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International Rice Research Notes

Using rice cultivar mixtures: a sustainable approach for managing diseases and increasing yield

Integrated natural resource management for rice production

Yields at IRRI research farm still close to climatic potential level

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Using rice cultivar mixtures: a sustainable approach for managing diseases and increasing yield

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The adoption of modern rice cultivars has increased annual production in the past three decades by 2.4% per annum and average yield by 71% (Khush and Virk 2002). Modern cultivars continue to replace thousands of traditional cultivars (Chang 1994). Although the number of landraces used in breeding modern cultivars has increased in the same period (Hossain et al 2003), many modern cultivars share the same genetic background (Chang 1994), which has contributed to the instability of resistance against several rice diseases with high epidemic potential.

A sustainable approach in managing modern cultivars is functional diversification. Functional biodiversity (Schmidt 1978) is based on the principle of using cultivars with diversified functions to limit the development of diseases. A growing number of studies show that, in natural ecosystems, functional diversity leads to higher stability (Petchey and Gaston 2002). This means that, in agroecosystems, haphazard cultivar mixtures do not necessarily control diseases and increase yield and that prolonging the useful life of resistance genes and increasing crop productivity may be achieved by taking into account the functional differences in disease resistance and other agronomic traits of cultivars. Such functional diversification can be achieved by using multilines and cultivar mixtures (Wolfe 1985).

The usefulness of mixtures, whether multilines or cultivar mixtures, for disease management has been well demonstrated for rusts and barley powdery mildews of cereals (Finckh et al 2000, Mundt 2002). Multilines are mixtures of genotypically identical lines (near-isogenic lines) that differ only in a specific disease or pest resistance gene (Browning and Frey 1981). Multiline cultivars of rice are widely used to prevent the breakdown of resistance against blast in Japan, where the first registered rice multiline was released in 1995 (Koizumi 2001). Cultivar mixtures refer to mixtures of cultivated varieties growing simultaneously on the same parcel of land with no attempt to breed for phenotypic uniformity (Mundt 2002). The use of cultivar mixtures is considered to be more practical and requires less investment than the use of multilines because there is no need to breed new cultivars. This can be easily implemented by resource-poor farmers in developing countries—all that they have to do is mix existing cultivars with favorable agronomic traits and performance. Mixing existing cultivars with more diverse genetic backgrounds than multilines can enhance functional diversity and improve yield by providing more chances for positive interactions among cultivars. Moreover, this offers better opportunities for on-farm conservation of genetic resources by allowing farmers to grow traditional cultivars.

Farmers in subsistence farming communities grow several cultivars in a field or adjacent field as a strategy to cope with heterogeneous and uncertain ecological and socioeconomic conditions (Bellon 1996). The success of the large-scale farmer participatory experiment in Yunnan, China, in which traditional cultivars and hybrid rice are interplanted to control blast and increase yield (Zhu et al 2000), has contradicted the long-held assumption that cultivar mixtures should be restricted to low-input and small-scale rice production systems. This has provided new insights into the important components that can help ensure the success of using cultivar mixtures as a large-scale genetic diversification scheme in modern rice production systems.

This article reviews the current knowledge about the mechanisms that account for disease reduction and yield increase in cultivar mixtures of multiple crops. It discusses the various determinants in the adoption of cultivar mixtures and the prospects for and challenges in using cultivar mixtures as a functional diversification strategy.

Mechanisms for reducing disease intensity and increasing yield and yield stability

The underlying mechanisms behind the reduction in disease intensity and the increase in yield and yield stability are relatively well understood in other crops (Mundt 2002). Much remains to be done in understanding the same concepts in rice cultivar mixtures, but it can be assumed that most of the mechanisms reported in mixtures of other crops could also operate in rice.

Mechanisms for disease reduction

Several review articles explain the various mechanisms by which cultivar mixtures reduce disease intensity (Mundt 2002).

Dilution effect. Disease is reduced in cultivar mixtures because of the increased distance between plants of the susceptible cultivar in the mixture (Browning and Frey 1969, Chin and Wolfe 1984). The presence of the resistant cultivar decreases the chance of the inoculum produced from the infected susceptible cultivar of landing on another susceptible cultivar. Most of the inoculum lands on the resistant cultivar, thus reducing the rate of disease increase.

Barrier effect. The resistant cultivar provides a physical barrier that restricts the movement of the inoculum from the susceptible cultivar (Browning and Frey 1969). For mixtures of differentially susceptible cultivars (i.e., both components are susceptible to different races of the pathogen), plants of cultivar A serve as a barrier for the race that attacks cultivar B, and vice versa.

Induced resistance. This occurs when races that are nonvirulent on a cultivar induce the plant's defense response mechanisms. As a consequence, any virulent race (genetically different isolate of the same pathogen that would normally infect the plant) invading exactly the same area of the plant cannot cause infection (Chin and Wolfe 1984).

Competition among pathogen races. The diversity of pathogen genotypes is expected to be higher in cultivar mixtures than in monoculture, thus increasing the chance of interactions and competition between pathogen races (Garrett and Mundt 1999). Competition among different virulent races may prevent a certain race from dominating and overcoming host resistance in cultivar mixtures, thus reducing disease in the mixtures.

Mechanisms for increasing yield and yield stability

Cultivar mixtures can have a higher yield and more yield stability than pure stands of the components (Finckh et al 2000). Yield advantages are more commonly observed in mixtures that have decreased disease intensity (Finckh and Mundt 1992, Mundt et al 1995). Aside from the reduction in disease, several mechanisms are believed to account for the increase in yield and yield stability in cultivar mixtures.

Complementarity. The yield benefit of cultivar mixtures may be a function of complementary resource use above- and belowground (Willey 1979). As in interspecific mixtures, a yield advantage occurs when cultivar components differ in their use of resources in space and time in such a way that overall use of resources is better than when components are grown separately. Complementarity usually occurs when component cultivars have different growth durations because the demand on resources occurs at different times (Fukai and Trenbath 1993).

