demonstrated to 100 farmers:

1) Farmers often decide to apply fertilizers according to the recommendation of the National Rice Department, advertisements, their neighbors' practice, or their budget, which sometimes are not enough to meet the recommended rates.
2) Farmers think that the fertilizer application based on CURE recommendation is too complicated. The recommendation must consider factors such as soil fertility, toposequence land types, previous yields and rainfall. Because farmers found these factors difficult to identify on their fields, they found it hard to follow the recommendations.
3) Using the rice seed drills and AWD approach could reduce their production cost.
4) The AWD fields and mechanized DSR need an appropriate approach for weed management.

In the demonstration fields, almost all farmers had never used a rice seed drill before. The results showed that, although the total grain yield was not significantly different, using the rice seed drill could reduce labor cost compared with the transplanting method. This could generate higher profit for the farmers. When compared with the dry rice broadcasting method, using rice seed drill could reduce the cost of seed by up to 50% and give higher yield. By using the rice seed drill, farmers could also easily take care of their fields. Upon learning and witnessing such promising results, farmers, whose fields were around the demonstration plots, have become interested in the rice seed drill and were planning to use the technology during the next season. Moreover, it has been recommended that a best management practices (BMP) poster on mechanized DSR be printed in Thai for the farmers to understand.

Meanwhile, upon the introduction and demonstration of AWD technique to farmers in 2014, it was observed to be suitable for areas that can cultivate rice in dry season when farmers pay for water resources. Moreover, AWD was found to reduce the cost of water use by up to 50% without yield reduction. Five farmers from Khueang Nai District in Ubon Ratchathani have shown interest in the technique and have expressed their desire to apply this method in the next cropping season. However, some farmers are concerned with weed problems especially with no standing water in the rice field.

Natural resource management space

Improved farming practices that are environmentally safe. All technologies developed under CURE are primarily for increasing the rice productivity and income of farmers in the drought-prone rainfed lowlands of NE Thailand. The project aims to integrate approaches by using genetics, appropriate practices, and integrated resource management to increase rice yield, reduce water demand, and water input for rice productions. In the dry season, many rice-producing areas face increasing water shortages.

AWD holds great promise in reducing water use and greenhouse gas emissions from rice cultivation without sacrificing yield output. It can also help farmers save on the cost of irrigation. SSNM, which aims at dynamic field-specific management of N, P, and K fertilizer to optimize the balance between supply and demand of nutrients in different field conditions, can reduce fertilizer application and can improve soil microbial biomass and biodiversity. Consequently, both AWD and SSNM technologies can provide farmers in drought-prone rainfed lowlands not only the option to increase yield but also help preserve the environment.

Policy space

Agricultural polices focusing on research and development. The National Rice Policy and Management Committee has set a goal of developing Thailand as a leading country for rice trade in the world market. In the short term, the Thai government will reduce the areas for off-season rice farming, assist farmers in rice production planning, and promote research and development to increase the potential for the production of high-quality rice. In the long term, it focuses on developing rice varieties with high yields but low production costs suitable in rainfed lowland in the NE, the largest rice growing area in Thailand. A target has been set to increase Thai rice production by 25% and reduce production costs by 20% by 2021 using the technologies developed by CURE. Upscaling of the technologies with support from government will have more impact and reinforce the recent policy.

Partnership and Institutional spaces

Linkages and integration of key institutions. Activities under the project are a result of collaborations and partnerships with different institutions (Table 10).

Learning space

Farmer-friendly guideline and publications. At the end of the project, a total of 130 farmer leaders and local extension staff participated in two workshops, *Kaset Sunchon (Agricultural Expedition)* and *Professional Rice Farmers,* held at Ubon Ratchathani. In these workshops, the drought-focused project implementers introduced the rice technologies to the farmers. All these technologies were developed, validated, and documented through a farmer-friendly learning material or guideline on nutrient management. Farmers were quite impressed by the innovative rice technologies for the drought-prone areas. But, they also made some critical comments such as difficulty in following the guideline on nutrient management. The guideline will be further modified to be more user-friendly.

Aside from disseminating innovative rice technologies to local partners and farmer-leaders, the CURE project team and partners organized training activities and conferences on data collection during on-farm demonstration trials, agricultural data management, and presentation skills. These capacities are important for large-scale on-farm activities.

The knowledge from the project was published in proceedings of national and international conferences such as the 3rd and 4th International Rice Congress, and in annual meeting of Rice Research Centers in the NE cluster 2010-2011. (See Table 11 for a list of knowledge management materials published under CURE.)

REFERENCES

Belder P, Bouman BAM, Spiertz JHJ. 2007. Exploring options for water savings in lowland rice using a modelling approach. Agric. Syst. 92, 91–114.

Haefele SM, Konboon Y. 2009. Nutrient management for rainfed lowland rice in northeast Thailand. Field Crops Res. 114:374-385. Available via https://docs.google.com/a/irri.org/file/d/0ByGk26Nk_MlAb2JIRHMyX2Mzb00/view.

Land Development Department, Thailand. 2013. Drought-prone areas in Thailand Available via http://irw101.ldd.go.th/irw101.ldd/data/images/drougth_56th.jpg.

Lampayan RM, Rejesus RM, Singleton GR, Bouman BAM. 2015. Field Crops Research 170. 95-108.

OAE (Office of Agricultural Economics). 2013. Agricultural Statistics of Thailand. Ministry of Agriculture and Cooperatives. Bangkok, Thailand.

Rice Research Institute, 2004. The recommendation of chemical fertilizer application based on soil analysis, DOA, Bangkok.

Soil Science Division, 2000. The recommendation: rice and cereal crops fertilizer applications, DOA, Bangkok, 129.

Table 10. Institutions that are involved and have supported the project.

Activity/year	Project Site	Partner Institution	Contribution/Role
All activities 2011-2014		IRRI (CURE-support from IFAD)	Financial, recommendations and evaluation
All activities 2011-2014		Bureau of Rice Research and Development	Comments and recommendations
SSNM/2015		Rice Department	Financial, recommendations and evaluation
SSNM/2014 No. farmers/fields: 10	Mueang, Phanna Nikhom, Phang Khon, Akat Amnuai, Kut Bak districts, Sakon Nakhon province	Sakon Nakhon Rice Research Center	Validation or demonstration fields, interview with the farmers, data collection and analysis
SSNM/2012-2013 No. farmers/fields: 8	Mueang, Nong Saeng, Kumphawapi, Si That, Nong Wua So districts, Udon Thani province	Udon Thani Rice Research Center	Validation or demonstration fields, interview with farmers, data collection and analysis
SSNM/2010-11 No. farmers/fields: 14	Bueng Kan, Phon Phisai districts, Nong Khai province	Nong Khai Rice Research Center	Validation or demonstration fields, interview with farmers, data collection and analysis
SSNM/ No. farmers/fields: 17 Year: 2012-2013	Mueang, Chanuman, Hua Taphan, Lue Amnat, Pathum Ratchawongsa, Phana, Senangkhanikhom districts, Amnat Charoen province	Ubon Ratchathani Rice Research Center	Validation or demonstration fields, interview with farmers, data collection and analysis, soil Analyses
SSNM/2012-2013 No. farmers/fields: 21	Mueang, Kut Khaopun, Khemarat, Trakan PhuetPhon, Natan, Pho Sai, Si Mueang Mai, Sirindhorn, Buntharik, Thung Si Udom, Nam Yuen, Khueang Nai, Samrong, Muang Sam Sip, Lao Suea Kok, Det Udom, Phibun Mangsahan, Warin Chamrap districts, Ubon Ratchathani province		
SSNM/ No. farmers/fields: 9 Year: 2012-2013	Maha Chana Chai, Pa Tio, Loeng Nok Tha, Thai Charoen, Kut Chum, Kho Wang, Sai Mun districts, Yasothon province		
SSNM/: 2014 No. farmers/fields: 11	Yang Chum Noi, Rasi Salai, Kanthararom, Kantharalak, Non Khun, Benchalak, Phayudistricts, Sisaket province		
AWD/2011-2014 No. farmers/fields: 8	Mueang, Khueang Nai districts, Ubon Ratchathani province		
DSR/ 2013-2014 No. farmers/fields: 12	Mueang, Khueang Nai districts, Ubon Ratchathani province		
PVS/2011-2014 No. farmers/fields: 38	Khong, Phimai districts, Nakhon Ratchasima province, Khueang Nai district, Ubon Ratchathani province	Ubon Ratchathani Rice Research Center Nakhon Ratchasima Rice Research Center	Validation or demonstration fields, interview with farmers, data collection and analysis
SSNM/2010-11 No. farmers/fields: 29 Year:	Chum Phuang, Lam Thamencha, Sida, Khong, Non Sung, Kham Sakaesaeng, Non Thai, Ban Lueam, Huai Thalaeng, Prathai, Phimai, Non Daeng, Bua Yai districts, Nakhon Ratchasima province	Nakhon Ratchasima Rice Research Center Sakon Nakhon Rice Research Center	Validation or demonstration fields, interview with farmers, data collection and analysis

Table 11. List of publications and posters created during the CURE project 2010-14.

Title	Author	Event and Venue	Presentation
Nutrient Management for Rainfed Lowland Rice in the Northeastern Thailand	W. Wongboon, Y. Konboon, V. Chamarerk, and P. Mekwattanakarn	The 3rd International Rice Congress, 2010, Vietnam	Poster
Alternate Wetting and Drying Technology for irrigated rice in the Northeaster in Thailand	W. Wongboon, V. Chamarerk, P. Chaiwat, and S. Haefele	The annual meeting of Rice Research Centers in the northeastern cluster, 2011, Thailand	Proceeding paper
Consortium for Unfavorable Rice Environments (CURE)	V. Chamarerk	The annual meeting of Rice Research Centers in the northeastern cluster, 2010, Thailand.	Proceeding paper
Site-specific Nutrient Management for Rainfed Lowland Rice in Northeastern Thailand	W. Wongboon, K. Sansen, S. Lertna, S. Saleeto, C. Srisomphan, V. Chamarerk, S. Haefele, Y. Kato	The 4th International Rice Congress, 2014, Thailand	Poster
Alternate Wetting and Drying Technology: An Option for Reducing a Production Cost in a Dry Season Rice Crop	K. Sansen, W. Wongboon, V. Chamareck, Y. Kato	The 4th International Rice Congress, 2014, Thailand	Poster

Thailand

Submergence-prone environments

Surviving the depths: Thailand's RD45 deepwater rice variety

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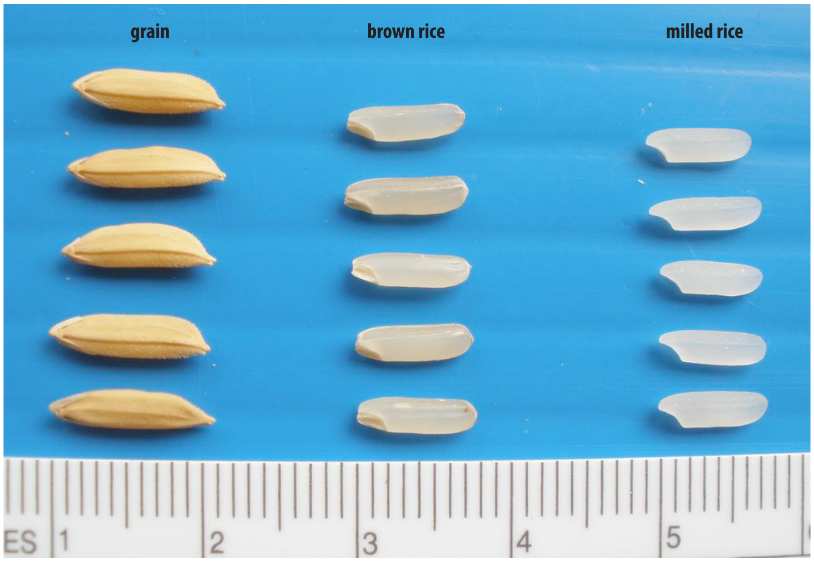
Rice is not merely a staple food to more than 65 million Thais. It is their life and culture, and their country's most important export crop. Add to the versatility of rice, breeding and promoting deepwater rice varieties such as RD45 is proving to be attractive to a market that is already being created.

RD45: Deepwater rice variety as good-tasting farmers' food

A promising line, PCR89151-27-9-155, or RD45, was developed to effectively adapt to flood-prone areas in Thailand. RD45 has been derived through the Deepwater Rice Varietal Research and Development Project, whose objective was to develop a deepwater rice variety that has good grain and cooking quality; and to produce food for the farmer's family and seeds for the next cropping season in the unfavorable rice ecosystem. The history of RD45 started with an initial idea for improving the quality of KDML 105, the most popular variety in the rainfed lowland ecosystem, which not only has good physical and chemical grain properties that make it soft and tender after being cooked, but is also aromatic. The improvement of this variety consisted of conventional breeding using KDML 105 as a donor and Hawm Nai Pon, a Thai traditional rice variety, and IR46, an IRRI rice variety, as sources for good aroma and high-yielding traits, respectively. The cross was made in 1989 at the Prachinburi Rice Research Center, designated as PCR89151, following the processes of progenies selection under natural and artificial conditions for resistance to biotic stresses and tolerance to abiotic stresses, as well as through on-station yield trials, and multi-location yield trials with farmers' participation. In 2010, an outstanding promising line, PCR89151-27-9-155, was drawn and released as a recommended variety to farmers in deepwater areas.

The second important idea is to validate and deliver RD45 for increasing yield and quality of rice in an unfavorable deepwater ecosystem. Because the fields remain submerged in water for more than six months and are usually subject to many stresses, such as problem soils and unpredictable combination of drought and flood, the deepwater rice ecosystem often suffers from low productivity. In addition, the deepwater rice grown



by farmers have highly chalky grains that tend to break easily and a high amylose content that makes the rice hard and fluffy when cooked, making them unpalatable for consumption.

Characteristics of RD45

The RD45 is photo-period sensitive variety that flowers from 25 October to 2 November. Its plant height is 170 centimeters, while its panicle length is 27.7 centimeters. Its grain has an average length of 10.2 millimeters, and width of 2.73 millimeters, making it longer and slightly wider than those of brown rice grain (7.44 millimeters length and 2.33 millimeters width). However, its slender shape, with slight chalkiness, is similar to brown rice.

- Its milling quality is 55.4 % of head rice. The amylose content of its grain is 16.35%. It yields 3.2 tons per hectare on average in deepwater (50–100 centimeters), and 4.0 tons per hectare in shallow water (<50 centimeters). Regarding the results of screening for elongation ability, RD45 shows good elongation ability (score 3) at water level 90 centimeters, intermediate (score 5) at water level 110 centimeters and poor (score 9) at 150 centimeters.
- It is best suited to grow at water depth of 50–100 centimeters, which is drained during mid-November.
- RD45 has an early maturity compared to other deepwater rice varieties, hence allowing farmers to plant during the short off-season.

Cooked rice – soft and aromatic

Sweet rice

Rice crackers

Sushi

- Besides being a soft aromatic rice when cooked, RD 45 is used for making rice crackers, sushi, and sweet rice for desserts.

The rise of deepwater rice varieties in Thailand

The rainfed ecosystem is one of the main rice ecosystems in Thailand, the other being irrigated. It is divided into four sub-ecosystems: deepwater, floating (also called flood-prone), upland, and rainfed lowland mainly distributed in the northeast and northern regions and make up about 79 % of the country's total rice production.[1] These rice ecosystems are not only prone to environmental stresses such as flooding, but are severely affected by them. In 2011, for instance, floods covered a significant portion of the country's rice fields, raising concerns about its effect on global rice supply and prices.

Much of flood-tolerant rice is mostly grown along the Chao Phraya River in the central plain of Thailand, the country's most productive rice area. Flood-prone areas have declined from 850,000 thousand hectares in 1982 to 500,000 hectares in 1992, approximately 5.8% of the cultivated rice area (Charoendham et al., 1995). However, it has also been reported that 21.9% of Thailand's total rice area is planted to flood-tolerant rice (Huke and Huke, 1997).

Flood-prone areas provide around one million tons of rice each year. There are two types of flood-tolerant rice grown. The deepwater rice (DWR) type, such as such as Ayuthaya1 that grows at an average water depth of 50–100 centimeters for 3–4 months. Another type is the floating rice (FR), such as Prachinburi2, Plai Ngahm Prachinburi, and Khao Bahnnah 432. These are grown at a water depth of 1–5 meters with a flooding period of 3–4 months.

Submergence tolerance is the most essential characteristic for DWR types, while good elongating and kneeing abilities to keep the first three leaves above the water level are desirable for FR. In the past, monocrop cultivation of traditional rice varieties gave low yields of only 1.2–1.8 tons per hectare. Since 2000, however, double cropping has been practiced using modern varieties (Sommut et al., 2004). High-yielding pre- or post-flood rice crops with short maturity duration have also been used in some areas of the eastern and central plains of Thailand.

Although, deepwater rice areas account for only 5% of the total 10-million-hectares rice areas in Thailand, they are home to 20,315 families. They encompass 62,246 hectares covering over 46 provinces, 162 districts, and 621 sub-districts (Chinucha, 2014).

DWR: RD45 at Flowering stage.

DWR: RD45 at Maturity stage.

[1] www.oae.go.th

Table 1. Different traits of four deepwater rice varieties.

Varieties	Flowering date	Height (cm)	Yield ton ha^{-1}	Brown rice shape (mm.)			Aroma	% amylose content
				Length	Width	Thickness		
RD45	25 Oct.-2 Nov.	170	3.2-4.0	7.07	2.13	1.75	Intermediate	16.35
AYY1	6-10 Nov.	180	4.4-5.1	7.69	2.32	1.87	None	26.35
PCR2	18-25 Nov.	180	3.6-5.2	7.29	2.34	1.86	None	30.20
PCR1	20-25 Nov.	170	3.4	7.03	2.48	1.88	None	28.40

Varieties in flood-prone areas of Thailand:

1. DWR growing at 50-100 centimeters. The popular varieties include Ayutthai, Prachinburi2, and Prachinburi1.
2. FR can grow and produce yield at a water level of 100-200 centimeters or more. Most of these are traditional varieties, such as Plai Ngahm Prachinburi, Khao Bahnna 432, Leuang Yai, and Khaew Yai.

Farmers in flood-prone areas grow rice only during the wet season. They plant in mid-April and harvest their rice crops in six to eight months. The yield FR is lower than of DWR and those varieties grow in rainfed lowland. The fields are affected by droughts during the early stage of planting, and then later experience prolonged flooding of three to four months.

When farmers' fields have enough water, they perform these two practices in growing the rice: (1) *Growing early maturing rice* (RD45) during the wet season. After harvesting RD45, they plant a non-photo sensitive variety with a short maturity period (95–100 days) for the dry season; and, (2) Growing rice only *before* and *after* flooding and fallow the field *during* the flooding period. Farmers take advantage of water from canals or pools for these two patterns.

However, majority of farmers in the flood-prone areas only grow rice during rainy season. The varieties they plant during this time are either deepwater or floating rice.

Top areas where deepwater rice is grown

The top five provinces of deepwater rice growing are Prachinburi (17,681 hectares), Nakhonnayok (9,704 hectares), Ayutthaya (8,859 hectares), Chaiyapom (6,908 hectares), and Nakhon Ratchasima (5,929 hectares) (Chinucha, 2014).

The famous varieties are Khao Leuang, Plai Ngahm Prachinburi, Khao Long, Khao Khaw Diaw and Leb Meu Nahng 111 (Chinucha, 2014). Moreover, there are modern deepwater varieties, namely Prachinburi 1 (PCR 1), Prachinburi 2 (PCR 2), and Ayutthaya 1 (AYY 1). Table 1 shows the different traits of these modern deepwater rice varieties.

In general, DWR farmers do not prefer rice with high amylose content (25–29%) because the cooked rice is

Fig. 1 Deepwater rice area of Thailand.
No. 18 Prachinburi
No. 12 Nakhonnayok
No. 10 Ayutthaya
No. 29 Chaiyapom
No. 20 Nakhonratchasima

FR: Plaingahm Prachinburi (PNG).

FR: Khao Bahnna 432 (KBN432).

friable and relatively tough. However, since the quality is suitable for rice noodle processing, the farmers sell their produce to rice mills and purchase good cooking quality rice, such as Khoa Dawk Mali 105 (KDML105). Although the farmers' preferred KDML105, the variety is not suited for deepwater ecosystem.