Compensation. Compensation usually happens between cultivars with different competitive abilities (Willey 1979). It occurs when the yield of one component increases while the other decreases without affecting the overall yield of the mixture (Khalifa and Qualset 1974). Compensatory tillering by resistant plants was observed when disease occurred early in the season (Brophy and Mundt 1991) and even in mixtures where disease intensity was not affected (Mundt et al 1995). Compensation was also observed in cultivar mixtures where the components differed in plant height (Khalifa and Qualset 1974).

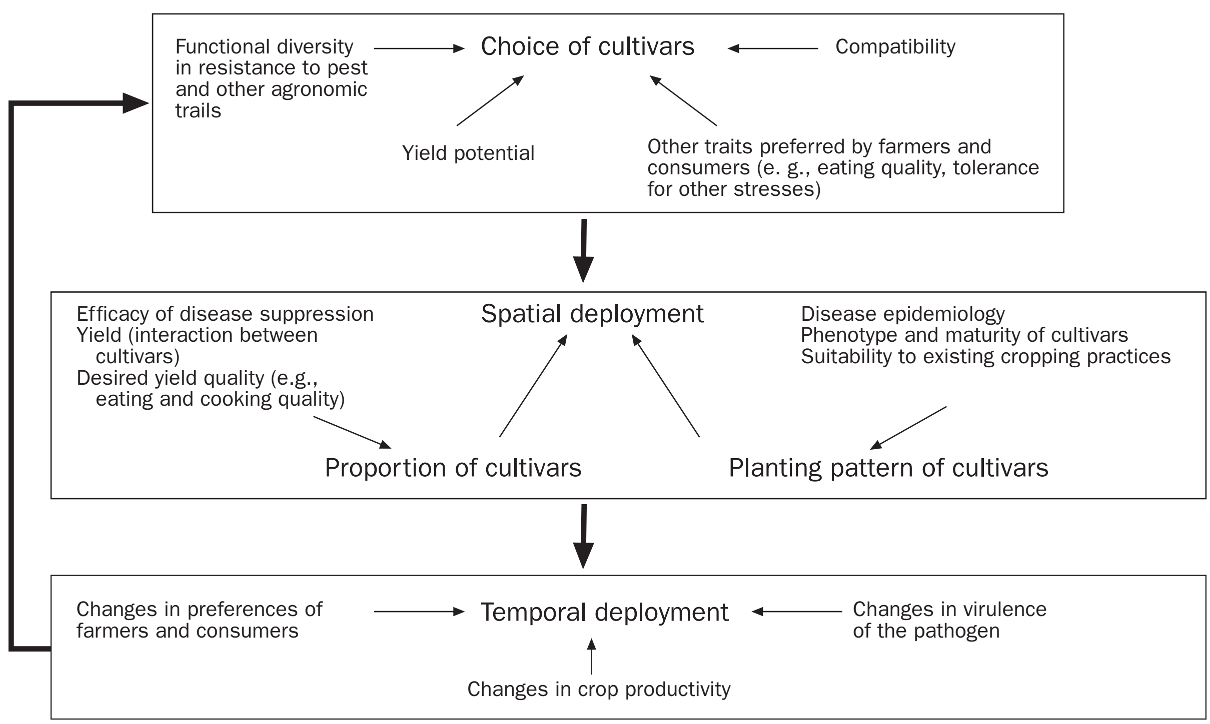
Facilitation. Facilitation is the positive effect of plants on the establishment or growth of other plants (Garcia-Barrios 2002). A component cultivar may benefit another component directly by improving microclimate, providing physical support or windbreaks, and ameliorating harsh environmental conditions, or indirectly by providing protection from other pests and diseases, and improving water-holding capacity (Callaway 1995, Garcia-Barrios 2002). Although rarely quantified, a form of facilitation observed in rice cultivar mixtures is the higher resistance to lodging of tall cultivars in mixtures than in monoculture.

Major determinants in growing rice cultivar mixtures

Various biological and socioeconomic factors must be considered in the choice of cultivars to be used in mixtures and their deployment in space and time. These factors and their interrelationships are summarized in the figure.

Choice of cultivars

Functional diversity of cultivars. An important prerequisite in using mixtures is the diversity of cultivars to be included in terms of functions, such as resistance to the prevailing populations of the pathogen, resource use, and other agronomic traits. The functional diversity approach can help reduce diseases and increase yield. Advances in genomics



Interrelationships among some factors that affect the adoption of rice cultivar mixtures.

and the recent completion of the rice genome may help determine the functions of genes and predict the performance of both traditional and modern cultivars to be included in the mixtures (Leung et al 2003).

Yield potential. The yield potential of the cultivars may be more important in some areas where farmers are more concerned with maximizing yield than reducing disease. Although disease reduction is expected to increase yield, a more preferable option is to choose at least one cultivar with high potential yield to increase the chances of attaining high yield.

Other traits preferred by farmers. Rice farmers do not always consider disease resistance or yield as the sole criterion in choosing cultivars. In areas where modern cultivars are widely adopted, market demand has increasingly become the most important selection criterion (Friis-Hansen 2000). Farmers may prefer to combine cultivars that fulfill different requirements as generally observed in rice-growing areas where multiple traditional cultivars are grown (Bellon 1996)—e.g. good eating quality for cultivar A and high yield potential for cultivar B. Most farmers, particularly in modern rice production systems, would prefer to mix cultivars that are similar in crop duration and phenotype to facilitate crop establishment and maintenance, harvesting, and marketing of harvested grains.