Breeding flood-tolerant rice through CURE partnerships

Although it accounts for a small portion of the country's total rice production, flood-tolerant rice still plays a major role for farmers who cannot plant other varieties of rice or crops that can be grown in flood-prone areas. Crops like lotus and jute are sometimes grown in some areas but these are more costly and riskier than cultivating flood-tolerant rice. Furthermore, other crops can be grown only in certain areas and have a limited market, and thus, are not highly profitable. Despite the few benefits, the farmers still opt to grow flood-tolerant rice.

Generally, farmers can recognize good grain quality as much as yield for their own consumption. However, they have grown accustomed to the rice varieties with poor grain grown in the flood-prone ecosystem by utilizing rice varieties with varying grain qualities. Farmers sell them to rice millers, who in turn sell the rice to parboiled rice millers, and rice noodle and rice flour producers. Buying rice with good grain quality for consumption is still an alternative.

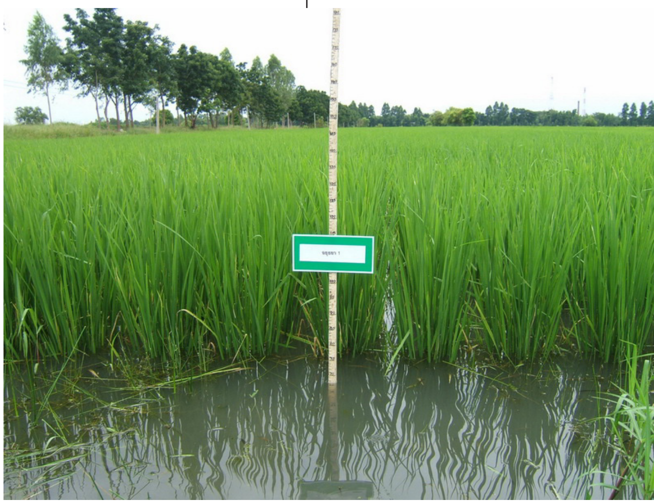
Difficulty in cultivating and disseminating rice varieties in the flood-prone ecosystem stems from an insufficient amount of quality seeds of adapted varieties since flood-tolerant varieties are usually location-specific and are costly. There is also lack of efficient extension system to disseminate existing technologies, breeders that work on the ecosystem, and attractive rice policies to encourage farmers to grow these varieties.

Fortunately, efforts to improve rice varieties with good grain quality as well as proper yield suitable for flood-prone areas have been made by researchers at PRRC, Rice Research Institute of Thailand, in collaboration with the International Rice Research Institute (IRRI), under the Thai-IRRI Deepwater Rice Collaborative Project on varietal improvement and training initiated in 1986. From that period up to 1990, three flood-tolerant varieties were released: RD 17, RD 19, and Huntra 60. These were tolerant to 50–100 centimeters water depth and carried some desirable traits from IRRI lines and Thai traditional varieties. Unfortunately, these varieties were not widely adopted by farmers due to the photoperiod insensitivity of RD 17 and high chalky grain of RD 19 and Huntra 60. However, it is important to note that RD 19 is the most appropriate prototype for a high-yielding flood-tolerant cultivar and is still being used in PRRC's breeding program.

The flood-tolerant rice collaborative project was strengthened further after the signing of the Memorandum of Understanding between the Ministry of

DWR; RD45 at Vegetative phase.

DWR; RD45 at flowering phase.



DWR; Ayuttaya1 (AYY1) at Vegetative phase.

DWR; Prachinburi2 (PCR2) at Vegetative phase.

Agriculture and Cooperatives and IRRI when Her Royal Highness, Princess Maha Chakri Sirindhorn visited the institute on 29 August 1991. As a result, a major part of the IRRI flood-tolerant rice breeding program was transferred to Thailand in 1992. IRRI and Thailand jointly developed and distributed plant breeding materials and associated technologies for improving production in flood-prone rice areas of South and Southeast Asia, with the PRRC responsible for improving flood-tolerant rice in the central plain of Thailand. PRRC's Rice Department was able to develop the promising line, PCR89151-27-9-155 that could effectively adapt to deepwater and has a quality close to KDML105. PCR89151-27-9-155 was conventionally bred in 1989 and took 10 years from crossing and selecting lines to get a promising line, and another 5 years for multi-location trials.

Since 2003, the collaborative project has been made more efficient for flood-prone rice ecosystems of Thailand in terms of validation and dissemination of new technologies for increasing productivity through the Consortium for Unfavorable Rice Environments (CURE). Seed production and distribution activities were supported by the Rice Department and the local government with the participation of the Department of Agricultural Extension, Ministry of Agriculture and Cooperatives. Table 2 traces the development of DWR variety in 1989 until its release in 2010 and distribution in 2011 onwards.

For three years (1998-2000), the line had been tested in deepwater rice intra-station yield trials. In 2001-2006, the experiment was conducted through farmer's field yield trials in Nadee, Mueang; Prachinburi, Pahkpee; Nakhon Nayok; and Chachoengsao. The yield of intra-station trial each year was 3.2, 2.7, and 2.7 tons per hectare, respectively. The plant height was 192–208 centimeters

Table 2: The development and distribution of deepwater rice variety, 2011–2015.

1989-1997	1998-2000	2001-2006	2007-2009	2010	2011-2015
-Breeding -Conventional selection	-Study on advance trial	-Study on multi-location trials -Physical & Chemical analysis in grain -Diseases & Insect pests -Fertilizer response -Elongation ability	Seed multiplication: Breeder seed	RD, released RD45 Seed multiplication: Breeder seed	Seed production and distribution -Breeder seed: PRRC -Foundation seed: PRRC -Extension seed: Prachatnakam Agriculture Cooperative (PAC), Community Rice Center (CRC) - More than 1,240 hectares and 620 families are growing RD45
Location: PRRC	Location: PRRC	Location :Prachinburi :Nakhonnayok :Chachoengsao	Location: PRRC	Location: PRRC	Location: PRRC, PAC, RC

and flowering occurred on 24 to 28 October. The water level was 65, 85, and 120 centimeters, respectively, with prolonged flooding of 67, 89, and 94 days. In addition, the line was studied for yield potential on shallow (10 centimeters) and deep water (64 centimeters). While the yield of shallow water was 4.03 tons per hectare, that of deepwater condition was 3.19 tons per hectare. The yield of four sites on farmer field yield trials were 3.4, 3.1, 3.1 and 3.7 tons per hectare (the water level was about 30 to 115 centimeters).

The four-year project, which began in 2011, was completed in October 2015. However, seed distribution continues in 2016-2017.

From the lab to the fields: PVS trials, seed production, and seed distribution

The pilot test was funded by the local Thai government. It was conducted in 100 sites involving 100 households from 10 sub-districts in Prachinburi Province spanning 69 hectares. There were a total of 99 participants, 62 of whom were male farmers and 37 were female.

From the crop samples taken of 15 m^2 with 3 replications per site, results showed that the average yield in 100 sites was 3 tons per hectare, with the maximum yield reaching 3.4 tons per hectare, and the minimum yield, 1.7 ton per hectare. Table 3 shows the comparison in yields of other local varieties against RD45.

The farmers involved in the project underwent training before the start of the pilot test. They were trained three times in rice seed production at PRRC to learn about seed production and the practice of removing off type at the vegetative stage, heading stage, and maturity stage. The farmers visited the Community Rice Center (CRC) at Jadee-hak, Ratchaburi where a rice seed production project was successful.

In 2010, the project launched interviews to assess the farmers' approval

Table 3: Data on rice yield of RD45 versus other local varieties.

Lists	Sub-districts (10 farmers/ Sub-districts)	Average yield (t/ha)
1	Nong Prong	2.2
2	Dong Kratong Yam	1.7
3	Kok Peb	2.4
4	Tah Ngahm	3.4
5	Nong Kee	2.8
6	Sunpan Tah	3.1
7	Wang Tahkian	3.0
8	Yan Ree	3.1
9	Gaw Loi	2.1
10	Bahn Hoi	1.8

Table 4: RD45 seed multiplication and distribution (ton), 2011–2015.

Years	PRRC		PAC Certified Seed (ton)	CRC Certified Seed (ton)	Total/ton (ton)	*Seed distributions (7 provinces)	
	Breeder seed (ton)	Foundation seed (ton)				**Areas/ha	No. households
2015	1	10	40	105	155	1,240	620
2014	1	10	40	95	145	1,160	620
2013	1	10	45	90	145	1,160	580
2012	1.5	15	40	87	142	1,136	568
2011	1.5	10	40	85	135	1,080	540

* seed rate 125 kg/ha.
** 7 provinces: Prachinburi, Nakhonnayok, Chachoengsao, Sakaew, Ayutthaya, Nakhon Ratchasima and Chaiyapom
Source: Prachinburi Rice Research Center (PRRC), Prachanthakam Agriculture Cooperation (PAC) and Community Rice Seed Center (CRC)

Table 5. Department of Rice seed standard.

Seed type (classes)	Purity seed (%) at least	Red rice (not over)	Other seed (not over)	Seed mix (not over)	Seed germination (%) at least
Foundation seed	98%	None	1 seed (in 500 gm)	2%	80%
Registered seed	98%	1 seeds (in 500 gm)	5 seeds (in 500 gm)	2%	80%
Certified seed	98%	5 seeds (in 500 gm)	15 seeds (in 500 gm)	2%	80%

of the variety. Results showed that, out of the 99 farmers, 92 liked RD45 for its ability to survive in deepwater. They also mentioned that they were impressed by the other traits of RD45 such as its high-yielding ability, big panicles, slender-shaped grains, gentle aroma, and softness when cooked.

Moreover, questionnaires were sent to 99 farmers asking about their acceptance of RD45. Ninety-two farmers accepted its cooking quality, plant type (such as height, length, etc.) and yield.

From 2011 to 2015, PRRC produced 1–1.5 tons of breeder seed and 10–15 tons of foundation seed (see Table 4). Certified seeds were produced by the Prachanthakam Agriculture Cooperation (PAC) and the CRC. PAC produced around 40–45 tons per year of certified seeds. CRC produced 85, 87, 90, 95, and 105 tons, respectively, for 2011-2015. The total foundation and certified seeds produced during the four-year period, were 135, 137, 145, 145, and 155 tons, respectively. The seeds have been distributed to nine provinces covering 1,080–1,240 hectares.

RD45 is grown in about 15% (27,386 hectares) of the total deepwater rice area in Nakhon and Prachinburi provinces, while the rest are planted with AYY1 (15%), PCR2, (15%), and other traditional varieties (55%).

Upon checking the seed quality, PRRC would report to a cooperative and community rice seed center (CRSC), which would then distribute the seeds based on the rice seed standard issued by the Department of Rice (Table 5).

Although the coverage and seed distribution of RD45 have increased over the years (as shown in Tables 6, 7 and 8), the impact of RD45 on farmers' income is yet to be assessed. However, initial projections made based on the seed distribution in 9 provinces from 2011-2015 are presented in Table 8. Moreover, as of 2015, a total of 285 RD45 seeds have been distributed, covering 2,280 hectares and 1,875 farmers (see Table 9).

Policy Space

Securing rice production through fair trade and rice development. Attesting to the government's commitment to mobilize and sustain the country's rice development, Prime Minister Prayut Chan-o-cha identified internal and external

Table 6. RD45 seed multiplication and distribution of foundation seeds (kg), 2011–2015.

Type of seed	Amount distributed (kg)	No. of provinces	No. of households distributed	Area coverage (ha)	Center involved in distribution
2011	10,500	9	1,833	5,280	PRRC
2012	15,000	9	1,833	5,424	PRRC
2013	10,000	9	1,958	5,640	PRRC
2014	10,000	9	2,133	6,144	PRRC
2015	10,000	9	2,292	6,600	PRRC

Table 7. RD45 certified seeds distribution (kg), 2011–2015.

Type of seed	Amount distributed (kg)	Province	No. of farmers distributed*	Area coverage (ha)	Center involved in distribution
2011	230,000	Prachinburi, Naknonnayok	1.917	1.840	PRRC, Agr.Co-op.CRSC. Smart Farmer
2012	240,000	Prachinburi, Naknonnayok,Sakaew, Chachoengsao	2.000	1.920	PRRC, Agr.Co-op.CRSC. Smart Farmer
2013	245,000	Prachinburi, Naknonnayok,Sakaew, Chachoengsao Ayutthaya	2.042	1.960	PRRC, Agr.Co-op.CRSC. Smart Farmer
2014	263,000	Prachinburi, Naknonnayok,Sakaew, Chachoengsao Ayutthaya, Nakhon Ratchama,Chaiyapom	2.192	2,104	PRRC, Agr.Co-op.CRSC. Smart Farmer
2015	285,000	Prachinburi, Naknonnayok,Sakaew, Chachoengsao Ayutthaya, Nakhon Ratchama,Chaiyapom,Chataburi	2.375	2,288	PRRC, Agr.Co-op.CRSC. Smart Farmer

PRRC: Prachinburi Rice Research Center, Agri. Co-op: Agriculture cooperative.

Table 8. RD45 seed distributions in Prachinburi, Nakhonnayok, Chachoengsao, Sakaew, Chantaburi, Ayutthaya, Nakhon Ratchasima and Chaiyapom

Year	Breeder's seed	Foundation seed	Registered seed				Seed distributions		Expected production/ income 2016	
	PRRC (kg)		Agr.Co-op	CRSC	Smart Farmer (Leader Farmer)	Total (kg)	No. households	Areas/ha	Yield (ton)	Income (bath)1/
2011	1,500	10,000	40,000	85,000	95,000	220,000	1,833	1,760	5,280	39,600,000
2012	1,500	15,000	40,000	87,000	99,000	226,000	1,883	1,808	5,424	40,680,000
2013	1,000	10,000	43,000	90,000	102,000	235,000	1,958	1,880	5,640	42,300,000
2014	1,000	10,000	56,000	95,000	102,000	256,000	2,133	2,048	6,144	46,080,000
2015	1,000	10,000	61,000	105,000	109,000	275,000	2,292	2,200	6,600	49,500,000

1/ 7,000 baht (1/198 USD) per ton (grain)

Table 9. Beneficiaries of stress-tolerant rice varieties, 2015

Country	Ecosystem	Varieties	Area (has.)	All
Thailand	Submergence	RD45		
		Breeder Seeds	6,600.00	2,292.00
		Foundation Seeds	6,600.00	2,292.00
		Certified Seeds	2,288.00	2,108.00
	Subtotal		**15,488.00**	**6,692.00**

factors which determine demand and supply of rice and those that influence Thai rice volumes, prices, and market condition. Among the factors he cited include production condition (particularly cultivation area), soil quality, irrigation system, technological advancement, R&D as well as climate change which amplifies the effects of floods, droughts, and other natural disasters. Moreover, according to PM Prayut, the global rice market has a tendency to grow steadily with increasing of demand and population, while rice production and trade face new and existing challenges, market volatility, and stiffer competition. Thus, the National Rice Policy Committee outlined a strategic development on rice market and trade policy and set a goal for "Thailand to become leader of world's rice market." This goal is to be achieved through the development of efficient market mechanism and cooperation with ASEAN member countries to ensure a balance between production and trade sectors, and for Thailand to become a consistent global rice producer, which will result in better livelihood of farmers, strong farmer institutions, and a fair trade system. There are seven strategies on rice outlined by the government: (1) sustainable and stable rice development plan; (2) creation of fairness in rice trade system; (3) promotion and implementation of rice production and trade at a standard level; (4) capacity enhancement of rice trade system; (5) promotion of rice consumption value; (6) creation of innovation; and (7) capacity enhancement of logistics management.

PM Prayut noted, however, that mobilization of such strategies will be a collaboration between public, private, people, and farmer sectors, with the private sector acting as a main driver in trading with support and facilitation from the public sector to ensure that rice trade system is operated in line with market mechanism. Cooperation and trade between the Thai private sector and large-scaled customers as well as opening new markets and establishing partnerships with rice-producing ASEAN countries will also be promoted.

Cultural Space

Cooking and eating rice in various ways. As the country's source of diverse cultures and traditions, rice in Thailand is versatile. Non-glutinous rice can be cooked and served as part of savory meals and snacks. The expression *Kin kao* (consume rice) represents how rice is central to Thai food culture. *Kin kao laew reu young* (Have you eaten rice yet?) is the common way of greeting among Thais.

Besides the usual way of boiling rice, there are various methods to recycle leftover rice. One way is to mix the leftover rice with newly boiled rice in the cooking pot. Lefover rice can be dried in sun as *Kao Taak,* which is generally consumed during long journeys in the countryside. Meanwhile, the crust at the bottom of the rice pan or pot is also eaten as *Kao Tang*. It is also used to make *Kao Tang Tod,* a dessert prepared by frying *Kao Tang* and sprinkling coconut flakes and sugar.

Another rice dessert is *Kao Tu*, which is prepared by grinding dried leftover rice and mixing it with syrup and roasted grounded rice grains. It is molded in the shape of a thick coin and smoked with fragrant candle, *kenanga,* and jasmine (Gomez, 2001).

REFERENCES

Buddhaboon, C., Rossopa, B., Dungsoongnern, P., Romyen, P., & Kunket, K. (2014). Proceedings from the Annual General Conference of Central, East and West Rice Research Center: Deepwater rice area in Thailand: Recent situation and trend. Thailand Rice Department, 26-28 March 2014, pp. 140-150.

Charoendham, P., Palaklang ,W., Niyomvit, L., Prommanart, P., & Charoensilp ,N. (1995). Survey of deepwater rice cultivation in Thailand 1992/1993 [Data file]. Prachinburi Rice Research Center,Thailand.

Childs, N. (2014). Rice Outlook No. (RCS-14K), November 2014. Economic Research Service, United States Department of Agriculture, USA. Gomez KA. 2001. Rice, the Grain of Culture. Siam Society Lecture Series, The Siam Society, Bangkok, Thailand, 20 September 2001.

Huke, R.E., & Huke, E.H. (1997). Rice area by type of culture [Data file]. South, Southeast, and East Asia. A revised and updated database. Los Banos, Philippines: International Rice Research Institute.

Land Development Department. (2013). Map showing the occurrence of flood in Thailand. Office of Natural Calamity and Agricultural Risk Prevention, Land Development Department, Thailand.

Prachinburi Rice Research Center. (2010). The summary report of the increase rice production efficiency and good rice variety distribution. Prachinburi Rice Research Center,Thailand. ISBN: 978-974-403-711-4.

Sommut, W., Bose, M.L., Singh, V.P., & Hossain, M. (2004). Agricultural and livelihoods in the flood-prone ecosystem in Thailand. Kasetsart J. 25: 69-89.

World Grain Situation and Outlook, USDA, November 2014.

Thailand

Salinity-prone environments

When salinity maligns rice productivity: Managing salt-affected paddy fields in NE Thailand by using new tolerant rice variety

Duangjai Suriyaarunroj

While the problem on salinity, which is detrimental to rice production, is yet to be resolved, researchers and community leaders continue to find ways to improve the condition and livelihood of affected farmers by championing promising technological interventions.

A good yield for a start

In an effort to help farmers obtain reasonable and profitable rice yields and incomes in salt-affected paddy fields, researchers at Nakhon Ratchasima Rice Research Center (NRM RRC) plan to promote the salinity-tolerant cultivar UBN02123-50R-B-3 to more farmers in the region and improve the traits of the popular glutinous rice, RD6, in terms of blast resistance, aroma, and salt tolerance.

In 2015, the researchers from the center provided seeds of different rice cultivars to farmers who selected their preferred cultivars a year prior to the participatory varietal selection (PVS). The seeds provided, which were based from what the farmers had collected, were classified as foundation seeds, and were grown during the wet season in the same year.

Manual harvesting proved better than mechanical harvesting, which caused the mixing of rice cultivars. In 2016, this farmers' group will perform seed multiplication and distribute the adopted technology and rice cultivars to new members in their group.

To compare the yield potential of three rice lines in saline soils, namely, UBN02124-RGD-MAS-90-5-2-2, UBN02123-50R-B-3 (with saltol), and UBN02124-RGD-MAS-192-5-5, trials were conducted in separate farmer's fields where soil salinity ranged from 0.51-1.24 dS/m and pH 5.96-7.63, while water salinity ranged from 1.85-2.25 dS/m and pH 5.82-7.09. The results showed that UBN02123-50R-B-3 gave the highest yield of 2.27 tons per hectare.