Spatial deployment of cultivar mixtures

Proportion of cultivars. Various studies suggest that the mean level of resistance of all components with respect to the population of the pathogen has a stronger effect on disease intensity than the number of components (Finckh et al 2000). Increasing the optimum proportion of resistant cultivars is expected to increase the efficacy of the cultivar mixture because of the dilution effect. However, the proportion of the resistant cultivars is dictated not only by the expected effects on disease intensity but also by its effects on yield and whether it can fulfill the requirements of farmers. Farmers who produce rice mainly for the market may prefer to grow a higher proportion of the cultivar that commands a higher price. In seed mixtures, the desired proportion may depend on the eating quality of the product. Furthermore, plant type may be a consideration. For example, in mixtures composed of cultivars that differ in height, increasing the proportion of the taller cultivar may adversely affect the growth and yield of the shorter cultivar.

Planting or spatial pattern of cultivars. In several cases, the efficacy of cultivar mixtures depends not only on the proportion of susceptible and resistant components but also on the planting pattern. If the initial disease is distributed randomly or uniformly, such as the foliar diseases caused by wind-dispersed pathogens, the efficacy of mixtures increases as the genotype unit area (GUA) decreases (Mundt et al 1996). GUA is the area occupied by an independent unit of host tissue of the same genotype. For cultivar mixtures to be effective against diseases, cultivars with the same level of resistance should not be adjacent to each other. A rice cultivar mixture in which the hills consist of seedlings belonging to different cultivars has a lower GUA than one with several rows of each cultivar alternating. Cultivar mixtures could be less effective for the control of diseases, such as bacterial blight, which is caused by a pathogen that is mainly dispersed by rain splash or water (Ahmed et al 1997). The inoculum dispersed by this mechanism usually lands close to the source plant; thus, rows of resistant plants cannot effectively serve as a barrier between rows of susceptible plants. Mixing seeds of a susceptible cultivar with those of other cultivars with functional resistance genes will result in reduced GUA and may effectively suppress bacterial blight.

Spatial pattern also affects yield and competitiveness of components in the mixture (Fernandez et al 2002). To improve yield, there is a need to consider a spatial pattern that would allow cultivars, especially those with varying phenotypes, to interact positively and compete less. Spatial pattern may, in part, be determined by its suitability to existing cropping practices, specifically with respect to crop establishment and harvesting.

Temporal deployment of cultivar mixtures

It may be necessary to change the composition of cultivar mixtures after a specific period of time. The use of saved seeds from one season to another may lead to a shift in the composition of cultivar mixtures due to the enhanced competitive ability of a component because of diseases (Alexander et al 1986). It may also decrease the productivity of cultivar mixtures even in the absence of disease (Khalifa and Qualset 1974). Changing the mixture composition after a given period could delay the shift of the population structure of the pathogen toward virulent races, which occurs after successive cultivation of the same cultivars. Another reason for changing the components is the change in the preferences of farmers and consumers.

The most common methods of mixing rice cultivars and their advantages, disadvantages, and applications are shown in the table.

Prospects and challenges

The main challenge in the use of cultivar mixtures as a functional diversification scheme lies in the fact that designing a system for mixing cultivars is a dynamic process. It should be customized not only to the diseases and cultivars but also to the various biotic constraints and cropping practices of farmers in a specific area. Several research issues must be examined in designing an optimum system; these are the most important: (1) What cultivars should be combined? (2) What are the effects of certain proportions and planting patterns on major diseases and other biotic constraints and crop productivity? and (3) What are the mechanisms (i.e., ecological and genetic bases) behind disease reduction and yield increase? The next step is to analyze practical issues. A system for mixing cultivars must be designed to minimize anticipated difficulties in crop establishment, harvesting, and milling and marketing of grains that are usually associated with the adoption of cultivar mixtures. It is also important to quantify the costs and benefits to determine whether the benefits, such as those derived from the increase in yield and reduction in fungicide use, can offset additional costs. Farmers in Yunnan, China, incurred additional cost in transplanting and harvesting, but they continue to interplant cultivars because the economic benefits exceeded the costs (Leung et al 2003).

The prospects for using rice cultivar mixtures appear to be more promising now than decades ago because of the availability of several new approaches that are important in choosing the right combination and spatio-temporal deployment of cultivars. Recent advances in genomics, coupled with phenotyping, allow the selection of cultivars with defense genes effective against the population of pathogens in a given location. More importantly, these advances may help in the selection of component cultivars that are functionally diverse with respect to disease resistance and agronomic traits. Experimental designs and various analytical approaches can now be used to evaluate disease epidemics and interactions of cultivars in mixtures and, consequently, allow for a more efficient identification of a system that suppresses diseases and maximizes positive interactions among cultivars. Moreover, various farmer participatory methods can be applied to ensure that a given system suits the social, cultural, and economic needs of farmers. Using a combination of these approaches, on-farm experiments are under way in China, the Philippines, and Indonesia to explore the use of rice cultivar mixtures.

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Methods of mixing rice cultivars and their advantages, disadvantages, and applications.