In the same year, 2015, researchers from the center also distributed rice seeds of the salinity-tolerant line to farmers in the villages of Khok Phrom and Dan Chake, Non Thai district, where farmers normally occupy an average of 2.4 hectares paddy field per family and where rice, corn, sugar cane, cassava, and chili pepper are usually grown.

In 2014, the UBN02123-50R-B-3 rice line was also distributed to farmers in Sakon Nakhon where paddy fields were affected by salinity. About 40 farmers from five villages in Phang Khon district attended training on growing new salinity-tolerant rice varieties and producing seed under saline condition. The farmers were interested in the salinity-tolerant lines but, because this line was non-glutinous and not the glutinous rice that farmers in the upper northeastern consume, there was a need to evaluate other suitable varieties. Thus, a new project aimed at improving the popular glutinous rice RD6 to be blast resistant, aromatic, and salinity-tolerant is underway. Moreover, it is also important to target the dissemination of UBN02123-50R-B-3 in areas where non-glutinous rice is more popular.

The need to solve the salinity problem: Backtracking to research beginnings

Soil and water salinity are critical constraints in to rice production in large rice-growing areas in Thailand and is particularly evident in the northeastern region. The northeastern region, also known as the Khorat plateau, is a saucer-shaped area situated at 90-200 meters above sea level. It occupies almost one-third of Thailand's land area, and encompasses nearly half the country's rice lands. The region produces both long-grain non-glutinous and glutinous rice. However, the average size of rice farms in this region is smaller compared to other regions. Irrigation potential in the region is limited due to the undulating topography. Soil erosion, droughts, and salinity during the dry season aggravate the problem. Moreover, the water-holding capacity of soils in the region is extremely low. Farmers in saline-affected areas in the upper part of the northeastern region prefer to grow sticky rice such as RD6, which is the most popular rice variety. On the other hand, farmers in the lower part of the region prefer to grow non-sticky rice, especially Khao Dawk Mali 105 (KDML 105). In both parts, however, farmers grow KDML 105 for the commercial market.

Researches on land preparation, water and soil management, nutrient management, and breeding for salinity-tolerant rice had been conducted to solve the problem on salinity in paddy fields. However, these presented no clear solutions probably due to the different environments and soil conditions in each area that required different management practices. In Nakhon Ratchasima, Sakon Nakhon, Khon Kaen and Udornthani Provinces, for instance, the recorded levels of soil stresses such as salinity had very high spatial variability ranging from 0.1–60 dS/m, and pH levels of 6.3–9.5.

In addition to the four provinces, there are other areas where salinity has spread out and has affected rice growing areas (Table 1). Currently, there are no suitable stress-tolerant rice varieties or technologies available for these areas. Moreover, the government has yet to make a policy to produce breeder's seeds, foundation seeds, and register seeds or extension seeds of salinity-tolerant varieties in areas where farmers

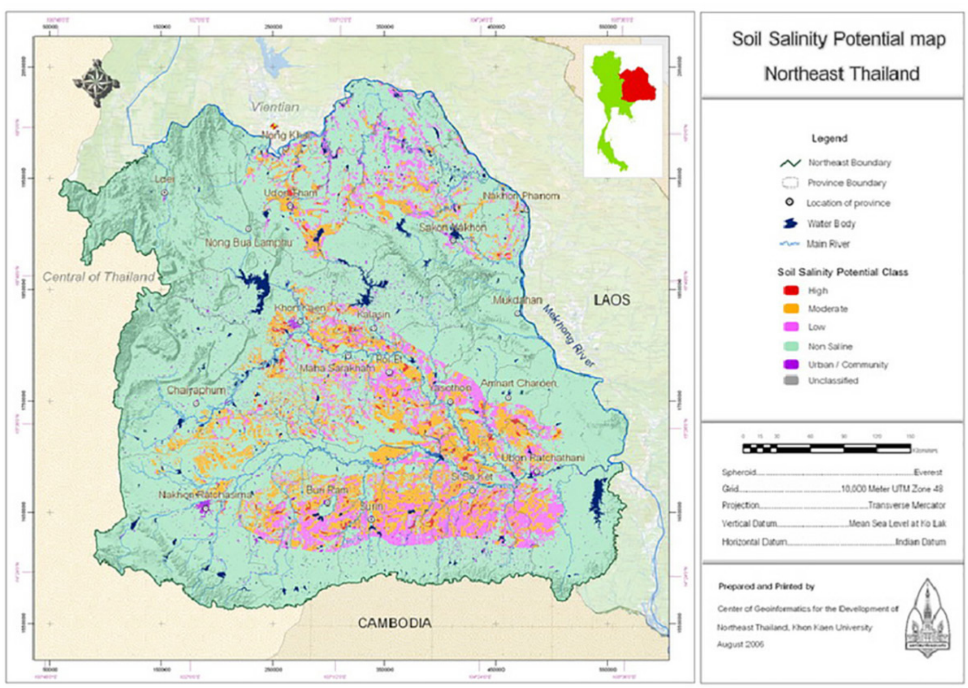


Figure 1. Rice production areas affected by salinity.

Table 1. Salt-affected areas in Northeastern Thailand, 1990.

Province	Class of salinity													
	1.lowland with highest salinity		2. lowland with high salinity		3.lowland with moderate salinity		4. lowland with slight salinity		5. upland with rock salt		6. non-saline area		Total	
	Ha	%	Ha	%	Ha	%	Ha	%	Ha	%	ha	%	ha	%
Kalasin	178.7	0.03	1,010	0.15	20,648	2.97	95,449	13.74	55,676	8.01	418,278	60.21	591,239	85.11
Khon Kaen	5644.2	0.52	120,956	1.12	70,931	6.52	233,651	21.46	216,348	19.87	422,613	38.82	961,342	88.31
Chaiyaphum	1740.0	0.14	4,140	0.32	175,990	1.38	90,060	7.05	115,845	9.07	754,109	59.01	983,484	76.97
Nakhon Phanom	293.3	0.05	101	0.02	313	0.06	128,477	23.18	272,638	49.19	131,641	23.75	533,464	96.25
Nakhon Ratchasima	22627.0	1.10	33,314	1.63	268,010	13.08	345,053	16.84	419,834	20.48	670,978	32.17	1,759,817	85.87
Buri Ram	45.3	0.01	3,451	0.33	53,154	5.15	344,527	33.38	274,950	26.64	330,053	31.97	1,006,179	97.48
Maha Sarakham	320.5	0.06	2,527	0.48	106,508	20.13	233,473	44.12	177,943	33.63	3,568	0.67	524,340	99.09
Yasothon	-	-		-	15,768	3.79	166,672	40.05	78,720	18.92	147,657	35.48	408,817	98.24
Roi Et	3679.0	0.44	110,057	13.26	96,902	11.68	337,107	40.62	94,390	11.37	173,842	20.95	815,977	98.32
Si Sa Ket	22.7	0.01	514	0.06	82,163	9.29	374,478	42.36	58,067	6.57	304,325	34.42	819,571	92.71
Sakon Nakhon	648.0	0.07	3,131	0.32	16,315	1.70	169,994	17.70	461,878	48.08	244,432	25.45	896,398	93.32
Surin	-	-	468	0.06	44,862	5.52	377,690	46.49	108,167	13.31	262,158	32.27	793,345	97.65
Nong Khai	280.0	0.04	152	0.02	4,307	0.59	237,979	32.45	426,129	58.12	28,880	3.94	697,727	95.16
Udon Thani	1838.2	0.12	3,895	0.25	52,095	3.34	226,672	14.54	328,045	21.04	790,370	50.70	1,402,916	89.99
Ubon Ratchathani	338.2	0.02	974	0.05	42,608	2.25	338,089	17.88	216,611	11.46	1,162,531	61.49	1,761,139	93.15

Note:
1. lowland with highest salinity = 1.02-2.05% salt patch (16-32 dS/m)
2. lowland with high salinity = 0.51-1.02% salt patch (8-16 dS/m)
3. lowland with moderate salinity = 0.26-0.51% salt patch (4-8 dS/m)
4. lowland with slight salinity = 0.13-0.26% salt patch (2-4 dS/m)
5. upland with rock salt = 0-0.13% salt (0-2 dS/m)
6. non-saline area

need them in small volumes. For the meantime, a small public office has been authorized to produce salinity-tolerant seeds and distribute them to farmers who need them for severely saline areas. However, the quality and amount of seeds it produces are insufficient to meet the demand.

In 2013, NRM RRC had been tasked with resolving the problem of growing rice in the saline-affected soil. The center had already conducted national researches for several years prior to its partnership with the International Rice Research Institute (IRRI). Valuable information for salinity-tolerant rice was provided to the center, thus, forging a new form of research partnership from the Consortium for Unfavorable Rice Environments (CURE) project under IFAD. Since then, the center had made significant progress in research, which included gaining knowledge, acquiring new technology, and exchanging rice varieties and information of salinity-tolerant rice varieties to Thai farmers.

After more than ten years, through experiments of growing rice in salt-affected area from 2013 to 2015 at Khok Phrom in Nakhon Ratchasim, researchers found three rice cultivars suitable in the saline-affected areas:

1. UBN02123-50R-B-3: An aromatic and blast-resistant salinity-tolerant rice line with 25.6% amylose content. It is photo-period sensitive and non-glutinous.
2. UBN02124-RGD-MAS-90-5-2-2: An aromatic salinity-tolerant rice line with good aroma and soft texture when cooked. It has an amylose content of approximately 15–18%.
3. UBN01070-RGDU-221-76-UBN-1-RGDU-1-2-38-NRM-1: A salinity-tolerant rice line with long grain and big panicle. When cooked, it has good aroma and soft texture.

UBN02123-50R-B-3 was developed in 2002 at Ubonratchathani Rice Research Center under the Research and Development of Rainfed Lowland Rice for Upper Northern and Northeastern Thailand Project using marker-assisted selection to help select the salinity-tolerant, aromatic, waxy and blast-resistant rice. The project, a collaboration between IRRI, the National Center for Genetic Engineering and Biotechnology, and the Rice Research Institute Human Resources Development project grant by the Rockefeller Foundation, conducted rice breeding using IR66946-3R-196-1-1 (FL496)—a progeny from the cross IR29/Pokkali—as salinity-tolerant donor and KDML105. Further studies of the agronomic characteristics of this line was conducted in observation trial, intra-station yield trial, inter-station yield trial, and farmer field yield trial in 2006-2010 across 13 locations in northern and northeastern Thailand where non-glutinous rice is grown.

The promising line was then analyzed for cooking quality and palatability. In 2011, it was tested for reaction to blast and bacterial leaf blight disease, brown plant hopper, gall midge as well as nitrogen-fertilizer response, as shown in Table 2. Finally, UBN02123-50R-B-3 was selected to be the aromatic, blast-resistant, salinity-tolerant line. The cultivar's characteristics were also analyzed. This cultivar is ready to be released, while the other two are still being tested in the field.

Meanwhile, UBN02123-50R-B-3 and UBN01070-RGDU-221-76-UBN-1-RGDU-1-2-38-NRM-1 were grown in 2013 in saline soil at NRM RRC, and were compared to 10 other salt-tolerant cultivars with KDML105 as check variety. Yield and yield component of the tested cultivars were recorded and analyzed (Table 3). Results show that the two lines produced higher yields than KDML105 but lower than the other eight lines that, however, were not accepted by farmers in the area.

Testing the salinity-tolerant lines in the farmers' fields

To disseminate salinity-tolerant rice production technologies and promote new salinity-tolerant rice lines, CURE activities were carried out in two villages in Nakhon Ratchasima. In Sida District, where the soil is slightly saline and acidic, three rice lines were grown and compared with the rice grown in highly saline fields. Out of these lines, UBN02123-50R-B-3 gave the highest yield in both growing areas during the assessment period. In

Table 2. Reaction to blast disease of three rice cultivars grown in the Rice Research Center in northern and northeastern Thailand.

Cultivars	Blast reaction					
	CRI	MHS	PRE	KKN	NKI	SKN
Wet season 2006						
UBN02123-50R-B-3	-	-	-	HR	MR	HR
KDML 105	-	-	-	S	S	S
RD15	-	-	-	S	S	S
Wet season 2008						
UBN02123-50R-B-3	-	R	MR	-	R	MR
KDML 105	-	S	S	-	S	S
RD15	-	S	S	-	S	S
Wet season 2009						
UBN02123-50R-B-3	MR	MR	S	-	R	R
KDML 105	S	S	S	-	S	S
RD33	R	S	S	-	MR	MR
Wet season 2010						
UBN02123-50R-B-3	MR	MR	-	-	MR	MR
KDML 105	HS	HS	HS	-	HS	HS

Sites:
CRI = Ching Rai Rice Researh Center
MHS = Mae Hong Son Rice Research Center
PRE = Prae Rice Research Center
KKN = Khon Kaen Rice Researh Center
NKI = Nong Khai Rice Research Center
SKN = Sakon Nakhon Rice Research Center

Blast reaction:
HR = Highly resistant
MR – Moderately resistant
R - Resistant
S - Susceptible

Table 3. Yield and yield component of rice cultivars grown in saline paddy field of Nakhon Ratchasima Rice Research Center, northeastern Thailand (2013 wet season).

Cultivars	Yield (t/ha)	Height (cm)	Tillering	Panicle/Hill	Days to Flowering	Panicle length	1000 Grain Weight	Filled grain	Unfilled grain
UBN01070-RGDU-221-76-UBN-1-RGDU-1-2-38-NRM-1	3.55	129.70	10	10	123	25.23	29.57	95	22
UBN02123-50R-B-3(with saltol)	3.47	132.63	8	8	117	26.47	27.37	113	25
IR11T242	3.70	97.97	14	14	112	26.73	27.50	85	24
IR11T235	3.97	101.00	13	13	83	24.44	24.63	97	26
NONA BOKRA	5.25	121.23	14	14	107	24.11	29.77	110	23
CSR 28	3.59	106.53	14	14	111	24.50	27.93	86	25
AT 401	4.17	107.30	10	10	112	24.61	30.10	140	30
A 69-1	4.68	105.90	17	17	86	24.17	29.33	96	23
IR10T105(IR85197-5-1-2-1)	4.88	110.70	15	15	121	26.33	28.63	108	29
UBN02123-50(R)-B-3	3.34	134.47	9	9	118	26.54	27.90	123	23
IR77674-3B-8-2-2-14-1-AJY 5	4.72	120.39	12	12	120	25.21	28.17	89	22
KDML 105	3.21	130.37	11	11	124	26.65	25.37	97	29
Mean	2.76	104.96	10	10	103	24.32	2.72	94	21
LSD	0.95934	9.49	2.72	2.70	17.65	1.80	0.26	17.34	7.82
C.V.(%)	21.2236	5.53	16.17	16.09	10.62	4.50	5.79	11.30	22.62

Khok Phrom village, three rice lines were grown under highly saline and alkaline soils. During the PVS at maturity stage, the farmers selected UBN02123-50R-B-3, which had the highest yield and the most preferred plant type. The same rice line was also tried in Sakon Nakhon where a high level of salinity in paddy fields was observed. The results of this field trial were highly variable although these indicated that UBN02123-50R-B-3 also gave higher yield than the other cultivars. Considering these results, training for farmers were conducted in the three districts to promote the new salinity-tolerant line.

In Khok Phrom and Khang Ploo villages of Non Thai District, where paddy fields were mostly affected by salinity, the farmers indicated a high demand for salinity-tolerant cultivars. Even farmers in Buri Ram, where the soil was mildly affected by salinity, expressed their desire to improve their rice-growing technologies to boost their rice production. Thus, the project aims to conduct similar training programs for improving rice yields in the salt-affected area of Phang Khon District in Sakon Nakhon in early 2016.

There is a wide spatial variability of stress in Khok Phrom where salinity ranges from 1–14 dS/m and alkalinity ranges from pH 6–13. Rice plants can be grown until they mature to give reasonable yield only in some areas where salinity and alkalinity levels are at 2 dS/m and 8, respectively. But most areas suffer from higher levels of salinity and alkalinity.

Upon learning of the farmers' interest in growing salinity-tolerant non-glutinous rice variety and the demand for its seeds, NRM RRC set up an experiment to evaluate and select the salinity-tolerant rice lines for this village through farmer participatory approaches in Khok Phrom. The activity involved a group of farmers that was eventually supported by the Department of Cooperative Auditing. The three tested lines, KDML105, RD6, and UBN02123-50R-B-3, were grown. The results showed UBN02123-50R-B-3 and KDML105 gave better yield in July than rice grown in August and September. This was because these lines are photoperiod sensitive and had longer duration for grain filling in July when the length of daytime was longer than in the other two months.

In 2013, to disseminate and promote the new salinity-tolerant rice lines to the farmers, another experiment was conducted to compare the characteristics of KDML105 and RD15 with UBN02123-50R-B-3 in salt-affected farmers' fields in Sida and Khok Phrom in July, August, and September. Farmers in these villages were very interested in the growth and agronomic characteristics of UBN02123-50R-B-3, which yielded 2.64 tons per hectare when grown in May and 3.89 tons per hectare in July. They requested for the seeds of the salinity-tolerant line, which they planned to grow in their own fields during the wet season in 2014. The results of experiment are shown in Table 4.

The UBN02123-50R-B-3 rice line was promoted to grow in saline farmer fields at Phang Khon District, Sakon Nakhon and

Table 4. Yield and yield component of rice grown in slightly saline soil at Sida district, Nakhon Ratchasima province, wet season 2013.

Sowing Date	VAR	Yield (ton ha^{-1}) at14%MC	DTF 75%	No. of grain (per panicle)		Tillering	Height (cm)	Panicle/ hill
				filled	Unfill			
May	RD15	1.43	146	85	10	7	148	7
	KDML	1.89	148	87	8	6	138	6
	UBN	2.68	153	97	11	8	152	8
	CV (%)	53	1.86	19	22.66	30.22	9.64	31
July	RD15	2.97	110	105	7	7	134	7
	KDML	3.78	116	123	9	7	145	7
	UBN	3.89	118	108	11	8	140	8
	CV (%)	12	2.70	14.15	23.03	9.58	3.61	9.58

at the upper part of northeast Thailand. Results showed that the new rice variety UBN02123-50R-B-3 gave higher yield in the alkaline saline soil of Nakhon Ratchasima. In Sakon Nakhon, where the soil is slightly acidic and saline, three rice varieties were grown during wet season in 2014. The results showed that rice grown in July, when rainwater was sufficient, had no difference in yield. But in August and September, when water levels dropped causing increase in salinity, UBN02123-50R-B-3 produced a higher yield than the other two varieties. Farmers agreed to grow this line, and requested the rice seeds for the next wet season.

CURE-supported activities

The following activities were enhanced and supported by CURE in collaboration with the Thai Rice Department, the Chai Pattana Foundation, Land Development Department, and the Office of the Non-Formal and Informal Education.

Trials on effective planting method. In 2013, a farmers' group in Khok Phrom, with about 120 members from 61 families and a combined paddy field of about 144 hectares, tried and accepted 40–45 day-old seedlings. Meanwhile, in a farmer's field yield trial, the researchers from NRM RRC transplanted 35-day-old seedling using 3 seedlings/hill method, while farmers used 5–7 seedlings/hill. No yield was recorded due to high salinity and alkalinity. In 2014, the experiment was repeated using older and fewer seedlings. Transplanting was done after a high amount of rain had occurred and the paddy field had been washed once to remove salinity. Farmers practiced 1–2 seedling/hill to reduce cost and improve rice production resulting in similar yield as before. During the wet season in 2015, the farmers transplanted 42-day-old seeds using 1 seedling per hill, and 4 kilograms per hectare of seeds for broadcasting in a field with salinity and pH levels ranging from 0.57–2.76 dS/m and 6.07–7.77, respectively, during the rainy season. The results showed that the 1 seedling per hill transplanting of 42-day-old seedlings gave higher yield than through seed broadcasting. With the farmers' current management practice, an average yield of about 2.5 tons per hectare was attained. The farmer's group agreed to share this practice of using 40–45-day-old seedlings with 1 seedling/hill method to members of the group from other villages.