Method	Example of Spatial pattern	Advantages	Disavantages	Applications
Random seed mixture	XOXOXXOOXO OOXOXXOXXO XOXOOOXOXX XOXOOOXOXX XOXOXXOOXO 1 susceptible: 1 resistant	• May result in high disease control • Facilitates crop establishment, management, and harvest if cultivars have the same height and maturity • Can be easily adopted for both transplanted and direct-seeded rice	• Functional diversity may be low as cultivars may have similar genetic backgrounds • Since seeds will have to be marketed as a mixture, proportion should take into account effect on eating and yield quality • Cultivars should have the same phenotype and maturity	A 1:1 seed mixture of IR64, a susceptible cultivar with good eating quality, and a resistant line effectively reduced tungro in southern Philippines at high and low disease pressures (R. Cabunagan and I.R. Choi, IRRI, unpub. results)
Single-row interplanting (interplanting one row of a susceptible cultivar between several rows of resistant cultivars)	XXOXX XXOXX XXOXX XXOXX XXOXX XXOXX XXOXX XXOXX XXOXX XXOXX 1susceptible: 4 resistant	• Functional diversity could be higher than in method 1 • Disease control in the susceptible cultivar can be high, but lower than in the seed mixture • Cultivars with different uses, height, and maturity can be mixed • Lodging of taller cultivar can be minimized	• Transplanting and harvesting can be laborious and time-consuming if cultivars differ in maturity	Interplanting susceptible glutinous cultivars with resistant hybrid rice cultivars (Zhu et al 002) was done in Yunnan and Sinchuan, China to control blast
Alternate-row interplanting (alternating several rows of susceptible and resistant cultivars)	XXXOOOXXXOOO XXXOOOXXXOOO XXXOOOXXXOOO XXXOOOXXXOOO XXXOOOXXXOOO 3 susceptible: 3 resistant	• Cultivars with different uses, height, and maturity can be mixed • Lodging of taller cultivar may be minimized but probably with lower efficacy than in method 2	• Disease control can be lower than in methods 1 and 2, especially if highly suscepti-ble cultivars are used • Transplanting and harvesting can be laborious and time-consuming if cultivars differ in maturity • Proportion of cultivars should consider effect on competition between cultivars that differ in height and maturity	Evaluated for efficacy against blast in upland rice in Lampung Province, Indonesia, using susceptible modern cultivars with high yield potential and resistant traditional cultivars with low yield potential; initial results showed no reduction in neck blast relative to monoculture of susceptible cultivar; future trials will consider modern cultivars with moderate susceptibility to blast

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2. Authors should submit figures (graphs, charts, illustrations, etc.) in Excel, if possible, or the original graphics application, and not as embedded files in MS Word. Photos/images should have a resolution of 300 dpi. Figures should not be smaller than 5.5 by 8.5 inches. Figures should be one to a sheet. Authors should use at least 0.5-thick pt. lines for graphs, boxes, etc., in figures.

3. Authors should make sure that no objects (graphs or charts) are embedded between text blocks. Photo files are also accepted in the following electronic file formats: jpeg, tif, and gif. File name and type of file must be indicated.

Integrated natural resource management for rice production

Suan Pheng Kam

Research over the past 30 years by the agricultural research community at large has made significant achievements in boosting productivity and alleviating poverty through increasing farm income. However, these agricultural advances have also had effects that resonate across the landscape, in some cases undermining the integrity of natural resources that people depend on to meet a wide range of needs. In addition, achieving further improvements in agricultural production has become more challenging than ever before. This has to be accomplished using land, water, biological, and other resources that are increasingly limited in supply in the face of increasing population pressure and competing demands from other sectors of economic development. Dr. Ian Johnson, president of the Consultative Group on International Agricultural Research (CGIAR) centers, succinctly summarized the importance of natural resource management (NRM) in his statement that "…mismanagement of natural resources may be the 'Achilles heel' of long-term sustainable development." These recent trends are driving a demand for broadening research and management approaches that are aimed not only at productivity gains but also at ensuring truly sustainable development in the economic, social, and ecological sense. These approaches have generally been described as *integrated natural resource management (INRM).* However, INRM means different things to different people, mainly because there are many facets of natural resources and there are many ways by which they are used to meet human needs.

This article attempts to explain and illustrate the INRM concept in the context of agricultural production and, in particular, rice-based cropping systems. Starting with defining natural resources in relation to agricultural use, it proceeds to identify key NRM issues and illustrate, by using examples, different levels and dimensions of integrating components of natural resource management in intensive, irrigated, and less favorable rainfed systems. Finally, it discusses the need for rethinking people's roles and changes in attitudes and the way in which NRM research and development is conducted, so that INRM can be meaningfully and effectively implemented.

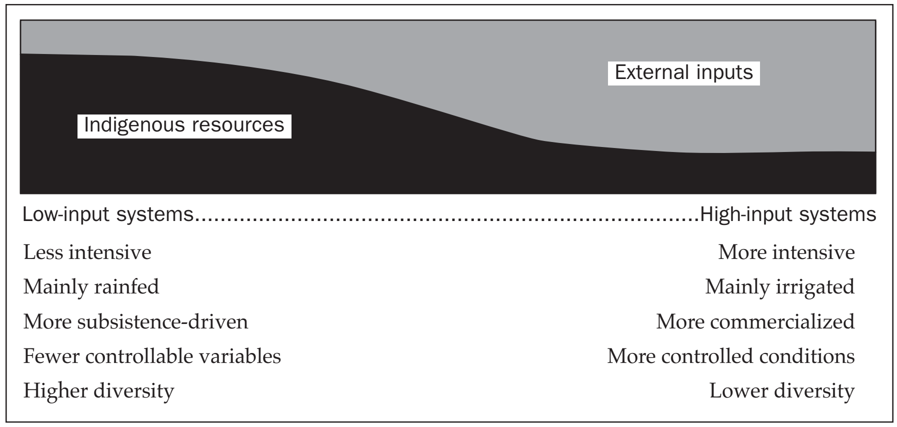

Fig. 1. General characteristics of agricultural production systems varying in relative dependence on indigenous resources and external inputs.

Defining natural resources in the context of agriculture

To support their livelihoods, farmers use a wide range of natural resources, including the rice plant and genetic resources, water, land, and soil mineral nutrients. They also depend on weather elements, especially solar radiation and atmospheric gases; and on naturally occurring beneficial biological organisms such as natural enemies of pests and soil microorganisms. In modern agriculture, farmers also use external inputs, particularly agricultural chemicals. These chemicals affect the natural flora and fauna populations and, if used in excess, may pollute the soil and water. *Natural resource management for agriculture encompasses all activities that enable farmers to grow a healthy crop and reap a stable and profitable harvest* to meet household food needs and earn a reasonable income. *Integrated natural resource management is an approach that applies a systems thinking in carrying out these activities such that productivity enhancement goals can be achieved without compromising the capacity of the natural resource base and its underlying ecological processes to continue supporting future agricultural production*.

Resource use for agricultural production

In rice-based production systems, we could consider the gradient of increasing *relative* dependence on external inputs from the largely subsistence, low-input rainfed systems to the intensive and commercially oriented irrigated systems (Fig. 1). NRM issues are different for the various types of rice-based production systems; accordingly, strategies and actions for more integrated management are different.

The intensive agricultural systems

In the intensive irrigated systems, the main NRM issues are related to the inefficient use of external inputs, which not only increases production costs but also causes environmental pollution (e.g., inappropriate use and overuse of fertilizers and insecticides), degradation (e.g., overextraction of groundwater, causing salinization), and erosion of biodiversity (e.g., eliminating natural enemies of common crop pests). The main strategy is to increase input efficiency by applying just enough inputs as and when needed by the crop. The following examples illustrate not only how this strategy is put into practice but also how the component technologies can be brought together in an integrated crop management (ICM) approach—an important move toward INRM *at the field level*.

Real-time, crop-oriented nutrient management technologies such as the leaf color chart for N management for rice (Yang et al 2003) and the site-specific nutrient management (SSNM) approach for tailoring P and K application rates according to yield target and soil nutrient-supplying capacity (Fairhurst and Witt 2002) are now practiced by farmers in various countries. Refraining from unnecessary spraying of insecticides against leaf feeders, especially at the early crop stage when the crop is able to compensate for any loss at the later growth stage, not only means cost savings but also constitutes an environmentally sound basis for pest management. Farmers increasingly recognize the additional benefits of bringing together component technologies into workable "packages." The Vietnam example of "Three reductions, three gains""(Box 1) illustrates the coming together of pest, nutrient, and seed management.

Three reductions, three gains

In the Mekong River Delta of Vietnam, farmers who started out adopting the "no-early-spray" practice, and thereby reduced insecticide use, are now embracing technologies that reduce other inputs—site-specific nutrient management for reducing fertilizer use and the drum seeder for reducing the number of rice seeds used in direct sowing. This provided the impetus for the "Three reductions, three gains" campaign that is now widely promoted by the Vietnamese government. The three gains as perceived by scientists are increased profit, improved health for humans, and better environment; as perceived by farmers, these gains are increased yield, better grain quality, and more profit. This shows that farmers have the more immediate productivity enhancement objective in mind. The environmental gain is more long term and of less immediate concern to farmers. Yet, if the combination of crop management practices that directly benefit farmers can also benefit the environment, the outcome is a win-win situation.

It is not difficult to conceive of ways by which additional components of ICM can be introduced. For example, the first line of defense against disease attack is to start the crop with healthy seeds and seedlings. Relatively simple methods taught to farmers for storing and maintaining high-quality seed stock that they save for the next planting go a long way toward improving seedling vigor. The seed health campaign in Bangladesh and elsewhere has gained widespread adoption. The strategy of seeking alternative, nonchemical ways of warding off diseases is clearly illustrated by the rapidly expanding practice in China of interplanting modern, high-yielding hybrid rice varieties that have high disease (in this case, rice blast) resistance with susceptible traditional taller glutinous varieties (Leung et al 2003). The crop mixture as a whole faces lower blast incidence without need for fungicide use. There are also unexpected spin-off benefits from this interplanting practice. Farmers are reintroducing blast-susceptible traditional varieties that have high sociocultural and market value and are getting decent yields in addition to those of the modern varieties with which they are interplanted.

There is also a growing concern about reduced water availability and assurance of water supply, hence the need for water-saving technologies for irrigated rice. Various management practices are now available for a range of water constraint conditions. These include (1) dry direct seeding to save water used for field preparation, at the same time saving on labor; (2) land leveling to reduce the amount of water needed to keep fields uniformly flooded, at the same time improving weed control; (3) alternate wetting and drying; (4) the use of raised beds; and (5) aerobic rice systems that progressively reduce the need for fully flooded fields all the time. These water-saving technologies in turn require rather different nutrient management regimes and pest management strategies that are appropriate for the shifts in weed flora composition and pest profiles resulting from changes in water regime in the rice field. This calls for not only more dimensions of integration in crop management at the field level but also *matching ICM with improved crop varieties* that are better adapted to conditions of reduced water availability.

It is also not difficult to conceive that the INRM approach can be extended *beyond the rice crop and beyond the field and farm levels*, particularly as natural resources are used over and over again and their flows and processes cover geographical scales larger than a farmer's field plot. Many agricultural areas are increasingly undergoing more intensified and diversified use, and proper management of the natural resources becomes even more critical if these production systems are to be sustained.

For example, millions of hectares in South and East Asia are grown to rice in the monsoon season, followed by wheat in the winter season. To improve the overall productivity of this rice-wheat system, management interventions for the rice crop cannot be made in isolation from interventions for the wheat crop. Hence, the efforts of the Rice-Wheat Consortium (http://www.rwc-prism.cgiar.org/rwc/index.asp), a research network of South Asian national agricultural research and extension systems, are increasingly focused on attaining better synergies in more efficient nutrient and water management strategies for the rice and wheat (or other) crops in tandem (Ladha et al 2003).

The diverse rainfed systems

Managing diversified cropping systems is even more challenging under rainfed conditions, when the time period for cultivation is restricted, especially in areas with climatic constraints. Generally, the lower input, rainfed systems are heavily dependent on and driven by the availability (in location, quantity, and time) of natural resources. Here, the main NRM issues are related to various productivity constraints (too much water, too little water, poor-quality water and soil, steep terrain), greater uncertainty in supply (and therefore higher risk to farmers), and limited windows of opportunity for agricultural production. Particularly in the less favorable and more fragile rainfed environments, such as areas prone to soil and water degradation, it is easy to tip the delicate ecological balances through mismanagement and very difficult to restore these checks and balances that are so important for long-term sustainable use of the natural resources. These are also areas where the poorer farmers are concentrated. These farmers mainly practice subsistence farming and have limited resources at their disposal to improve their livelihoods, much less to concern themselves with the long-term environmental consequences of their present activities.