Practical ways to improve paddy field. Instead of leaving the salt-affected paddy field fallow during the growing season, as some farmers had done, the leader of the farmers' group tried to improve the soil by building the bund to prevent the saline water from infiltrating the field and ploughing up and over the field to incorporate plant matter into the soil. He did this annually for five to six years. During the rainy season, he also drained the water in the field to keep fresh water within.

Introduction of water reservoir. Most fields with no water reservoirs for young seedlings during the early period due to droughts produce very low or no rice yield. Setting up a water reservoir closest to a salt-affected paddy field with 2–3 centimeters of water can help young seedling survive droughts when water from normal rain recedes at the later stages of rice growth.

Rainfall distribution recordings. For a decade, the head of the community farmers' group had recorded the annual rainfall distribution in each area to establish a rice growing plan. In 2014, this plan was used as a guide in selecting the date with the high confidence or percentage of rainfall for transplanting. The results in both the trial field and actual farmer's field showed good rice grain yields. In 2015, the same rainfall distribution plan was used, and farmers obtained good yield as well.

Consistent findings on rice yield of the new salinity line. In 2013, a Thai royal project requested UBN02123-50R-B-3 rice seed to grow in salt-affected area at Phu Phan Ratchanivet Palace paddy field in Sakon Nakhon (Fig. 1). The result showed that the line gave good yield in mildly saline soil. To test the feasibility of cultivating this cultivar under different soil conditions, it was grown in a salt-affected farmer's field at Khok Phrom in 2014. The same cultivar was compared with KDML105 and RD15. The results of the study showed that UBN02123-50R-B-3 gave the highest yield under the farmer's field condition.

Figure 1. UBN02123-50R-B-3 rice cultivars grown at Phu Phan Ratchanivet Palace paddy field in 2013 wet season.

Figure 2. Comparing rice grown between farmer practice and adopted technology during 2015 wet season after 3 years of rice varieties selection and technology transfer.

A new farmers' group formed: Non Thai farmers' group

Sixty-one villagers (16 men, 45 women) from 13 villages in Non Thai formed the Non Thai farmers' group. The members were interested in the stress-tolerant rice varieties and technologies set up in a farmer's field yield trial. They practiced the new technologies in their own paddy field beside the research area (yields of both trials conducted by farmers and researchers have not been obtained as of publication date). Based on field observations, the rice fields that belong to farmers who did not join the group obtained an average rice yield of only about 0.4 ton per hectare compared to the farmers' fields that followed the adopted technology and used recommended rice cultivars as shown in Figure 2.

For this group of farmers, a preference analysis for rough, milled, and cooked rice was performed. Results are presented in Table 5.

It was found that, initially, for rough rice, almost 100% of farmers preferred local cultivars, particularly Khao Pahk Maw 148 because of the large grains. In terms of milled rice, however, most preferred Khao Tah Haeng 17. More farmers did not select UBN02123-50R-B-3 based on its milled grain quality, which was rough, and the texture, which was similar to KDML105 that farmers did not like (Table 5). However, when cooked, it was the most preferred cultivar because of its aroma and softness compared with the others.

Spreading good seeds and promising technologies

In 2015, farmers in Non Thai were the first to obtain the new salinity-tolerant line and technology to be tested in their salt- and alkaline-affected paddy fields. They transplanted 42-day-old seedlings of the new rice line in their fields using the 1-seedling method. Although the rice yield they obtained was not so high (Table 6), they were pleased nonetheless with the good grain yield considering they hardly had any harvest several years before.

From the results of rice grown in the wet season of 2015, members of

Table 5. Preference analysis of farmers in Nakhon Ratchasima province for UBN02123-50R-B-3 rice cultivar compared to Leuang Pratew 123, Khao Tah Haeng 17, and Khao Pahk Maw 148 (2014).

Type	Cultivars	Pimai district, Nakhon Ratchasima province		
		No. of farmers	Like (%)	Dislike (%)
Rough rice	UBN02123-50R-B-3	35	49	51
	Leuang Pratew 123	32	63	37
	Khao Tah Haeng 17	34	32	68
	Khao Pahk Maw 148	34	97	3
Milled rice	UBN02123-50R-B-3	35	57	43
	Leuang Pratew 123	34	32	68
	Khao Tah Haeng 17	34	68	32
	Khao Pahk Maw 148	34	56	44
Cooked rice	UBN02123-50R-B-3	34	53	47
	Leuang Pratew 123	32	6	94
	Khao Tah Haeng 17	33	12	88
	Khao Pahk Maw 148	32	9	91

Table 6: Yield of salinity-tolerant rice grown in farmers' field at Khok Phrom village in 2015 wet season.

Planting method	No	VAR	Yield (ton ha^{-1}) AVG
Broadcast	1	UBN02123-50R-B-3	2.2
	2	UBN02124-192	2.1
	3	UBN02124-90	2.5
	4	G45-2-67-29-NRM-1	1.5
	5	KDML 105	1.8
Transplanting	1	UBN02123-50R-B-3	3.6
	2	UBN02124-192	3.0
	3	UBN02124-90	4.0
	4	G45-2-67-29-NRM-1	2.1

the farmers' group were able to get the seeds for the next growing season and disseminate them to new members in other provinces. The group leader, Mana Siang Santia, explained that their next goal was to distribute the salinity-tolerant rice seeds and appropriate farming practices to salt-affected paddy fields to more farmers with the same problem.

DRIVERS OF CHANGE

The frontrunner: the leader of Non Thai farmers' group. Mr. Mana has been a strong advocate of salinity-tolerant rice varieties, encouraging other farmers to learn and cultivate such varieties, for more than three years. Before his exposure to salinity-tolerant varieties, the paddy fields in his district were unproductive. For a few years, Mr. Mana had been in contact with the Land Development Department and had attended rice seminars organized by several institutions. He was recognized as an excellent local field philosopher by the local government. Nowadays, he collaborates with several government and non-government organizations on rice and soil researches to help farmers in his own district in Nakhon Ratchasima to grow rice properly (Fig. 4).

Partner projects: From royalty to grassroots. Breeding activities for salinity-tolerance were supported by NRM RRC, the Chai Pattana Foundation (under Her Royal Highness Princess Maha Chakri Sirindhorn), and the Thailand

Land Development Project. These were welcome developments for farmers who still performed their long accustomed practices in cultivating rice in salt-affected paddy fields, which produced very low or no yields, and lost interest in seeking assistance from the government. In addition to these projects, in 2014-2015, a school for non-formal education participated in studying the technologies and practices for growing recommended rice cultivars in saline-affected farmer's fields. After obtaining the appropriate technology and rice cultivar suited for their target fields, the school will distribute the rice seeds and appropriate technologies to farmers who have the same paddy field condition. The school's project will be conducted in the next two years.

Technological support: CURE's evaluation and selection of salinity-tolerant rice cultivars for saline soils. CURE's objective to reduce risk and improve farmers' livelihood complements the goal of the Thai Rice Department to conduct research and development for salt-tolerant rice by facilitating the scaling out of developed technologies. With the support from IFAD and other sources, the selection of salinity-tolerant rice cultivars for using as donor and for continuous improvement was conducted to achieve these objectives. Ninety genotypes of rice composed of 58 lines from the International Network for Genetic Evaluation of Rice of IRRI, 20 genotypes from Thai breeding program, and 12 from the Rice Gene Discovery Unit at Kasetsart University were evaluated during the 2013 wet season using randomized complete block with 3 replications with KDML105 as check variety. The test cultivars were transplanted using 25 days old seedlings where soil salinity and soil pH ranged from 1.9–2.1 dS/m and 6.6–6.8, respectively, and the water salinity and pH ranged from 3.6–3.95 dS/m and 6.6–7.1, respectively. The results showed that 11 cultivars yielded higher than the check variety; the top three yielding cultivars were NONA BOKRA (5.3 tons per hectare), IR85197-5-1-2-1 (4.9 tons per hectare), and IR 77674-3B-8-2-2-14-1-AJY5 (4.7 tons per hectare) compared to KDML105 (3.2 tons per hectare). The selected cultivars will be used as donors in the breeding program to improve salinity tolerance.

Financial space

Opportunities for scaling-up. At the beginning, rice lines were developed from 2000-2014 through PhD scholarships supported by the Rockefeller Foundation. The rice lines were then studied in the rainfed lowland rice areas in upper northern and northeastern Thailand from 2004-2012 through funding provided by the Thai government, the Rice Department, the Rice Gene Discovery Unit at Kasetsart University, and the National Science and Technology Development Agency. In 2013, the rice lines were disseminated to farmers in Nakhon Ratchasima and Sakon Nakhon. The study was continued in 2014 to the present with funding from CURE and the Thai government.

Meanwhile, preference for non-glutinous rice is major factor in the marketability of salinity-tolerant rice. Most Thai people prefer aromatic and soft textured rice such as the non-glutinous KDML105 and the glutinous RD6. Populations in the lower part of northeastern Thailand mostly consume non-glutinous, aromatic rice that has soft texture, while most farmers in the upper part of northeastern Thailand consume glutinous rice. When new rice varieties are to be introduced, farmers and consumers alike will consider the same properties of rice based on their preference. In fact, the idea of a new salinity-tolerant line, which is non-glutinous, did not immediately appeal to the farmers since the new salinity-tolerant rice has a high amylose content (25.6%) which tends to cook firm and dry. Even though some farmers prefer hard-textured rice, they will refuse to grow a different rice cultivar due to the commercial popularity of soft-textured rice and fear of losing profits.

Policy space

Policies with emphasis on technology transfer. The Thai Rice Department policy is currently targeted at transferring technology to farmers and helping them cope with rice production constraints. The policy emphasizes creating new technologies to mitigate, if not solve, the adverse effects on local rice fields that will be practical to use in similar unfavorable environments. At present, Nakhon Ratchasima Rice Research Center is improving the Thai Rice Knowledge Bank to add new technical knowledge that is targeted to address specific problems in different areas.

Moreover, the Bureau of Rice Research and Development started a new policy in 2009 encouraging researchers to conduct studies that will prove to be practical for farmers to use in suitable areas, and will support the dissemination of the adopted new technologies or best practices for farmers in target areas. However, in some cases, stakeholders are opposed to the development and dissemination of new rice varieties to keep prices for their existing varieties high and protect their interest.

Political space

When the authorities don't take heed, and agricultural manufacturers secure their profit. Because there was only a small group of farmers in salt-affected area, and the volume of rice seed needed was likewise small, the government showed little attention to the problem, discouraging the farmers from seeking help. Meanwhile, manufacturing companies of fertilizers, herbicides and insecticides are stakeholders that are indirectly involved in the development technology. Manufacturing companies may oppose the usage or adoption of new technologies if these aim to reduce the use of fertilizers, pesticides, or herbicides to protect their businesses. Farmers who believe and prefer using these chemical products may also disagree in developing such technologies.

Partnership space

Community leaders championing new technologies. The head of the community farmer's group is the first partner to generate the dissemination of new salinity-tolerant rice line and the adopted technologies. With the assistance of the chief of Non Thai District Agricultural Extension Office, the Non Thai office of the Non-formal and Informal Education planned and invited the members of the farmers' group to learn about the salt-tolerant rice, the appropriate technology, and follow up the activity to reach the objective of the group. After the success of the current group, the technology will then be mobilized to paddy fields with similar condition to improve their livelihood as well.

Learning space

Learning materials for knowledge dissemination. Two posters were used to disseminate the salinity-tolerant rice line and the technology used for its evaluation and selection during the Rice Congress in 2014. A training module, *Rice improvement technology for salt-affected area at KokProm village tambon Non Thai, Non Thai district, Nakhon Ratchasima province*, was released in 2015. A leaflet was also prepared for sharing the technology about the new salinity-tolerant rice and discussions on adopted technology with farmers, lecturers, extension officers, and researchers during the training for Non Thai Office of the Non-formal and Informal Education and Udorn Thani farmers' group in January 2016.

REFERENCES

Arunin, S. (1984). Characteristic and management of salt-affected soils in the Northeast of Thailand. Ecology and management of problem soil in Asia, Taiwan. Food and Fertilizer Technology Center for the Asian and Pacific Region, (FFTC book series no. 27).

Arunin, S. (1992). Proceedings of the International Symposium on Strategies for Utilizing Salt-affected Lands: Strategies for utilizing salt affected lands in Thailand. Bangkok: Department of Land Development, Ministry of Agriculture and Cooperatives, 17–25 February 1992, p 26–37.

Yuwaniyom, A. (1997). Salt soil from Northeast Thailand. Official information about salt soil. Salt soil improvement group and Division of salt and water conservation. Land Development Department: 115-119.

Land Development Department. (2002). Soil salinity map of Khon Kaen Province. Bangkok.

Nagase, K. (1992). Proceedings of International Symposium on Strategies for Utilizing Salt Affected Lands: Improvement of salt injured paddy field in Tung Kula Rong Hai Northeast Thailand. Bangkok, Thailand, 17-25 February 1992, p 519-531.

Saraphirom P, Wirojanagud, W., & Srisuk, K. (2013). Impact of climate change on waterlogging and salinity distributions in Huai Khamrian subwatershed, NE Thailand. Environ Earth Sci. 70:887-900.

United States Laboratory Staff. (1954). Diagnosis and Improvement of Saline and Alkali Soils. In: Agriculture Handbook No. 60 USDA. 160 p.

Yuvaniyama, A. (1994). Management of Saline Soils in the Northeast of Thailand. Thesis. Tokyo University of Agriculture. Japan. 212 p.

Yuvaniyama A. (2004). Manual of saline soils management and reclamation. Technical paper of research and development of salt-affected areas group [in Thai]. Bangkok: Land Development Department.

Vietnam

Salinity-prone environments
Submergence-prone environments

Keeping Vietnam's rice bowl productive through climate-ready varieties

Nguyen Thi Lang, Rakesh Kumar Singh, and Digna Manzanilla

Rice production is no longer dictated by quantity alone, but it now also involves the quality of rice, and requires compatibility with the environment to ensure some level of sustainability to the farmers' livelihood.

Increasing rice productivity along with improving quality

Across the globe, a number of challenges have continuously impaired rice production. These include (i) the increasing presence of damaging insects and diseases which encourage indiscriminate use of pesticides; (ii) fertilizer abuse due to increased pressure on yield; and (iii) the expansion of cultivated marginal lands that are mostly prone to submergence and drought. The combination of numerous methods based on recent advances in genomic research has been developed to address these challenges, and at the same time, to develop quality rice varieties for export (Lang et al., 2010).

To increase productivity and improve quality, new rice varieties need to be resistant or tolerant of numerous biotic and abiotic stresses and to include high levels of nutrients. They must save on water as well as pesticides and chemical fertilizers. Great efforts have been focused on germplasm research to discover genes resistant to disease and pests, efficient in using N and P, and characterized with good grain quality and productivity. Innovative approaches like screening of novel genetic resources, introgression of donor alleles using marker assisted selection (MAS) and multiple biotic and abiotic stress tolerance with high yield and good grain quality have been employed recently to sustain the growth in rice productivity (Buu and Lang, 2007).

Encouraging collective action for widespread technology adoption

Rice is a major export commodity of Vietnam and a source of livelihood for smallholder farmers, particularly in the Mekong Delta, which contributes more than fifty percent of the country's total rice production. Millions of farmers in the Delta region live below poverty level as their farming is affected by occurrences of drought, flooding, and salinity from saltwater intrusion. Some 156,290 hectares of total rice area in Vietnam are affected by submergence, while an estimated 1,867,910 hectares of the total rice crop area are affected by salinity. The Consortium for Unfavorable Rice Environments (CURE) recognizes the importance of developing modern climate-ready rice varieties as well as associated management practices that respond to the challenges of climatic variability in such stress-prone areas. In the case of Vietnam, a rice variety whose seeds are yet to be multiplied, first needs to undergo evaluation trials at the Cuu Long Delta Rice Research Institute (CLRRI). Moreover, an equally daunting task is bringing the new varieties to the farmers' fields where productivity is still not at optimal level due to the different stresses and because there are institutional constraints related to extension activities. The national protocol for varietal release and dissemination requires that provincial officers and farmers are invited to assess the performance of the varieties in the field. Upon initial assessment and acceptance, farmers and local staff in the districts and provinces would evaluate the variety this time for deployment and multiplication. This is an ideal strategy to bring rice varieties to the local farmers. The Ministry of Agriculture and Rural Development (MARD), CURE as funded by the International Fund for Agricultural Development (IFAD), and other funding institutions, which share the same goal of raising productivity in the submergence- and salinity-prone rice areas in the Mekong Delta, supported the development, validation, and eventual dissemination of climate-ready varieties. The key in achieving such goal involves partnerships and participatory approaches for a need-based strategy of developing varieties and eventual delivery to farmers. CLRRI, as a NARES partner, has been part of CURE since 2005, with collaborative research focused on varietal development of salt-tolerant varieties.

With the development of climate-ready varieties, scaling-up or dissemination of seeds is done by province, following the locality's plan every six months, that is, Winter – Spring and Summer–Autumn. For instance, in the case of Winter–Spring crop, the plan of Can Tho is to expand OM7347 cultivar as the province's own initiative to cover a wider area. Normally, this expansion initiative requires inclusion of five key rice varieties, that is, local or extra varieties and promising varieties, all of which are to be included in the plan for developing the rice sector for each province.

Advancing rice research through collaborations

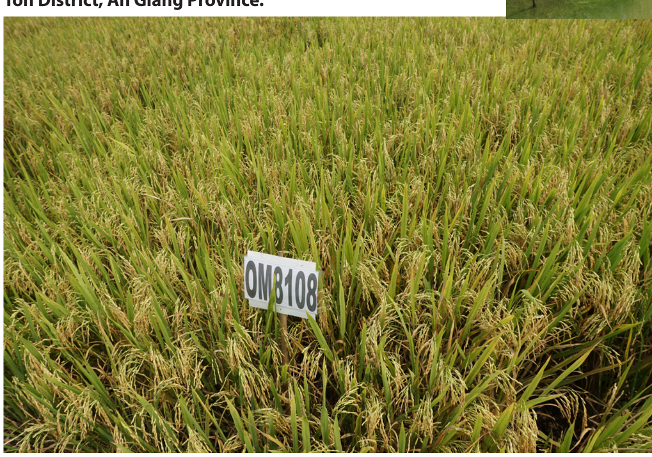
Confronting the huge challenges of developing varieties in the less favorable rice areas necessitates partnerships and strategies that capitalize on and foster synergism. Having strong financial support from the government and other external programs, Vietnam has been successful in scientific and development work leading to releases of a significant number of climate-resilient varieties and suitable crop management practices. The well-focused development agenda of the national government has been a driving force in raising the level of productivity in difficult rice ecosystems. Moreover, Vietnam's participation in CURE as a network of institutions has also been instrumental in catalyzing support, resources and capacities that is now creating impact on Vietnam's rice productivity at the farmers' fields, and producing surplus for local and export markets.

For more than a decade, CLRRI has been breeding for submergence, salinity and anaerobic germination using marker-assisted selection (MAS) by taking off from the prior knowledge and system of rice breeding at the institute. In collaboration with other Vietnam institutions, and IRRI under the IFAD-funded CURE program and

Model rice at Ap Ba village, Thi Xa, Gai rai disctrict, Bac Lieu province, Dong Xuan season.

Climate Change Affecting Land Use in the Mekong Delta (CLUES) project as funded by the Australian Centre for International Agricultural Research (ACIAR), CLRRI has developed several climate-resilient rice varieties such as submergence- and salinity-tolerant varieties by introgressing *Saltol* and *Sub1* QTLs into elite genotypes. For its expansion efforts, partners distributed seeds of submergence-tolerant elite lines for field evaluation in farmers' fields. Since 2010, CURE partners in Vietnam have aimed at (1) breeding and developing new rice varieties (two to three varieties) suitable for export standards and adapted to the conditions in the Mekong Delta, submergence-tolerant, early-maturing, high-yielding, and with good quality, and resistant to major insects/pests; (2) and establishing technical procedures for cultivation of new rice varieties in sub-agro-ecological zones of the Delta.