Under these circumstances, the main strategy is to help farmers effectively use (and expand where possible) their windows of opportunity for food production to meet their immediate household needs ("fill their rice bowls"), in ways that can incrementally release resources for them to diversify their income-generating activities (Fig. 2). The circumstances are quite varied, making NRM for agricultural development in rainfed environments particularly challenging—hence an even greater need for integrated approaches, as single interventions are not likely to have much real impact. As in the case of the irrigated systems, there can be several scales of integration in NRM. Managing these resources judiciously requires practices and actions that are at and beyond the field/farm to the landscape level, and beyond the household to the community.

At the field level, there is still considerable scope for crop management interventions to improve crop productivity, particularly in areas where technologies targeted for favorable conditions are not suited. Much more attention needs to be placed on the influence that water availability (and quality, in some cases) and its management have on other aspects of crop management, including establishing the crop, applying nutrients, and controlling weeds and pests. Integrated crop management is even more critically needed for rainfed systems.

Recent advances in biotechnology to complement conventional breeding are opening up opportunities for incorporating traits that make the rice plant, including popularly grown varieties, better adapted to adverse environmental conditions. The emergence of well-adapted varieties—e.g., for submergence and salinity tolerance—will happen faster than ever before with such concerted efforts for crop improvement. These developments must be accompanied by equally concerted efforts to develop matching crop management practices that will help realize the full potential of the improved germplasm. This calls for integration between ICM and crop improvement.

Because rainfed production systems (especially the predominantly subsistence types) tend to be more diversified, farmers try to manage and spread their limited resources over a range of farm activities. Therefore, crop management strategies need to consider the total resources at the disposal of the farm household and ways of optimizing their use within a cropping system, rather than a particular crop or season. Many of the improved varieties targeted for less favorable rainfed conditions are also of shorter growth duration, hence reducing the period that the rice crop occupies the field and allowing for a tandem crop to be accommodated within the available time window suitable for cropping. Appropriate crop establishment (e.g., direct seeding instead of transplanting) and management practices (e.g., water harvesting and soil

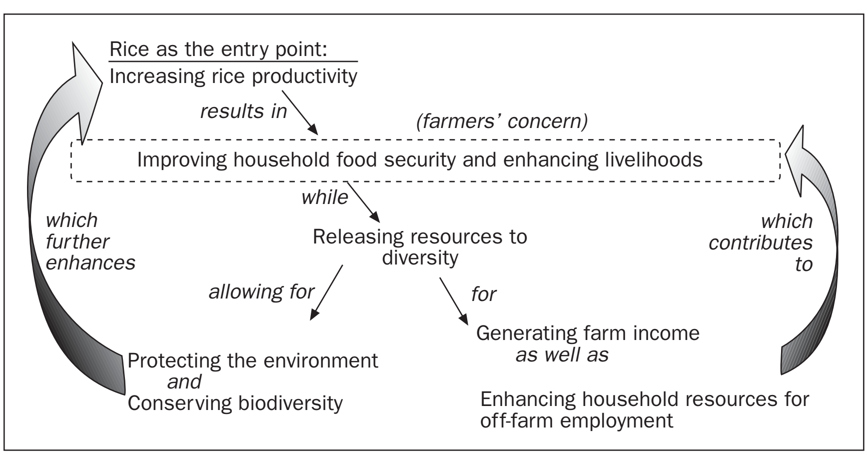

Fig. 2. An exit path from food insecurity, poverty, and environmental degradation.

moisture conservation) can further stretch and optimize the time and resource use in favor of intensifying agricultural production under rainfed conditions. It has been shown that even managing the land in fallow, between cropping seasons, can benefit the environment and improve the income of farmers.

Integration *at the landscape level* is important in managing natural resources in rainfed systems that are heavily dependent on natural resource stocks and flows (e.g., of water and nutrients), especially if these are limiting. A recently completed project in Bac Lieu Province in the Mekong River Delta in Vietnam (see Box 2) illustrates the relevance of applying an INRM approach at the regional level for effective and sustainable land and water resource management for both rice- and brackish water shrimp-based production systems in the coastal lands that are partially protected from salinity intrusion (Tuong et al 2003).

While there is a compelling ecological basis for managing natural resources beyond the field and farm levels, this would also directly benefit farming communities and farmers who use and manage resources across different landscape positions. Interactions across the landscape or toposequence become more significant for NRM in hilly and mountainous areas, especially where the fragile ecosystems are being transformed and subjected to more intensive use because of increasing population pressure. There have been successful attempts at conservation-friendly alternatives to shortened slash-and-burn cultivation cycles (Sanchez and Hailu 1996, Husson et al 2001), and an active consortium of research organizations, the Consortium for Alternatives to Slash and Burn, is devoted to promoting these alternatives (http://www.asb.cgiar.org/txt_only/home.htm). However, successes are still limited relative to the extent of the problem of unsustainable agricultural development in the uplands across all continents.

Recent transformations in upland agriculture in southwestern Yunnan Province in China (see Box 3) illustrate how it takes a chain of interventions introduced at several levels to achieve widespread impact of sound NRM practices that bring about improved livelihoods and more rational land and resource use. The success of the Yunnan case may not be directly prescriptive of all upland areas suffering from nonsustainable land use. Moreover, there is room for further improving the entire system, and its components, to ensure long-term sustainability. Nonetheless, this is a real case example of the strategy depicted in Figure 2. It illustrates the need for technology advancement to be supported by appropriate policy intervention and effectively adopted through community action and private-sector participation.