With CLRRI's involvement in CURE activities, at least 11 varieties have been supported that have now been released (Table 1). Most of these stress-tolerant varieties can provide, on average, a yield advantage of 1.0–1.5 tons per hectare compared to that of the farmers' popular varieties. CLRRI records show that the average yield of a popular variety in the mid-1990s was only 3.0 tons per hectare. But with the use of new rice varieties that have been released over the years, the average yield has increased and in fact, has reached 5.5 tons per hectare in 2015 for salinity-tolerant varieties, and about 6.0 tons per hectare for submergence-tolerant varieties (Fig. 1 and 2). The released varieties that have been developed through MAS are OM4900 (both for salinity- and submergence-prone areas), OM8108, and OM6677; and for submergence, OM8927, IR64-Sub1 (recommended), and OM10252. The other varieties in the table have been developed through conventional breeding methods that required at least a decade–worth of work. Results of adaptation trials were used to pass the rigorous evaluation process. For instance, Fig. 3 shows the comparative yield performance of three varieties included in trials in 2011-2012, which indicated the good performance of submergence-tolerant varieties, particularly OM 4900. This eventually became part of the bases for farmers' selection and continued adoption in affected environments to this day.



Rice varieties growing at Tan Thuan Village, Ta Danh, Tri Ton District, An Giang Province.

Table 1. Most in-demand stress-tolerant varieties and their characteristics

Genotype	Maturity (days)	Origin	1000 grain wt. (g)	Amylose (%)	Cooked rice quality	BPH	Blast	BLB (score)	Yield (ton/ha)	Remarks by farmers
Salinity-tolerant varieties										
OM4900	95–100	Origin: C53/ Jasmine 85/	28.8	16.8	Glutinous, and aromatic rice; "World's longest cooking rice"; excellent for cooking, requires less water	Tolerant	Tolerant	3–5	7–8	Excellent (Salinity-tolerant, high-yielding, aromatic) no lodging
OM6377	95–100	IR64/Type3 LN_1	27.5	19.6	Glutinous, soft, excellent for cooking, good elongation trait, requires less water	Tolerant	Tolerant	5	6–8.5	Good (Salinity-tolerant) Kien Giang, Bac Lieu, and Tra Vinh (5% of areas grow this variety)
OM8108	93–85	Hybrid of M362/ AS996	27	24	Glutinous	Tolerant	Tolerant	3–5	6–8	Very good (Salinity-tolerant, high yielding)
OM5953	95–100		26	22	Glutinous, hard	Tolerant	Tolerant	3–5	5–7	Very good (Salinity-tolerant, high yielding)
OM5629	95–100	Origin: C27/IR64/ C27	27.3	24.5	Glutinous	Tolerant	Tolerant	3–5	5–7	Excellent (Salinity-tolerant, high-yielding); Bac Lieu, Kien Giang and Tra Vinh; farmers liked the variety; >408 ha in 2009 and increased to 1,496 ha in the Mekong Delta in 2010.
OM5954	95–100	Origin: OM 1644/OM 1490/ OM 1644	27.5	21.86	Glutinous, aromatic	Tolerant	Tolerant	3	5–7	Good (high-yielding), tolerant of salinity, alkalinity, iron and boron toxicity, and phosphorous and zinc deficiency; suitable for irrigated and rainfed lowland areas; popularly grown in salinity- and alkaline-rice areas such as Kien Giang, Tra Vinh and Long An
OM5981	95–105	IR 28/ AS 996/ AS 996	27.5	23.5	Glutinous	Tolerant	Tolerant	3–5	5–7	Good (high-yielding, tolerant of salinity, alkalinity, iron and boron toxicity, and phosphorous and zinc deficiency; suitable for irrigated and rainfed lowland areas
OM6677	95–105	M 22 and AS 996	26.8	23	Glutinous	Tolerant	Tolerant	5	5–7.5	Very good (Salinity-tolerant, high yielding)
Submergence-tolerant varieties										
OM8927	95–100	Pana/ IRSub1	25.6	21	Glutinous and aromatic	Tolerant	Tolerant	3–5	6–7	Good (Submergence-tolerant, high-yielding)
IR64-Sub1 (recommended for release)	105–110	IRRI	26.5	24.5	Glutinous	No data	No data	3–5	3–4	Excellent (Submergence-tolerant)
OM4900	95–100	OM606/ IR4459262-1-3-3	28.8	16.8	Glutinous and aromatic	Tolerant	Tolerant	3–5	7–8	Very good (Submergence-tolerant, high-yielding, aromatic)
OM10252	95–100	OM6162/ OM6161	27.5	22	Glutinous	Tolerant	Tolerant	5	7–8.5	Very good (Submergence-tolerant, high-yielding)

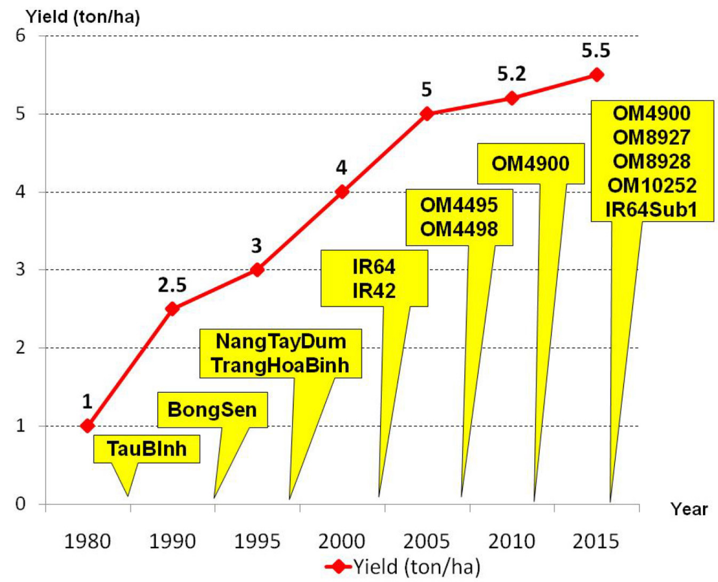


Figure 1. Average yield of salinity-tolerant varieties in coastal areas in southern Vietnam, Mekong Delta.

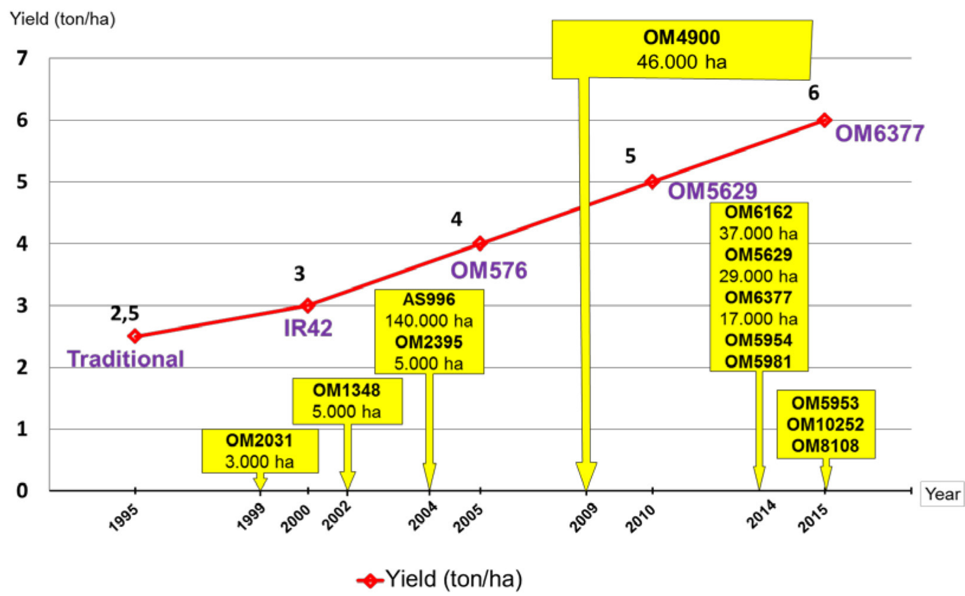


Figure 2. Average yield and areas planted with stagnant submergence-tolerant varieties in coastal areas in southern Vietnam, Mekong Delta.

From breeding to adaptive research to varietal releases

Over the past years, a number of milestones in rice breeding development in Vietnam have contributed to the country's efforts to raise rice productivity in areas affected by climate change. Improvements in country protocol in varietal testing and releases came along with the advances in breeding activities. One of which is the application of MAS. Conventional breeding normally takes five to ten years, but with MAS, it only takes three to five years to develop and formally release a variety in Vietnam. The use of MAS in breeding has since been instrumental in expediting the process of varietal development as it also emphasizes traits associated with flood- and salinity-tolerance in rice.

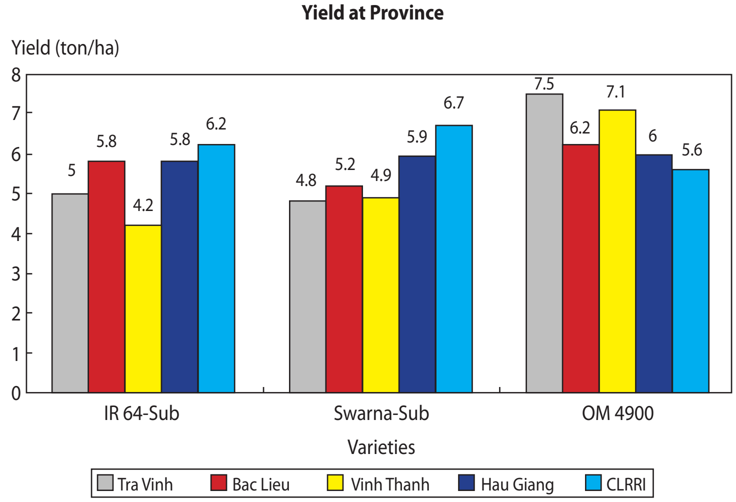


Figure 3. Yield of varieties tested in four provinces in the Mekong Delta, 2008-2009.

Breeding anew: Key developments

Comprehensive plan for varietal development and dissemination. With support from the government and projects on the development and dissemination of submergence-tolerant varieties, such as in 2005–2009, the Ministry of Foreign Affairs of Japan (MOFA), implemented by IRRI with NARES partners provided funds for a comprehensive management plan for new rice varieties in the unfavorable ecosystems in Southeast Asia, including Vietnam. The plan charted the (a) assessment for the areas most affected and likely to be affected by typhoons and other climatic variations; (b) assessment of the varietal characteristics to meet the needs of those farmers (because of different planting times and growing seasons across the target provinces); (c) meeting with scientists, extension workers, civil society organizations in affected parts of Vietnam to plan on the distribution of seed and other adaptation activities to ensure farmer acceptance of seeds; (d) development of a seed multiplication and distribution activities for different varieties; and (e) identification of the most likely partners to participate in the finalization of technology adaptation, evaluation, and dissemination.

Evaluation of salinity- and submergence-tolerant varieties in the farmers' fields. The CLRRI-CURE activities aimed at bringing advances in molecular biology to areas affected by salinity and submergence such as based on performance stability, which is an important consideration to enhance likelihood of adoption upon release. CLRRI has been testing performance of genotypes under different conditions in terms of maturity, grain yield, and stability index. Overall, the data showed that the performances of the selected varieties were fairly stable in salt-affected areas. Some of these lines are now being outscaled and are continuously spread into larger areas. Molecular biologists at the CLRRI assist in identifying genes for tolerances of different abiotic stresses. In sum, 14 single and multiple crosses were made to combine salinity-tolerance and high grain quality into high-yielding genetic backgrounds.

One objective in developing stress-tolerant varieties is to introgress salinity-tolerance gene into the genetic backgrounds of some modern OM and IRRI varieties with different growth durations, salinity stress tolerance, and good grain quality. Backcrosses were done to combine quality rice into the high-yielding genetic background. Parental genotypes were used in hybridization for transferring salt tolerance gene(s) into modern popular rice varieties. A total of 25 populations, were selected based on tolerance of salinity and plant type from F_4 population while 1,200 progenies were selected from F_3–F_7.

Combination of traits for multiple stresses. One of the difficulties in rice areas severely affected by variable climate conditions is the occurrence of multiple stresses over a cropping season. To address this concern, the breeding program of CLRRI, with the help of MAS, used a pyramiding technique to combine genes responsible for tolerance of combination of stresses. For instance, in 2013, in breeding high-yielding rice varieties tolerant of submergence and medium stagnant water stresses, a total of 10 single and multiple crosses were done to combine submergence and medium stagnant water tolerance, early-maturing period, and quality rice into the high-yielding genetic background. Genetic diversity is emphasized as a success factor in breeding, as well as in understanding the relationship between genotype and phenotype. Strategic development of the varieties was focused on the following: (a) adaptation to effects of stagnant water and submergence flooding, both at the seedling stage and flowering stage, (b) improved yield to exceed 5–6 tons per hectare, and (c) providing the basis of genetic diversity.

Emphasis on grain quality. Grain quality is considered an important trait contributing to farmers' preference of a variety. This is also taken into consideration in breeding activities to know which traits are most popular among traders. For instance, to develop long and medium slender grain rice cultivar, 200 crosses were made in 2011. The F_2, BC_1, BC_2, BC_3 seeds were planted at CLRRI in the wet season and dry season. Samples of seeds from each harvested plant were sent to the Riceland Foods Quality Assurance laboratory, a PCR biotechnology company at CanTho, for grain quality evaluation. Selected crosses were evaluated for amylose content, aroma and blast resistance. The best yielding lines selected from these experiments were advanced to the CLRRI and Uniform Rice Regional Nursery (URRN). Twenty advanced long grain lines were also tested in 13 provinces for trials, indicating that long grain rice cultivars could be ready for release in the near future.

Improvements in technical evaluation. There were some changes made in developing new technologies for farmers. Extension workers as well as researchers had participated in training programs about these new technologies and on improved communication practices. During the training programs, farmers and researchers received training handbooks, which are considered to be valuable references for subsequent researches. The specific training programs were about the following topics:

(a) identification and evaluation of submergence-tolerant breeding lines
(b) assessment of the performance of these breeding lines under submerged and normal growing conditions
(c) implementation of evaluation trials in farmers' fields
(d) establishment of communication system with farmers on how to manage new varieties and the subsequent seed generations

Adaptation trials and participatory approaches

Evaluation of promising lines in more sites. Before CLRRI joined CURE, the institute's protocol for varietal releases involved on-station, testing of the performance of the variety at CLRRI, with on-site trials in only one location per province during two seasons for comparison, and which would involve 100–200 farmers. But in 2008, with recommendations from IRRI-CLRRI partnerships under the Japan MOFA project for the dissemination of submergence-tolerant varieties and associated management practices in Southeast Asia, of which Vietnam was a partner-country, this protocol was later modified to include more locations, more farmers, and more varieties for evaluation. This led to a better understanding of the multiple stresses and differences in farmers' preferences for varieties in the actual farmers' field conditions. Such multi-location trials generated better results, which confirmed the stable performance of the varieties.

From varietal selection to production of the prototypal rice variety, processes executed in well-maintained facilities under the careful management of the state. Technical staff members are expected to be knowledgeable about the most commonly preferred traits of varieties such as amylose content to understand the process and technical standards for good quality seeds, which will consequently result in high quality and marketable varieties in the Mekong Delta. Improving the quality and value of commercial rice is crucial in supplying the kind of rice that will complement the taste of both local and foreign consumers. The authenticity and purebred level of variety, one of the highly critical requirements for the producers, is an indispensable standard to increase the value of exported rice grain.

Feedback from the farmers and consumers. To determine the preferences of farmers, CLRRI incorporated feedback in the varietal selection from more farmers by involving them after the variety has been developed. The protocol increased the number of varieties from 10 to at least 16 varieties. The variety trials also gave emphasis on the gender aspect of rice production by integrating the feedback from women farmers who contributed significantly to labor supply. In all of the adaptation trials, the feedback of the farmers is systematically collected and used as basis for improvements in breeding activities, such as what is reflected in Table 1.

These changes resulted in a more effective breeding program, and improved gene pool that would cater to food sufficiency programs and to provide rice to farmers in the Mekong Delta. The CLRRI program has produced varieties with high yield and good quality grains to cope with the competitive trade in the world market.

Improved management practices. There are nine key activities for farmers to learn to check if rice farming would produce good quality grains and better yield. These include the following:

1. selection of varieties
2. use of good quality seeds
3. land preparation and leveling
4. weed control
5. use of fertilizers and soil improvement
6. water management
7. integration of the management of pests
8. the concomitant of rice need removal at phase 4
9. harvesting at the optimum time

As more funds became available, evaluation of practical results from the practices of farmers on the subject provided common processes for cultivating varieties, which was called system of practical control of sustainable agriculture or good agricultural practices (GAP) under integrated rice management system (IRCM). under integrated rice management system (IRCM). Through a two-year assessment, nine manuals were published to help farmers continue to check the output of all practical activities to integrate rice management system.

Sowing the good seeds: Seed multiplication and technology dissemination

A major outcome of the CURE activities is the multiplication and distribution of seeds of varieties that can enhance rice farmers' productivity in fragile ecosystems. CURE partners adapted various strategies to enhance farmers' access to these varieties and their associated management practices. Seeds in packets were distributed together with flyers, technology bulletins, posters, and other information, and education and communication (IEC) materials that can help farmers better grow their main crop.

While new stress-tolerant varieties are already available, the farmers still need to gain better access to the seeds and understanding of what these can do to help alleviate their condition when affected by stresses.

Submergence-tolerant rice varieties released in 2012, namely, OM 8927 and IR64-sub1, are also recommended for release at a state level. OM 8927 has a duration of 95–100 days, yields 5–6 tons per hectare, and has long slender grain, while IR64-sub1 has a duration of 105–110.

To avoid further losses in the future of poor farmers currently suffering from the floods, efforts for seed supply and conversion of additional varieties to submergence-tolerant ones are urgently needed. However, seed availability is still far from satisfactory level. Based on data presented in the CURE Phase I Terminal Report in 2014, CURE started to disseminate seeds in minikits (2–5 kg) of most popular varieties in 2011. From

Short duration rice tolerant variety at Gia Rai, Bac Lieu; EC=10DS/m.

2011-2015 the project provided seeds of stress-tolerant varieties in the following locations:

- OM8927 - An Giang (100 kilograms), Hau Giang (500 kilograms), Dong Thap (500 kilograms)
- OM8108 - Hau Giang (800 kilograms), Can Tho (200 kilograms), AnGiang (1500 kilograms), and Vinh Long (300 kilograms)
- IR64-Sub1 - CanTho (200 kilograms), Vinh Long (50 kilograms), AnGiang (100 kilograms) and Dong Thap (100 kilograms)
- OM10252 - Hau Giang (100 kilograms) and Can Tho (100 kilograms)

The CLRRI distributed seeds of MNR3 and OM5629 in Ben Tre; the seeds of OM6677, OM8108, and MNR4 in CaMau; those of OM3673 and OM5629 in Soc Trang; and those of OM90L and OM10252 in Bac Lieu. Supply of seeds was ensured by: (1) multiplying large quantities of seeds of available varieties on the farms for immediate distribution; (b) distributing seeds to target areas; and (c) establishing seed multiplication facilities in target areas.

Besides seeds, training activities were also conducted to teach farmers in the processes involved in developing stress-tolerant varieties. A total of 450 farmers from six provinces were trained in evaluating salt-tolerant breeding lines, managing the seeds, and conducting field trials of new varieties. Meanwhile, 100 farmers participated in a workshop on

Table 2. Amount of certified seeds (kg) of OM 4900 distributed to clubs in each province affected by salinity and submergence, 2011–2015.

	2011	2012	2013	2014	2015
Tra vinh	3000	3000	2000	200	2000
Long An	500	1000	100	750	1000
Ten Giang	700	400	1000	1500	2000
BenTre	600	400	700	500	700
Soc Traang	300	2000	2000	2000	4000
Kien Giang	2000	2500	4000	4000	2000
Ca Mau	30	50	200	200	200
Bac Lieu	400	2500	700	700	1000
Dong Thap	4000	4000	2000	200	2000
Hau Giang	200	2300	700	500	2000
Vinh Long	400	300	500	500	200
Can Tho	450	450	100	100	2000
An Giang	10,000	7000	8000	10,000	12,000
Total	**22,580**	**25,900**	**22,000**	**21,150**	**31,100**

Table 3. Most popular salinity-tolerant varieties (seeds in kg.)

	Variety	Tra vinh	Long An	Ten Giang	BenTre	Soc Traang	Kien Giang	Ca Mau	Bac Lieu	Dong Thap	HauGiang	Vinh Long	CanTho	An Giang
2011	OM5629	300	900	500	300	6000	700	90	500	0	700	20	500	200
	OM6377	300	200	300	300	400	400	500	400	500	0	0	0	7000
2012	OM5629	800	900	500	500	7000	900	100	5000	0	900	300	20	300
	OM6377	450	0	300	300	400	400	500	400	400	0	0	0	9000
2013	OM6677	300	600	300	600	2000	700	400	2000	600	600	0	0	0
	OM5629	300	600	300	100	5000	700	400	6000	0	800	200	0	600
	OM6377	390	300	300	600	2000	700	700	500	600	700	0	0	9000
2014	OM6677	0	0	400	300	400	500	600	3000	500	500	0	0	0
	OM5629	800	900	400	300	3000	500	600	9000	0	600	100	0	600
	OM6377	470	0	400	300	400	500	600	3000	500	500	0	0	9000
2015	OM6677	700	700	500	600	0	2000	3000	3000	700	500	0	0	0
	OM5629	700	700	500	100	5000	2000	3000	9000	0	500	100	0	600
	OM6377	590	400	300	600	2000	1900	500	5000	700	500	0	0	9000

the introduction of new varieties in Vinh Long. CLRRI developed a new protocol describing rice production for farmers.

Pathway of technological dissemination

CLRRI provides super foundation seeds and foundation seeds to select sites where there will be enough capacity to provide and multiply them. From CLRRI, seeds of stress-tolerant varieties and other farming technologies reach the farmers' fields through farmers' clubs. For instance, in the following provinces, there are clubs with 10–15 farmer-members who produce certified seeds, which are then distributed to other farmers. The following are the number of farmers' clubs in different provinces:

- Camau—10 clubs with 10–15 members each
- HauGiang—259 clubs (but for rice, only 29 clubs which provide 80 tons of seeds per year)
- KienGiang—450 clubs
- TraVinh—225 clubs with 10–15 members each
- AnGiang—459 Clubs with 10–15 members each

In 2015, the total number of seeds of the popular variety OM 4900 distributed to the farmers' clubs reached about 31 tons in 2015. Table 2 shows the distribution of the seeds of OM 4900 from 2011 to 2015, while Table 3 presents the amount of seeds of popular salinity-tolerant varieties distributed to different provinces in the same period.

Potential application site

For the salinity- and submergence-tolerant varieties, scaling-out can be done by region, where the stresses have been determined and estimated. In different provinces, based on results of multi-location trials, the potential expansion areas for dissemination and farmers' use of the popular varieties are presented in Tables 4 and 5. For CURE sites, the areas are shown in Figure 4, where seeds of the new varieties are targeted to be distributed.

Reaping smart

Cultivating stress-tolerant varieties are expected to meet market needs and thus, increase income for farmers. The research on new varieties suitable for the stress-prone environments has proven beneficial. Scaling up of the new varieties can provide additional income to the farmers. For instance, OM5451 is a popular farmers' variety and is widely cultivated. However, the average yield of OM 8108 compared with that of the glutinous rice variety of OM5451 is higher by approximately 1.33 tons per hectare in summer-autumn. And since the export market strongly demands a certain type of rice with the rate of high head rice, the cultivar of OM8108 is suitable. Meanwhile, the price of local rice in the market is higher than that of OM5451 of about 200 VND/kilogram (0.01 USD/kilogram). Based on Table 6, the total income per hectare of a farmer from cultivating OM8108 increased to 6,580,000 dong (USD 292.2) compared to that of OM5451 in winter-spring. Further, the total income per hectare of OM8108 increased to 9,093,600 dong (USD 407.9) compared to that of OM5451 in summer–autumn season.

The above values are based on the data collected in Bac Lieu province (Hoa Binh district), which involved 35 farmers.

The development of these new varieties have also created significant contribution to export market. For instance, in 2015, An Giang province exported 189.7 tons of rice seeds of OM4900, 50.12 tons (one season) of OM2512, and 83 tons of IR 50404. A total of 3,567 farmers from 61 clubs and groups produced the seeds for export.

DRIVERS OF CHANGE

Government support: national to local units. Besides managing trade and export of rice from Vietnam, the national government through MARD also offers different provisions. For one, the government provides for the storage of the seeds. It also purchases seeds from the farmers. Since the seed system is very slow, the government provides price subsidy when the price is very low for the farmers.

Table 4. Potential areas for expansion of salinity-tolerant varieties.

Province (District)	Yield Potential (ton/ha/ cropping)	Cropping intensity (/year)	Level of Salinity (indicate level of EC)	Recommended varieties
Bac Lieu (HoaBinhTown)	5–6	3	EC = 8–10 ds/m	Region of 3 crops: 2 for salinity and another crop OM 10252, OM8108, OM5629, OM90L, OM6677, OM8104, OM6707, and OM2517,
Tra Vinh (Cau Ke district)	6–7 tons under normal condition; under saline soil, 4–5	2	EC = 8–10 ds/m	OM6677, OM8108, OMCS2009, and OM5953 are recommended
Soc Trang (My Xuyen district)	6–6.2	2 varieties + another crop	EC = 10–12 ds/m	OM4900, OM6162, OM3673 and OM5629
Ben Tre (Ba Tri district)	5–6	1 cropping, since areas are severely affected by salinity	EC = 12–15 ds/m	OM4900, OM5629
Ca Mau (Tran van Thoi District)	3–5 (yield is very low caused by salt, sulfate soil, and drought)	1 crop	EC = 12–15 ds/m	Affected by acid sulfate (in the soil) TaiNguyen, Mot bui Lun, OM8108, OM6677, MNR4, OM4900, and OM6162
Kien Giang (Kien Luong district)	6 – 7	2 crops	EC = 12–15 ds/m	OM5629, OM5841, OM4900, and OM6677

Table 5. Potential areas for expansion for submergence-tolerant varieties.

Province (District)	Yield Potential (ton/ha/per cropping)	Cropping intensity (in one year)	Type of flooding	Recommended varieties
An Giang	8–9	3	Submergence	OM 10252, OM8108, OM90L, OM6677, OM4900, and OM2517,
Bac Lieu	6–7, under normal condition; salted soil is 4 – 5 tons/ha	2 crops	Stagnant flooding	OM6677, OM8108, OMCS2009, and OM5953 are recommended
Tra Vinh	5–6	2 varieties + another crop	Stagnant flooding	OM3673 and OM5629
Soc Trang	5–6	2 crops	Stagnant flooding	OM4900
Ben Tre	3–5	2 crops	Stagnant flooding	Affected by acid sulfate (in the soil) TaiNguyen, Mot bui Lun, OM8108, OM6677, MNR4, OM4900, and OM6162
Ca Mau	5–6	1 crop	Stagnant flooding	OM5629, OM5841, OM4900, and OM6677
Hau giang	6–7	3 crops	Stagnant flooding	OM4900, OM6161, OM4218
Can tho	6–7	3 crops	Stagnant flooding	OM4900, OM6162, OM7347
Dong thap	9–10	3 crops	Submergence	OM4900

Stagnant flooding – duration of 95 to 100 days, depth of 50-80 cm.
Submergence – 2 to 3 weeks of flash flood

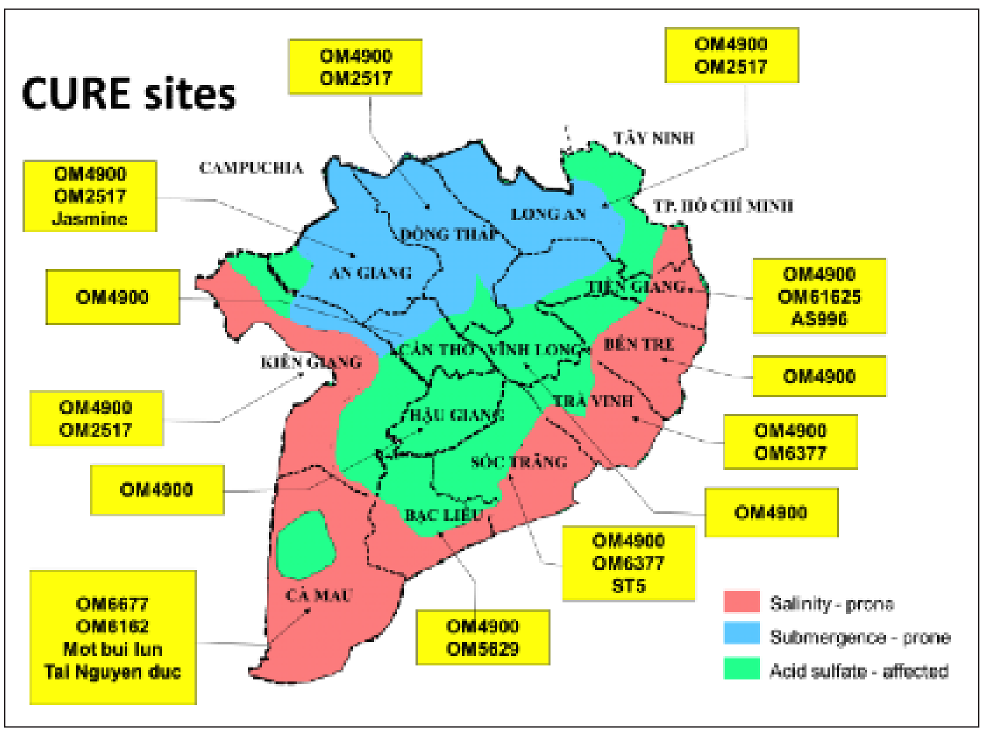


Figure 4. Potential application sites for the popular/farmers-preferred new stress-tolerant varieties, 2014–15.

Table 6. Total income of 25 farmers per hectare in Tri Ton district, An Giang Province, 2014 .

Target	Winter- Spring		Summer – Autumn	
	OM8108	OM5451 (farmer's popular variety)	OM8108	OM5451(farmers' popular variety)
Yield (tons/ha)	8.5	7.17	6.6	4.92
Selling Price (dong/kg fresh rice in field)	6,200	6,000	6,000	5,800
Total income (dong/ha)	52,700,000	43,020,000	39,600,000	28,536,000
Total income (USD/ha)	2,225.1	1,929.9	1,776.5	1,280.1
Target	Đông Xuân (dry season) 2014		Hè Thu (wet season) 2014	
	OM6677	AS996	OM6677	AS996
Yield	7.9	7.05	5.8	4.50
Selling Price (dong/kg fresh rice in field)	6,200	6,000	6,000	5,700
Total income (dong/ha)	48,980,000	42,300,000	34,800,000	25,650,000
Total income (USD/ha)	2,197.2	1,897.6	1,561.1	1,150.7

For instance, when seeds cost 1,000 VND (USD 0.04), the government purchases them for 2,000 VND (USD 0.09). Having a communal system, the government also provides the biggest field for farmers with small land area, which cannot grow sufficient production for their family.

In 2000–2005, the MARD also implemented *Developing new varieties for export program* in the whole country. And in 2006–2010, the ministry focused in the Mekong Delta because the yield in the region was noted to be high, and the yield of released varieties was reported to be increasing. In 2006–2015, the same program was resumed to further develop the drought-tolerant varieties using MAS. In the same period, another program by the Ministry of Science and Technology (MOST) studied the QTL for salinity. This was pursued by MOST to improve and combine the gene for drought and salinity tolerance in 2013 until 2017.

Meanwhile, the local government in the provinces decide on which varieties to grow for the salinity and submergence areas. The local government provides foundation seeds for farmers, and free training activities for control of pest, diseases, and insects, along with the management practices.

Enduring partnership: CLRRI and IRRI. Since 2000 to date, CLRRI and IRRI have been actively encouraging and promoting projects to provide rice varieties in the provinces, which have become a policy advocated by MARD.

Related projects/collaborations with international organizations and the local government that are related/similar to CURE project/activities in Vietnam include the following:

1. Breeding for of salinity tolerance in Bac Liêu : 1999–2001
2. Breeding for salinity tolerance in An Giang 1995–2000
3. Project for breeding salinity-tolerant rice varieties in Tien Giang, 2001–2003,
4. Project for breeding salinity-tolerant varieties by mutation: Collaborating International Energy Institute: 2001–2005
5. Project for developing map of salinity-tolerant rice varieties: State initiated, 2001–2006. Result of developing map for salinity tolerance and selecting by molecular marker.
6. Studying rice varieties tolerant of submergence and salinity in the Mekong Delta: 2004–2008 (CP7).
7. Ministry of Foreign Affairs (MOFA) of Japan supported project on disseminating submergence-tolerant rice varieties and associated management practices in Southeast Asia (including Vietnam), 2008–2010
8. Studying breeding technology for tolerance of salinity and drought in Mekong Delta, initiated by MOST: 2013–2017
9. Selection of varieties for salinity-tolerance and submergence-tolerance,

capacity enhancement and knowledge management activities under CURE (2005–2018)
10. Project of Climate Change (CLUES), funded by ACIAR in 2011–2015

Farmers leading technological innovations. The strong advocates of technology are still the local leaders, who are usually the president of the commune and director of province of the agriculture agency. They are key personalities since they have influence over the decision of the people in a community. While the farmers can observe the trials or their neighbors' field and exchange information among themselves, if the local community does not accept or refuses to accept the technology or rice variety, the technologies or varieties cannot be completely applied and disseminated. Moreover, sometimes unexpected difficulties in the management delay or hamper the dissemination such that the new rice varieties do not reach all farmers. Messengers from farmers also have influence over the decision to adopt or refuse newly released rice varieties.

Private companies/organizations purchasing seeds and rice. Companies and retail traders generally make the huge purchases. However, there is no incentive yet for private seed companies to sell, or invest in the villages to sell seeds. Only the government-owned local seed centers are producing the seeds at the provincial level.

Scientists and researchers leading rice research initiatives and innovations. Scientists are the ones who select which cultivar and what technique should be applied. They work closely with farmers to guide them on what to do, and teach them suitable techniques to grow the stress-tolerant varieties. In other words, scientists provide the technical know-how to the farmers, along with the local extension staff in the village. There is a network of extension workers from the provincial, district, and to the village level. There is also strong partnership between scientists and the farmer-leaders who are highly regarded and respected in the community.

A consortium for change: CURE. CURE supports mechanisms and triggers local impact. Under CURE, scientists discuss and transfer the information to farmers, design experiments, and strategize on how to disseminate the technologies and varieties to the farmers effectively. CURE emphasizes on the importance of participatory approaches, seed health management, and other important technologies. If the model proved to be sustainable, an incentive is provided by the CURE project.

The consortium is a unique platform for the collaborative research activities among scientists/researchers in one country or between countries to get new information that can be disseminated to the farmers.

Policy and institutional spaces

Engaging the different sectors, both private and public. To achieve the goal on sustainability, certain policies can be set up. A policy for procuring temporary storage for the farmers would be of great help. It is crucial to mobilize the State and people to work together. Advocacy organizations such as farmer association, the women's union, the people's committees and extensions and other groups involved can help efficiently expedite the technology adoption. Moreover, each has a role to play and all work must be shared among the extension center, Department of Plant Protection, Department of Agriculture, secretary of the commune, commune and district extension stations, District's Department of Agriculture, good farmers, and even communal police. It is also important to note that local qualifications have differences in the capacity of officials and various cultural groups; for the foundation seeds, the price is paid 60% by the government and the remaining 40% is paid by the farmers. Moreover, knowledge and information should be made more accessible since an unknown number of qualified women and people in ethnic regions are reluctant to make write-ups, and women have less opportunities to access information.

Cultural space

Making knowledge-sharing collaborative and accessible. Classes and seminars are highly appreciated, particularly those that are comprised of different components of farmers, in which many local departments, farmers and cooperatives are also involved. On the other hand, language interpretation of technical terms, domestic and foreign news, the story portrait of villages and other provinces in the KMUs should be taken into consideration.

Learning space

Giving importance to training researchers. The CURE project has contributed in improving the quality of scientific research and capacity building of the staff with parallel integration within the project research plan and thesis completion of students of the center. Meanwhile, training courses for farmers and technicians were conducted from 2006 to 2010 in which 2,560 farmers from four provinces namely, Can Tho, An Giang, Hau Giang, and Bac Lieu were trained. In 2011, 2012 and 2013, four workshops were held to discuss and to complement appropriately useful information for the project in which rewards for the local staff participating in the project and financial incentives to the farmers with good harvest were given. In 2013, a three-day class on MAS application in breeding was arranged for farmers and technicians, which was participated in by 315 farmers from six provinces: An Giang, Can Tho, Vinh Long, Hau Giang, and Dong Thap.

Under IFAD funding, a training activity was conducted for farmers and farmer-leaders on various topics, including participatory varietal trials (PVS) in the provinces of An Giang, Cantho, Bac Lieu, Hau Giang, Vinh long, Travinh, Kien Giang, Long An, Ca Mau in the Mekong Delta. Leaflets on the suitable management practices for the new stress-tolerant varieties were also distributed to the farmers. Capacity strengthening and staff development were done through non-degree training activities.

In the future, stronger linkages and exchanges of knowledge through project networks and meetings will be conducted as these will also give considerable impacts on capacity strengthening. Consultations will be arranged with scientists, extension workers, civil society organizations in affected areas to plan on the distribution of seeds and other adaptation activities to assure farmer acceptance of seed, and determine the required quantity of seed for distribution. Consultation and meetings with people from different sectors involved in the project will also be organized to address the development of seed multiplication plan for the stress-tolerant varieties needed in different areas; to encourage partners to participate in the finalization of seed development and distribution;

Training of women at Vi Thuy District, Hau Giang Province.

Providing seeds for farmers at Hau Giang.

and to identify training needs for each research activity in terms of technology adaptation, evaluation, and dissemination.

REFERENCES

Buu, B. B. & Lang, N.T. (2007). Protocol for Plant Breeding. Agricultural Publisher. Ho Chi Minh City, Vietnam.

Consortium for Unfavorable Rice Environments. (2014). Consortium for Unfavorable Rice Environments (CURE) Phase I Terminal Report. International Rice Research Institute (IRRI). Los Banos, Laguna. Philippines.

Lang, N.T. & Buu, B. B. (2010). Developing New Varieties With Excellent Cooking and Eating Qualities for CLRRI . Final report. Cuu Long Delta Rice Research Institute (CLRRI).

Table 7. Training programs conducted by CLRRI and partners to raise the capacities of farmers on participatory varietal selection, 2011–2015.

Area/ Location	Male	Female	No. of people involved	Outcome
An giang	217	116	333	The farmers preferred varieties - OM 7347, OM4900, OM8928, OM6677
Can tho	245	98	343	The farmers preferred varieties: CanTho1, CanTho2, OM10041, OM8928, OM4900, OM6L, OM4488
Bac lieu	307	85	392	The varieties OM 6328, OM 10252 , OM 90L and OM 6677 were selected.
Haugiang	413	92	505	The farmers preferred varieties: OM7347, OM8018, OM4900, HG2, CanTho2, CanTho3, OM6L
Vinh long	248	48	296	The farmers preferred varieties: OM4488, OM6162, OM4900
Travinh	379	78	457	The varieties OM4900, OM5451 and OM6677 were selected.
Kiengiang	232	34	266	The farmers preferred varieties: OM4900, OM2517, OM 6377, MNR4
Long an	237	30	267	The farmers preferred varieties: OM4900, OM 7347
Ca mau	296	63	359	The varieties OM 4900, OM 8108 and OM 6677 were selected in Tep Hanh, Mot Bui Do, Tai Nguyen Duc
Total	**2,574**	**644**	**3,218**	

Vietnam

Upland systems

Restoring local rice varieties to manage climate variability and fight food insecurity in Northern Vietnam

Luu Ngoc Quyen, Le Khai Hoan, Nguyen Van Chinh, and Pham Thi Sen

Through the combined efforts and commitment of various stakeholders, the restoration model developed for one local rice variety has been upscaled and is continuously being improved to fortify the production systems of more local rice varieties, and raise the livelihood of farmers in the region.

Rice in the northern mountainous region

The northern mountainous region (NMR) of Vietnam is comprised of 14 provinces that span approximately 100,965 km^2, which is equivalent to about 29% of the country's total land area (Thông tin nông thôn Viêtnam, 2013). To this day, rice is the only staple food crop for over 15 million local farmers in this region who are among the poorest in the country. They are also the most vulnerable to natural disasters and climate shocks (General Statistics Office, 2013).