Managing water and land resources at the interface between fresh and saline water environments

About 160,000 ha of coastal lands in Bac Lieu Province in the Mekong River Delta of Vietnam were targeted in the late 1980s for complete salinity protection to allow intensified rice production. However, while the sluice construction progressed in the 1990s, an emerging enterprise of brackish water shrimp pond culture and changing market conditions (fall in world rice price and boost in shrimp exports) resulted in two main production systems—intensified rice-based farming in the eastern, fully protected part, and shrimp-based aquaculture in the western yet-to-be protected part. The two systems had conflicting demands for fresh and brackish water. The conflict escalated in 2000 when affected shrimp farmers breached embankments to access saline water, prompting a reconsideration of the 1980s land-use policy. The key to turning around a situation of conflict to one that accommodates both needs lies in reconfiguring the operation of the sluice gates to manage a dual brackish-fresh-water regime. This was achieved with the help of a hydraulic model, refined under an IRRI-led, DFID-funded project, to explore scenarios of sluice operation that allow carefully controlled entry of saline water to the western part for shrimp raising during the dry season, followed by flushing out using fresh water at the start of the rainy season for rice cultivation. Using evidence produced by the project on the impact of the salinity control scheme on rural livelihoods, particularly of the poor, the provincial government obtained national approval for changing the land-use policy, thus paving the way for more diversified use of the fresh and brackish water resources for livelihood improvement. With this, more targeted natural resource management interventions can be developed for productivity improvement of the various components of the rice- and shrimp-based production systems at the farm and field levels. Further investigation is also needed to address sustainability issues of this managed system—e.g., impact on aquatic biodiversity and linkage with inland capture fisheries.

Agricultural development in the uplands of Yunnan Province, China

Over the past 4–5 years, a chain of events caused some dramatic transformations in the uplands of western Yunnan Province, where nonsustainable use of the sloping land, especially for extensive cultivation of low-yielding upland rice by mainly poor ethnic populations, used to be prevalent. A team of scientists from the Yunnan Academy of Agricultural Sciences successfully developed high-yielding upland rice varieties that yield substantially higher than the traditional varieties, albeit with higher input levels. These facultative upland varieties yield even higher under terraced conditions, with the availability of bunded water later in the growing season. These yield gains enable domestic rice requirements to be met with less land, reduced soil erosion, and improved water-use efficiency. This prompted the provincial government, with subsequent approval of the central government, to formulate land-use policies that (1) disallow unbunded upland rice cultivation on slopes exceeding 25°, (2) set quotas of per capita rice land deemed sufficient to fulfill household rice security at the improved yield levels, and (3) rehabilitate sloping lands released from upland rice cultivation ultimately to forest. Local agricultural development and extension agencies were brought in to promote cropping and livestock diversification programs. The private sector was also called upon to support the input supply and commodity marketing chain. Overall, there have been impressive improvements in the livelihoods and living conditions in the participating villages across more than 10 counties in the southwest region of the province.

Managing people to manage the natural resources

To have impact, research for NRM must involve the ultimate users—the farmers—and also other stakeholders who can potentially help or influence what farmers do. These include local authorities, extension personnel, development NGOs, and the agricultural private sector and policymakers. INRM as an approach has to be woven into the fabric of interactions among researchers and these various stakeholder groups. Hence, the INRM approach is especially amenable to participatory modes in conducting research and management. There is now available a wide range of participatory methodologies and tools that researchers and extension personnel can use to engage more active involvement of farmers, communities, policymakers, etc., in NRM activities and decision making at various spatial and social scales.

Conclusions

The descriptions above of several instances involving varying levels of integration in managing natural resources for agricultural production illustrate that INRM can be a living concept that is implementable to serve the goals of sustainable development. The examples also show that INRM does not need to be all-embracing in integrating everything. Rather, it makes better sense in reality to integrate only those additional aspects, stakeholders, or scales that can reasonably be expected to have an influence in solving the problem at hand. INRM may be centered on specific technologies that open up opportunities for improved resource management, as illustrated by the Yunnan case, or it may embrace broader natural resource management strategies, as in the Bac Lieu example. INRM as described here is more ***a changed approach to research and management rather than a prescribed set of methodologies***.

Nevertheless, there have to be certain elements or conditions that together engender this change in approach.

- It requires a systems thinking to articulate a common understanding of the problem at hand, so that attention is placed on tackling not only components of the problem but also the interactions among them that may have profound influence on the success of individual technologies. A multidisciplinary representation at the problem identification stage allows researchers and target stakeholders to "see" beyond one's sphere of experience. A group of people arriving at a common understanding of the problem may have different motivations, mandates, and capacity to tackle it or aspects of it; what is important is that they do so, knowing how they can collectively contribute to solving the problem at hand.
- Integration is necessarily achieved by increments. Partnerships cannot be forced, nor can all aspects of integration be preplanned. Many successful INRM cases often did not even start off as being purposefully integra-

tive. What matters is that when some intervention makes headway, the opportunities to enhance its impact are recognized and seized upon.

- In the long run, there needs to be a change in the prevailing, largely sectoral R&D culture and organizational arrangements toward a more integrative outlook and mode. Incremental reinforcements of the benefits of integrative efforts over some period of time can help change mind sets. This again is a process that cannot be forced, but has to be allowed time to develop and evolve at all levels of the R&D organization.

In the long process of engendering change, an attempt to modify existing research and development efforts to achieve higher levels of integration incrementally does, on balance, seem to be a sensible thing to do. The sharing of successful INRM case studies helps not only in transferring the tangible knowledge and products but also in broadening minds and perspectives that INRM approaches can, and do, work.