In this region, rice is cultivated in three different production environments [Ministry of Agriculture and Rural Development (MARD), 2014]:

(i) Irrigated lowland (about 248,000 hectares or about 56% of the rice production area);

(ii) Rainfed lowland (about 192,00 hectares or about 44%);

(iii) Most of them are terraces along hill contours where wet rice is produced, mostly one cropping during the wet season; and

(iv) Sloping lands where upland rice is produced in one cropping during the wet season;

To cope with varying rice environments and meet their needs, the farming communities (composed of 30 ethnic groups with various culture and traditional farming practices), have developed, conserved, and produced highly diverse local rice varieties over the years.

These varieties are well adapted to the local climate and land conditions. Most of these also have good taste, aroma, and quality. Some examples of the varieties that exhibit these traits are Chiem Huong and Nep Tu Le in Yen Bai Province; Gia Dui, Khau Mang, and Nep Rau in Ha Giang; Seng Cu and Khau Nam Xit in Lao Cai; the Nep Tan in Dien Bien; and the Khau Nua Lech in Bac Kan.

During the 1980s and the 1990s, however, in the effort to fight hunger and poverty, newly developed high-yielding rice varieties, including hybrid rice, were intensively introduced in the region to replace the traditional varieties. On one hand, this helped the country increase its food production. On the other hand, it also caused rapid erosion of local genetic resources, reduction of the genetic base of production systems, and increased the problems of instability and high risks of crop failure.

Since about ten years ago, rice production in the NMR has faced increasing problems caused by unpredictable adverse climate conditions (such as floods, extended cold periods, early winters, and prolonged dry seasons). These factors have triggered increasing demands for developing inbred rice, particularly local varieties that require less input and face lower risks of crop failure. Thus, an increase in the sharing of inbred varieties was again observed in the region's rice area.

According to the 2010 and 2012 surveys by the Institute of Policy and Strategy for Agriculture and Rural Development (IPSARD) and the Northern Mountainous Agriculture and Forestry Science Institute (NOMAFSI), respectively, the area shared by inbred rice in the NMR, on average, was about 70% for the winter-spring season and over 80% for the summer season. The average yield of inbred rice was 5.2 tons per hectare (Bui Chi and Nguyen, 2011). However, despite the technological advancements on breeding new inbred and local varieties, farmers were experiencing increasing problems on limited access to quality seeds. This was because the bulk (about 80%) of inbred rice seeds used in production in the NMR was farm-derived and with poor quality control.

In 2005, to remedy the situation regarding seed security and restoration of local rice varieties, NOMAFSI, FAO Hanoi, and the provincial Department of Agriculture and Rural Development (DARD) proposed a project to support the development of local rice varieties and the farm-seed production and supply system in upland communities. The aim of the project was to enhance the resilience of local rice production systems to climate shocks and improve the livelihoods of farmers through the production and delivery of high-quality rice to the market.

From establishing local rice restoration model to market branding

Building a model for restoration of local varieties using Chiem Huong

Chiem Huong is an improved inbred variety imported from China in the 1990s. Known for its good quality, the variety has been cultivated in Yen Bai Province since 1992. In 2006, the Government of Yen Bai approved NOMAFSI's proposed project to work together with Yen Bai DARD to support the Dai Phac commune in Van Yen District of the province to restore the variety. In 2008, to maintain Dai Phac group's operation, the Consortium for Unfavorable Rice Environments (CURE) supported NOMAFSI as part of the partnership activities of the workgroup on upland rice-based ecosystems.

This restoration effort involved the following activities:

1. Purification and production of foundation seeds

The NOMAFSI researchers, who specialize in rice breeding and line selection, with support from the farmers and the local extension staff conducted the purification and production of foundation seeds in the "native" place of Chiem Huong in the Dai Phac commune.

The process involved the following substeps:

i. *Description of Chiem Huong*. A descriptor table specifically for Chiem Huong was developed since it was

not available from the Plant Genetic Resources Centre, where local rice varieties are preserved. Data were gathered from elder farmers with good knowledge of the variety, people working on the variety, and available references about the variety gathered for the descriptor table. Focus group discussions were organized in finalizing the descriptor table.

ii. *Individual and line selection*: 200 individual plants matching the variety's descriptor were selected from the best farmers' field. The seeds of the selected plants were cultivated as separated lines, (for example, 200 lines were subjected to selection in 3–4 consecutive seasons).

iii. *Production of foundation seeds*: Seeds of the best lines that match the characteristics in the descriptor table were used for the propagation and production of foundation seeds.

2. Support to local farming community to produce certified seeds of the target variety

Local varieties are typically suited only to certain land and climate conditions so the demand for the seeds of these varieties is low. This makes the commercial seed production of local varieties an unattractive investment for seed companies. Providing local communities with modern seed production technology is one of the prerequisites for the production of a purified variety.

In the fields of the farmers' organization, NOMAFSI specialists served as facilitators while local community members (including farmers, extension officers, and community leaders) were the implementers.

This process involved the following substeps:

i. *Establishing a farmers' rice seed group*. This involved the selection of farmers based on their willingness, commitment, knowledge, and learning capacity), identification and allocation of a suitable area for seed production, participatory development of the group's regulations, and securing the official approval for establishing the group. The approval of the community authority (the Commune People Committee) is an important indicator that the effort has the strong support of the local decision makers. Without their support, the effort will not have any sustainable outputs and significant impact.

ii. *Building the capacity of the farmers' rice seed group*. This

involved the enhancement of the group's capacity to carry out and manage its activities such as planning, implementing, and monitoring undertakings in marketing and negotiation, among others.

iii. *Building the capacity of the farmers' rice seed group in quality seed production and storage*. This involved the development of a model field, organization of farmers' field schools, and on-the-job training for the application of information and communication management strategy in producing and storing quality seeds of the purified variety. The quality seed production and storage practices developed were not specific to Chiem Huong and could be used by farmers in producing and storing quality seeds of other varieties to meet the production needs.

iv. *Supporting the farmers' rice seed group to produce and store quality seeds of the purified variety*. This involved the "three together"—planning together, doing together, and conducting monitoring and evaluation (M&E) together. Local extension officers and technical staff from the provincial DARD and NOMAFSI staff worked together with farmers throughout the cropping season, from seed preparation to harvesting and postharvest activity, so that farmers could follow the integrated crop management (ICM) technologies to produce quality seeds. This was repeated for a few cropping seasons until the farmers could properly apply the technologies on their own.

v. *Field inspection and certification of seeds produced by the farmers' rice seed group*. Inspection with technical support from local technical officers, or NOMAFSI staff were conducted in fields of all the members of the farmers' group as an internal quality control. However, a designated field inspection organization is required to conduct the certification of the seeds if the seeds are to be exchanged or traded outside the district, according to national regulations. No certification is required for seeds intended for supply and use within the district.

vi. *Supporting the community in registering purified local variety*. This was done by the provincial DARD with support from NOMAFSI. The registration process is required for promoting the use of certified seeds and for developing the production of a target variety. Only seeds of varieties approved by MARD for large-scale commercial rice production can be traded nationwide, according to the national regulations.

vii *Supporting the farmers' rice seed group in selling quality seeds they had produced*. This is important to sustain not only the farmers' group, but also the development of the target variety. Efforts were made to link the farmers' rice seed group with rice producers in other communities within the district.

The District People Committee (DPC) and leaders of the farmers' seed group played major roles in this activity. The DPC adopted a policy to support farmers in other communities, and buy and use the quality seeds from the farmers' rice seed group. The committee also encouraged farmers to extend the production area of Chiem Huong to increase their income and benefits. Moreover, inputs were spent on developing links between the farmers' rice seed group with some commercial seed companies to produce certified seeds that could be sold and used outside the district. The provincial DARD and NOMAFSI mainly facilitated this activity while the leaders of the farmers' rice seed group negotiated and drafted the contract with the seed companies.

The farmers' rice seed group in the Dai Phac commune initially started with 19 farmer members under the supervision of a three-staff management unit. The management unit ensured the group operated based on the approved regulations. The group currently consists of 48 members, 32 women, and 16 men, who can efficiently perform integrated crop management (ICM) to produce quality seeds of Chiem Huong variety. The group produced 32 tons of certified seeds of the local variety Chiem Huong in 2014. In 2015, farmers reported a higher net return from the production of quality seeds compared with the production of rice for food. On average, farmers earned a gross return of USD 2,131 per hectare and a net income of USD 1,570 per hectare, more than 20% higher than income from the production of normal rice. Aside from seed production and storage, the Dai Phac farmers' rice seed group also practiced line selection to conserve and purify their local varieties as required.

3. Support to outscale the production of the target local variety

The ultimate aim of the project is to establish the sustainable development of the local rice variety that has resilience to climate variability and can help increase household income. Outscaling of the improved variety was conducted simultaneously with the two previously mentioned activities, and involved the following substeps:

i. *Participatory validation and refinement of ICM technologies for production of quality rice of the target variety*. NOMAFSI, in partnership with the extensional officers and selected farmers, conducted experiments to identify the most appropriate density, fertilization levels and methods, and water management, harvest and postharvest technologies. (See Annex 1 shows the technology package for the production of Chiem Huong). Application of this ICM technical package could help farmers increase their rice yield by 18–20%. NOMAFSI identified rice production areas that are suitable for the target variety in consultation with the local people. NOMAFSI also consulted researchers

who have been working on the target variety, studying the characteristics of the land, water, and climate in areas close to the area where the variety originated, and conducting participatory varietal selection (PVS) of the variety in different locations.

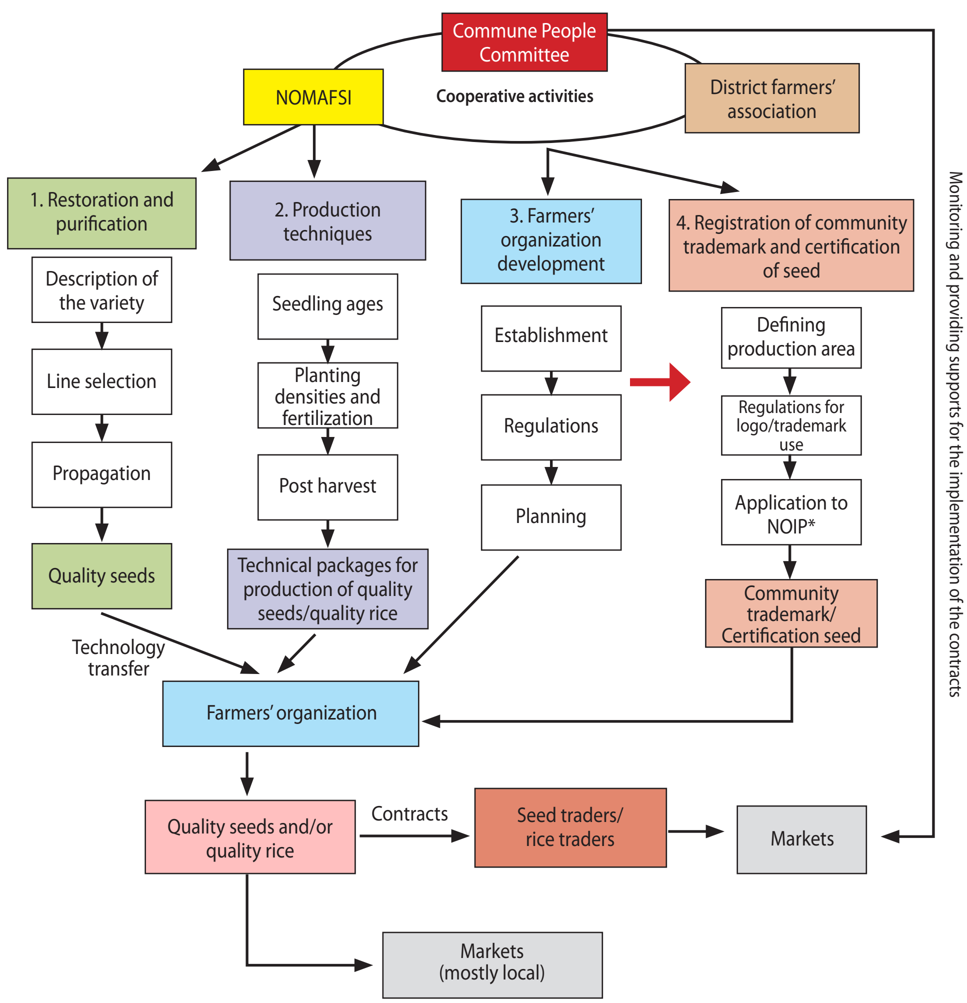
ii. *Promoting the adoption of the technologies developed through developing demonstration models, organizing farmers' field schools (FFS), field days, and cross visits.*

iii. *Supporting the development of supply chain for rice of the target local variety*. This is vital to the sustainable development of the target local variety. Farmers will only continue to produce the rice only when they can profit from selling their rice. This activity included:

- Supporting the community in developing a trademark and logo for the target rice product, registering the trademark, and formulating regulations for the use and management of the trademark
- Marketing and developing links between the production of the local rice variety

NOMAFSI, in partnership with the DARD of Yen Bai carried out activities to re-release Chiem Huong. MARD included the local rice variety in the list of rice varieties approved for commercial scale production.

Chiem Huong is now widely produced in Yen Bai where it has become a well-known high-quality local rice variety. Now, out of the total area of 5,500



Scheme 1: Activities implemented for restoration of the local variety Chiem Huong
* NOIP: National Office of Intellectual Property of Vietnam

hectares (or 27–30% of the province's total rice production area), Chiem Huong is grown in 1,800 hectares in Van Yen and Van Chan districts. It produces an average yield of 5–5.2 tons per hectare and contributes a net income of USD 1,3012 per hectare per season. Compared with other rice varieties produced in the region (e.g., Nghi Huong 305), the net income from Chiem Huong is 20–25% higher, according to the DARD of Yen Bai.

The steps and activities conducted for restoration of the local variety Chiem Huong are summarized in Scheme 1.

Upscaling of the model for restoration of other local varieties

Since 2008, with financial support from FAO, CURE, MARD, and government offices in the provinces, and by linking with the national upland livelihood program, NOMAFSI upscaled the same model developed for Chiem Huong to restore other local rice varieties.

As a result, seven local varieties selected for their good qualities, were purified and re-released (see Table 1). The growing areas, total production, yield, and quality of these local varieties have significantly increased.

Not all the steps or activities in the model for restoring Chiem Huong were upscaled for restoring other varieties. For example, for the Seng Cu, Khau Nam Xit, and Gia Dui, only the restoration activity model was applied. The supply chains for these varieties were not developed because the producers are selling their rice spontaneously at local markets and to local collectors and traders. All the activities have been upscaled for the Nep Tu Le, Nep Tan, and Khau Nua Lech but more effort is needed to further improve them and make the models sustainable.

In all the locations and for all the target varieties, farmers who were involved directly in the project could successfully produce, store, and supply quality seeds after receiving training and technical support from the project staff (see Table 2).

Through farmer-to-farmer learning, a number of farmers not directly involved with the project also learned large-scale production and supply of seeds of purified varieties. However, because farmers often opted to produce and exchange seeds individually rather than as part of a group, farmers' rice seed groups have not been sustainably developed for all the varieties. Only the farmers' rice seed group in Dai Phac commune was able to operate effectively and sustainably. Based on observations, various problems must be considered, solved, and improved for a group to achieve effective and sustainable operation. Proactive participation and support of local authority, seed companies, and research institutions are also necessary for the model to work (see Scheme 2). In most cases, linking with a seed company is a key factor. Encouraging the involvement and support of the commune and district authority are also crucial for a sustainable and continuous operation of the group.

Based on 2015 project estimates with farmer beneficiaries, seed production could bring better economic benefits compared with the production of rice for food. When the family labor was included in estimating production costs, rice production for food did not bring significant economic benefits to growers. For most varieties, the net income was negative.

However, the rice seed production model could bring a net income from USD 377 to 738 per hectare, depending on the rice variety. On average, for each additional USD 0.04 in labor input, the famers could earn a net income of USD 179–404 (for spring crop season) and USD 90–495 (for summer season), depending on the rice variety. Thus, for one additional working day spent for rice seed production, farmers could make USD 7–27. Both the gross return and net income from seed production were higher compared with producing rice for food (Table 2).

After the intervention, the production areas of the target varieties doubled and even tripled in some locations. Moreover, by using quality seeds and suitable ICM technologies, both yield and quality of the rice varieties were improved. The yield increased by 10–26%, depending on the varieties and seasons, while the input cost per hectare reduced by 15% (Table 2). The net benefits of producing restored varieties increased by 20–25% compared with producing the same variety but not purified. Meanwhile, many households have used the high quality

Table 1: Characteristics of local rice varieties restored.

Variety	Place of origin	Main characteristics
Chiem Huong	Yen Bai	Imported from China in 1990, and cultivated in Yen Bai since 1992. Improved lowland variety Heat-sensitive rice variety Matures in 120 days Planted in both the summer and spring seasons Grain yield is 5.5–6.0 tons/hectare/season High grain quality, light aroma, and distinct taste
Nep Tu Le	Yen Bai	Traditional lowland variety Heat-sensitive specialty glutinous rice variety Reaches maturity in 140–150 days Suitable for the summer season Grain yield is 4–4.5 tons/hectare/season Distinct aroma, taste, and stickiness
Gia Dui	Ha Giang	Traditional lowland variety Heat-sensitive variety Reaches maturity in 150 days Suitable for the summer season Grain yield is 4–4.5 tons/hectare/season High quality rice, tender when cooked, good aroma, and taste
Seng Cu	Lao Cai	Traditional lowland variety Heat-sensitive variety Reaches maturity in 100–110 days Suitable for both the summer and spring seasons Grain yield is 4.0–5.0 tons/hectare/season Cooked rice is tender, aromatic, and tasty
Khau Nam Xit	Lao Cai	Traditional lowland variety Heat-sensitive variety Reaches maturity in 130–135 days Suitable for both the summer and spring seasons Grain yield of 3.5–4.0 tons/hectare/season Cooked rice is soft and aromatic
Nep Tan	Dien Bien	Traditional variety Heat-sensitive sticky rice variety Reaches maturity in 155–160 days Suitable for the summer season Grain yield is 3.5–4.0 tons/hectare/season Cooked rice has good aroma, taste, and stickiness.
Khau Nua Lech	Bac Kan	Traditional lowland variety Heat-sensitive sticky rice variety Has long growth duration of 160 days Grain yield is 4.0–4.5 ton/ha Cooked rice is good in terms of aroma, taste and stickiness.

Yen Bai. For instance, in 2016, about 50 tons of Chiem Huong high-quality seeds were used by about 2,600 households. For other restored rice varieties, 1 to 20 tons of high-quality seeds were distributed to local farmers annually.

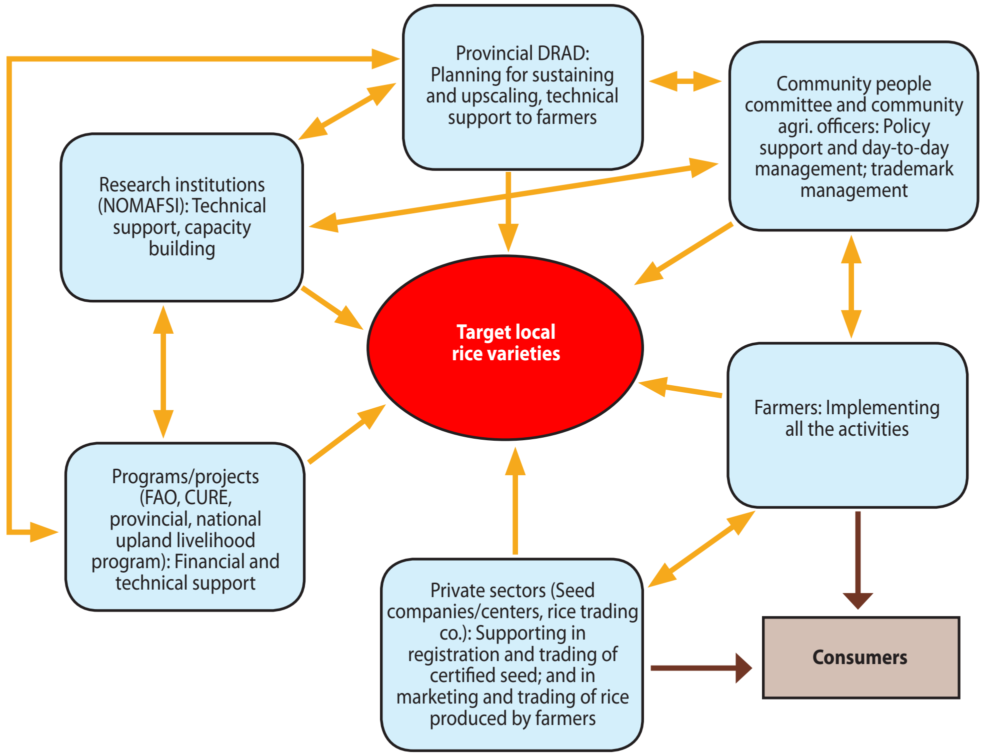
For the Seng Cu variety, the process of genetic purification and production of foundation seeds were completed by the AGI (Agricultural Genetics Institute). NOMAFSI only supported farmers to produce quality seeds and extend the production.

Upon approximation, farmers' income significantly increases when market links are developed and local rice products are sold. The net income could increase up to USD 1,346 –2,019 per hectare (up to 131%) compared with other rice varieties as shown in Table 3. Moreover, farmers could also improve their knowledge and experience in local rice germplasm conservation, seed production, and adoption of ICM for production of quality rice seed and quality commercial rice.

Table 2. Summary of results obtained in restoration of local rice varieties

Variety	Main activities	Year[1]	Location and rice environment	Funding source	No. of seed producers farmers supported by the projects	Amount of seeds produced and supplied by farmers in 2014 (tons)	Number of households that received seed	Yield increase	Production area before the intervention (hectares)	Production area in 2014 (hectares)
Nep Tu Le	Restoration Technical production Registration of community trademark	2005-08	Van Chan District, Yen Bai	Vietnam Government Lowland and terrace	10	-		14–18%	50	100
Chiem Huong	Restoration Technical production Organize farmer group Registration community trademark & seed certificate	2006-15	Van Chan and Van Yen Districts, Yen Bai Lowland and terrace	FAO CURE Community people of Yen Bai	48	50	2,600	20%	1,100	1,800
Gia Dui	Restoration multiplication of seed	2006-08	Xin Man and Hoang Su Phi Districts, Hà Giang Lowland and terrace	Community people of Ha Giang	10	3	260	10–15 %	30	150
Khau Nam Xit	Purification and multiplication of seed	2010-13	Bac Ha District, Lao Cai Terrace	Vietnam Government	15	6	400	20–26%	5	30
Seng Cu[2]	Purification and multiplication of seed	2010-13	Bat Xat, Muong Khuong District, Lao Cai Lowland and terrace	Community people of Lao Cai	10	5	52	10%	-	400
Nep Tan	Restoration Technical production Registration of community trademark	2012-14	Dien Bien Dong District, Dien Bien Lowland and terrace	CURE Vietnam Government	18	6	400	20–23%	40	80
Khau Nua Lech	Restoration Technical production Organize farmer group Registration of community trademark	2010-15	Ngan Son District, Bac Kan Lowland and terrace	CURE Community people of Bac Kan	20	3.5	180	10–15%	15	35

[1] For the Seng Cu variety, the process of genetic purification and production of foundation seeds were completed by the AGI (Agricultural Genetics Institute). NOMAFSI only supported farmers to produce quality seeds and extend the production.
[2] Including also seed amount produced by 'non-project' farmers (project spill over)



Scheme 2. Stakeholders involved in restoration of a local variety.

DRIVERS OF CHANGE

Each activity in the restoration process of the local rice variety required the combined efforts of different stakeholders who each performed significant roles and contributed to accomplishments of the project (Table 4).

Role of stakeholders in a local rice variety restoration and development:

- *Provincial government* promulgates strategies and policies to support rice production (seed and grain), gives right to build collective trademark (use place name, plan production area), and instructs relevant organizations to carry out strategies and policies.
- *Provincial DARD* advises provincial people committee in developing plans for agriculture and forestry production, varietal restoration; proposes mechanisms and policies to support seed and rice production; collaborates and supports the implementation of rice projects; checks and monitors seed sale process; accepts research results and transfers them to relevant organizations (such as seed center and extension center); and develops a master plan for agricultural production, including restoration of local rice varieties. It also provides technical support (through the extension network) to communities,

Table 3: Net income from selected restored varieties.

Variety	Total production cost without labor cost (million VND/ha)	Total production cost without labor cost (USD/hectare)	Total income (million VND/ha)	Total income (USD/ hectare)	Net income (million VND/ha)	Net income (USD/hectare)	Compared with the other rice varieties	
							Increased income	Variety in comparison (*)
Nep Tan	14.0	628	59.5	2,669	45.5	2,041	95%	Nhi uu 838
Khau Nua Lech	15.0	673	60.0	2,692	45.0	2,019	131%	Nhi uu 838
Chiem Huong	12.0	538	41.6	1,866	29.6	1,328	32%	Nghi Huong 305

*popular varieties in the location

Table 4: Main activities of the restoration process of a local rice variety and role of stakeholders.

Activities	Stakeholders or implementers	Role of stakeholders
I. Restoration, purification, and production of foundation seeds		
1. Identification of the value of the target variety and potential for outscaling of its production area	Provincial DARDs	Provide information on agriculture production strategy of the province, knowledge, and reports about the variety
	District people committee, extension officers	Provide information on agriculture production strategy and plan of the district to develop local rice
	"Experienced" farmers	Provide information about the local rice variety
	NOMAFSI and/or other research institutes	Work all the above stakeholders to collect information and develop a proposal for the restoration of the variety
2. Description of the target variety	NOMAFSI and/or other research institutes	Build descriptor table
	Farmer and local staff DARD	Characterize each rice variety
3. Purification of the variety and production of basic foundation and foundation seeds	NOMAFSI and/or other research institutes	Restore and purify Introduce technology to farmers and local staff
	Master farmers	Participate in implementing all the field work
4. Registration of purified variety	DARDs	Build dossier and complete the registration process as required
	NOMAFSI and/or other research institutes	Provide consultation as required
II. Production and provision of quality seeds (community-based seeds)		
5. Establishing farmers' rice seed group and developing its regulations and establishing its managing unit	NOMAFSI and/or other research institutes	Consult for group formation, provide support in drafting and finalizing the group's regulation
	Commune people committee	Approves the group's formation Identifies and allocates land area (suitable for seed production)
	Farmers	Actively provide feedback, observations, and advice, and be involved in the group's formation, and the development of the group's regulations
6. Building capacity of the farmers' rice seed group and collective action	NOMAFSI and/or other research institutes DARDs	Develop and implement training programs Consult on developing group's plans Provide on-the-job training
	Group management unit	Actively participate in all activities and enforce the group's management activities
7. Improving capacity of farmers to produce quality seeds	NOMAFSI and/or other research institutes DARDs	Develop a model for demonstration on ICM for seed production Develop and implement training programs (FFS) Conduct field inspection and monitoring
	Management unit and members of the farmers' group	Actively participate in all the activities and use ICM technologies for seed production
8. Monitoring, field inspection, and certification of certified seeds produced by farmers' rice seed group	Seed center	Conducts field inspection and certification of certified seeds
	Crop production department	Provides support on the policy and legislations as needed
9. Supporting the farmers' rice seed group to sell seeds within the district	Provincial people committee	Promulgates policy supporting local and quality rice production
	District people committee	Promulgates policy to support farmers to use quality seeds of restored varieties for quality rice production
	Commune people committee	Monitors and supports the seed supply process; implement the provincial and district policies
	The group's management unit	Actively scouts for potential markets and perform the seed supply activities according to the policies of the people committee.

Table 4. Continued.

Activities	Stakeholders or implementers	Role of stakeholders
10. Supporting the farmers' rice seed group to sale seeds with trademark (to markets outside the district)	NOMAFSI and/or other research institutes DARDs	Support to build relationship with companies
	Seed center/s Seed companies	Draft the contract with the group; produce packages with stamp and logo and necessary technical support for processing and packaging
	Commune people committee	Monitors the fulfillment of the terms in the contract/s between the farmers group and center/s or companies
	Farmers' rice seed group management unit	Represents the members of the group in the contract and provide seeds following the contract Promotes exchange seeds in the community Scouts for potential markets and traders to work with the farmers' groups for seedling seeds
III. Assistance for upscaling and outscaling of the production of the target variety		
11. Validate and refine ICM package for the target variety	NOMAFSI and/or other research institutes DARDs	Implement participatory trials to identify suitable density, seedling age, fertilization, harvest, storage, among others
	Farmers	Participate in implementing and evaluating the trials
12. Improving capacity for farmers to adopt ICM technologies for production of quality rice	NOMAFSI and/or other research institutes DARDs	Build demo model/s Conduct training activities (FFS) Provide on-the-job training activities
	Local people committees and extension staff	Actively participate in all the activities
13. Building collective trademark and exploit and manage the trademark	NOMAFSI and/or other research institutes DARDs	Identify geography for production Consult to complete the dossier and submit to NOIP (design logo, stamp, regulation, among others)
	Province people committee	Provide certificate to use place and variety name to build trademark
	District farmer association or other suitable community's organization/s	Hold ownership of the trademark Comply with all the required steps and protocol for certification (completing the dossier to register trademark) Develop and realize regulations for using and managing the use of trademark
	District people committee	Monitors the use of the trademark by communes, organizations/individuals who use trademark
	Farmers' rice seed group, farmers, or companies	Use trademark according to the regulation Print bag, package, sale product with protected trademark, logo
14. Support in developing links to markets	NOMAFSI and/or other research institutes DARDs	Support to link with companies/markets Provide consultation as required for contracts between parties (buyers and sellers)
	Farmers' rice seed group, farmers, seed companies	Contract with companies and traders Sell product
	District/commune people committee	Monitors contract signing and implementing process

particularly on sustaining and scaling-up the projects after their completion; provides financial and policy support; and monitors and evaluates the implementation process.

- *NOMAFSI,* a research and technology transfer agency, supports local organizations to restore rice varieties, research, and develop production recommendations; and provides consultation in forming farmers' group to produce and sell product. It also supports local organization to register trademark; improves farmers' capacity on production and market approach and sales; and helps link farmers and farmers' organizations to companies and traders (seed and grain).
- *Projects and donors (FAO, CURE, IRRI).* These could mobilize financial support

for local research organizations to implement local rice restoration and development project. Experts in these organizations could support in the implementation of projects, or hold workshops and training programs to share knowledge and experiences of national and international research industries.

- *Commune people committee, commune agricultural officers* make the production and variety application plans in the areas they manage. They also implement policies that support seed production; collaborate with other organizations with similar research activities; monitor seed distribution process; instruct units at commune level to do relevant programs, projects, policies; and check the contract signed between farmers/ farmers' organization, and companies/ traders.
- *District farmer associations*. The associations build dossier to register collective trademark for local rice and send to NOIP. They grant the right to traders, companies or individuals who want to use the trademark. They monitor day-to-day trademark use of traders and companies, or individuals, and revoke license if users violate any of the trademark regulations. They also support communes to form the same interested farmers' groups.
- *Seed companies or centers*. The companies make a unit that operates under DARD. Their role is to maintain seeds after varietal restoration, participate in the production of seeds at the community, draft a contract to collect seed from farmers' groups, and provide high quality seeds for distribution in the provinces.
- *Rice processing and trading companies* are important in trading rice grain since they make contracts with farmers or farmers' organizations to collect the product. They mill and process the rice grain. They have to protect trademark and logo, print bag with protected logo, and package and sell the product.
- *Farmers and farmers' organizations* are at the center of all activities. They are the beneficiaries of the project and their support for the policies and efforts of the national government in restoring and developing local rice varieties are crucial in fulfilling the overall target goals of the project. They directly carry out project activities, and participate in the research (e.g., building characteristic description and implementing trials).

Financial space

Creating strong linkages and finding sustainable funding sources. The scaling-up will result in increased income and help improve local production and economy. For scaling-up to be successful, the linkages among stakeholders need to be strong, effective, and sustainable. Within the life of projects, however, these linkages are normally not strong enough and further financial investment, often from local governments, is required. Funds for scaling-up other rice local varieties are also required and funding source can be from the national and provincial governments, CURE, FAO, and other donors.

Environment space

Boosting the genetic base of local rice varieties. Restoration of local rice varieties improves not only household rice production and income, but also the germplasm of valuable local rice varieties by increasing the genetic base of the production systems, and reducing the risks of crop failure caused by pests or climatic shocks. Moreover, the adoption of restored varieties and ICM technologies can help reduce the problems of greenhouse gas emission and environmental pollution with balanced fertilizers levels and reduced application of pesticides and nitrogen fertilizers.

Policy space

Promoting policies for long-term benefits of growing local rice varieties. Policies supporting the involvement of all stakeholders, especially seed companies and rice processing and trading enterprises, will greatly facilitate the upscaling process. Also, many high-yielding rice varieties are available (both from official and non-official market links without clear origins). Many farmers (and officers) often do not consider the cost-benefit of rice production but simply choose varieties with high yields. Thus, for the long-term interest of the communities, the government should adopt policies that encourage the farmers to produce local rice varieties, analyze cost-benefit of production activities, and consider the long-term environmental benefits of such practice.

Institutional and capacity space

Involving more sectors in the project. As previously discussed, for each target variety, two value chains are needed to be developed: rice seed production and rice production for food. The commitment of stakeholders in these two chains is a prerequisite to capacity building. In the NMR, training, workshops, forums, and field days are typically organized for capacity building. However, the involvement and commitment of stakeholders remain problematic since there are no definite measures to effectively address the issue. Moreover, recommendations or suggestions to encourage the other sectors to invest in the project, such as incentives for the private sector, would be advantageous.

Cultural space

Integrating technologies into diverse farming traditions. Each local rice variety has been developed, conserved, and used for a long time by a farming community using traditional knowledge to meet their specific needs and purposes. Thus, restoration of these varieties has a great value in the conservation of diverse cultural features and rich indigenous knowledge of 30 ethnicities living in the mountainous regions. However, for scaling-up to be successful changes in the farming practices of the farmers are recommended, such as in terms of adopting advanced techniques for plant management (ICM). This cannot be easily achieved due to the resistance of farmers to change. Thus, integrating local traditional knowledge into the development of advanced techniques is necessary, as well as raising awareness on modern farming technologies to local communities need to be given attention to.

Partnership space

Linking individual stakeholders to work together. All the stakeholders mentioned (see Scheme 1) need to be mobilized to join in the effort to restore local rice varieties.

Learning space

Focusing the efforts to suit the farmers' needs and competence. Capacity building in the form of training activities were conducted to ensure the efficient adoption of technology and to equip the farmers for technological interventions, From 2010 to 2015, in cooperation with local extension program, training activities in local variety purification, restoration, rice integrated crop management (RICM), and farm seed production were organized in Cao Bang, Dien Bien, Lao Cai and Yen Bai provinces with the total participation of 1,084 farmers (551 women and 533 men) as shown in Table 5. The training sessions were organized through the cropping seasons using FFS method.

The decisive factor that contributed to the success of scaling-up process is the proactive participation and commitment of local community members, including the commune and district people committees, local agricultural officers, and farmers. The support from other stakeholders, including research institutions, donors and private sectors, are equally important as well. Also, a suitable outreach approach, such as training materials and methods that suit the local farmers' capacity and written in the languages local farmers can understand, needs to be implemented. Daily on-the-job training activities are also required. Moreover, farmer-to-farmer learning proves to be effective in disseminating advanced management techniques and local rice varieties.

Table 5. Capacity building of farmers for seed purification and multiplication and ICM technology for food rice production, 2010-2015.

Training program	2010	2011	2012	2013	2014	2015	Total		
							Male	Female	Total
Seed purification and multiplication technique	113	0	90	20	89	120	219	213	432
ICM technology	0	70	195	245	0	120	427	203	630
Total	113	70	285	265	89	240	646	461	1062

REFERENCES

Thong tin nong thon Viet Nam. (2013). *Vị trí địa lý, điều kiện tự nhiên và dân số của Vùng trung du và miền núi phía Bắc*. [Geographical Location, Natural conditions and population of the midlands and northern mountains].

General Statistics Office. 2013.

Ministry of Agriculture and Rural Development, 2014. *Cơ sở dữ liệu nông nghiệp nông thôn các tỉnh* [Online Database of agriculture and rural province].

Bui Chi Buu and Nguyen Thi Lang. 2011. *Cải tiến giống lúa phẩm chất gạo tốt tiếp cận chiến lược mới*. [Improved Rice Varieties of Good Quality New Strategic Approach].

ANNEX

The technology package for the production of Chiem Huong variety

1. Seed preparation and incubate

Seed quantity: 30 kg per hectare

Soak and incubate

Soak seed in warm water (54^{0}C) for 30–36 hours. Wash the seed every six hours and replace the water.

Incubate

Seed will germinate in 50 to 60 hours after soaking in warm water. Maintain a temperature of 30–32^{0}C and moisture of 85–90% during the germination.

2. Seedling growing

Transfer the seed in field or seed bed after sprouting.

3. Land preparation

Plough, remove weeds, and level the field. Maintain water level at 2–3 centimeters.

4. Transplanting

Transplant seedling at 2–3 true leaves stage with density of 40–45 hills/m^2, and 1–2 seedling per hill

5. Fertilizer application rate (per hectare)

Organic fertilizer: 8 –10 tons, urea: 200 kilograms, kali clorua (potassium chloride): 140 kilograms, super phosphorus: 420 kilograms

Application methods

Basal application: apply all organic, super phosphorus and 40% of urea before transplanting

First top dressing: apply with 40% urea, 50% kali clorua as rice starts tillering

Second top dressing: apply 20% urea, 50% kali clorua when rice begins forming panicle (20–25 days)

6. Water management

From transplanting to start of tillering, keep water level in the field at 3–5 centimeters. Drain water when each hill has 8-10 tillers. Maintain the water level at 3–5 centimeters during the flowering stage. Drain the water from milk to ripening stage.

7. Pests and disease management

Inspect field regularly for presence of pests and diseases. If pests or diseases appear, control using recommendation of plant protection units.

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Framing questions on scaling-up technologies

General Outline	Question: What information is needed?
IDEAS	1. What is the intervention that is to be scaled-up? Is it a new idea (innovation) or an idea adopted and adapted from prior practice elsewhere? 2. Background of the project 3. Domain of potential application/site (description) 4. Whose idea is it? 5. Has it been tested/piloted/evaluated? Validation status (where it was tested)
VISION	6. Goal and objectives of the project 7. What is the appropriate ultimate scale of the intervention? i.e., how many people, households, districts, etc. could and should ultimately be reached, not merely by CURE-IFAD project, but also by other related partner projects 8. Expected outputs/benefits of adoption
DRIVERS OF CHANGE	9. What or who are the drivers that are pushing, or are expected to push, the scaling up process ahead? 10. What does CURE do to develop and support these drivers/enabling mechanisms?
SPACES/ DIMENSION/ SCOPE	11. Space has to exist or be created so the intervention can grow to achieve the desired scale. What does the government do to ascertain or help create this space in its multiple dimensions?

If scaling-up were to succeed, space has to be created for the initiative to grow. The most important spaces are:

- Fiscal/ financial space: Fiscal and financial resources need to be mobilized to support the scaled up intervention; and/or the costs of the intervention need to be adapted to fit into the available fiscal/financial space.
- Natural resource/ environmental space: The impact of the intervention on natural resources and the environment must be considered, harmful effects mitigated or beneficial impacts promoted.
- Policy space: The policy (and legal) framework has to allow or needs to be adapted to support scaling up.
- Institutional/ organizational/ staff capacity space: The institutional and organizational capacity has to be created to carry the scaling-up process forward.
- Political space: Important stakeholders
- Cultural space: Possible cultural obstacles or support mechanisms need to be identified and the intervention suitably adapted to permit scaling up in a culturally diverse environment.
- Partnership space: Partners need to be mobilized to join in the effort of scaling up.
- Learning space: Knowledge about what works and doesn't work in scaling up needs to be harnessed through monitoring and evaluation, knowledge sharing and training.

12. Challenges and recommendation