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Yields at IRRI research farm are still close to the climatic potential level

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Highest dry-season yields obtained at the IRRI Research Farm declined from 9-10 t ha^{-1} in the late 1960s and early 1970s to less than 7 t ha^{-1} in the late 1980s; the comparable yield decline in the wet season was from about 6 to 4 t ha^{-1} during the same period (Cassman et al 1995). In 1991, research teams led by Cassman, Kropff, and Peng initiated investigations into the cause of the yield decline at IRRI. In the wet season of 1991, wet-season yields of 6 t ha^{-1} were achieved with modified N management to improve the congruence between N supply and crop demand (Cassman et al 1994), and these yields were comparable with wet-season yield levels achieved in the 1960s and early 1970s. Based on these results, Kropff et al (1994a) developed, parameterized, and evaluated the ORYZA1 simulation model for yield potential in rice. Based on simulations from this model, Kropff, Cassman, and van Laar (Kropff et al 1994a, b) predicted that, in most years, dry-season yields could be increased substantially with improved N management. Using a historical weather database from the IRRI Climate Unit, the model predicted that the dry-season yield potential would range from 8.5 to 10 t ha^{-1} in 8 of 10 years with a mean potential yield of about 9.3 t ha^{-1}, when the crop was transplanted in early January, which is the optimal transplanting date to achieve maximum yield at this site (Kropff et al 1993, 1994b). In the dry season of 1992, a yield of 9.5 t ha^{-1} was obtained with IR72, and a hybrid variety yielded 10.7 t ha^{-1} under improved N management (Kropff et al 1994b). In a subsequent study, Dobermann et al (2000) confirmed the role of improved N management in restoring yields close to yield potential levels at the IRRI Research Farm.

Since 1992, maximum dry-season rice yields of IR72 at the IRRI Farm have ranged from 9.03 to 9.58 t ha^{-1} under the optimum crop management systems (Peng et al 2003). In the dry seasons from 1998 to 2001, however, highest yields of IR72 were 17% lower than that in the 1992-98 period. Regression of yield on several climate variables was used to help identify the causes of this decline. It was concluded that the most likely causes for the reduction in maximum yield obtained in the 1999-2001 period, compared with yield levels achieved in 1992-98, were lower solar radiation and higher nighttime temperature. Both higher night temperature and less solar radiation would result in a reduction in net C assimilation rates: the former because of increased rates of maintenance respiration and the latter because of a decrease in photosynthetic rates. Pathak et al (2003) also reported that the decrease in solar radiation and increase in minimum temperature were responsible for the negative yield trends of the rice crop from 1985 to 2000 in the Indo-Gangetic Plain. The objectives of this paper were to demonstrate the effect of improved crop management since 1992 on yield potential at the IRRI Research Farm and to determine if the observed yield decline during 1998-2001 can be explained by changes in solar radiation and nighttime temperature using a well-validated ecophysiological simulation model.

Methods

The ORYZA1 model (Kropff et al 1994a) was used to estimate rice yield potential in the dry season at the IRRI Research Farm from 1980 to 2001 based on actual climate data from planting to maturity. Here, we define yield potential as the yield that can be achieved with an adapted rice cultivar when grown without limitations from water, nutrients, or pests. Parameter values used in these simulations were based on values derived for IR72 from the 1992 dry-season experiments as described by Kropff et al (1994a, b). Comparisons of simulated and actual yields were based on the yield of best entry in a long-term continuous cropping experiment from 1979 to 2001 at the IRRI Research Farm (Dobermann et al 2000) and the highest recorded yields of IR72 in replicated agronomic trials under the optimum crop management systems at the IRRI Research Farm for the 1992-2001 period as reported by Peng et al (2003).

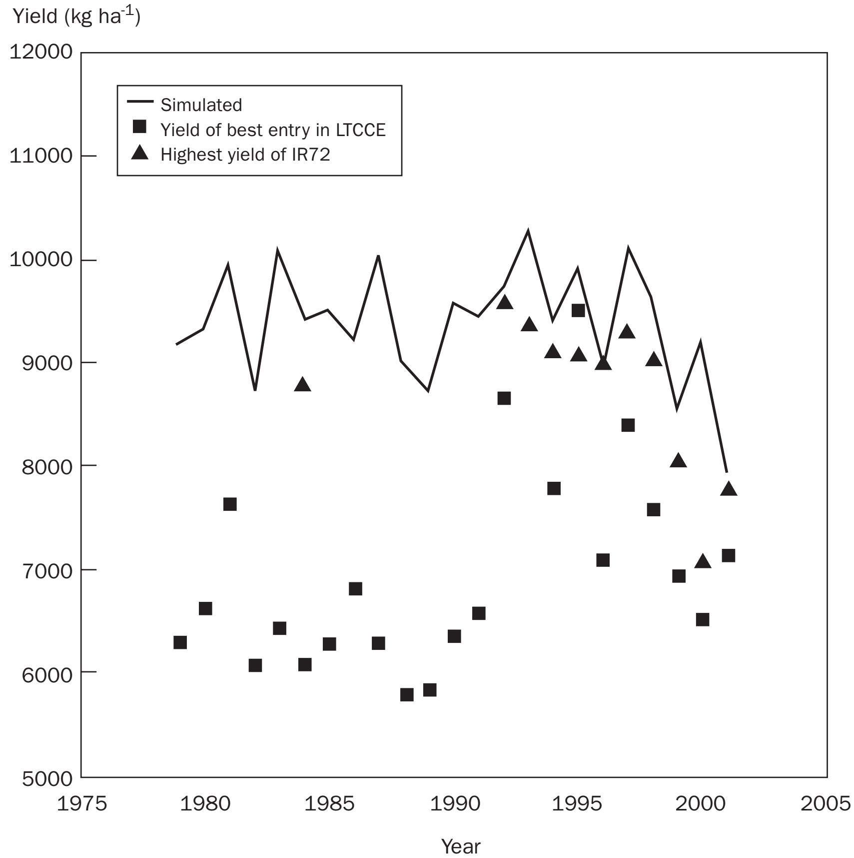
Results

The simulation results based on the actual data of solar radiation and temperature for the period 1979-2001 clearly indicate the large yield gap of about 3 t ha^{-1} between potential dry-season yield and the yield of the best entry in the long-term continuous cropping experiment at the IRRI Research Farm before 1992 (see figure). In contrast, the simulated yield potential is much closer to the best entry yield in the long-term continuous cropping experiment from 1992 to 2001. The average difference between simulated potential yield and the yield of best entry in the long-term continuous cropping experiment was about 1.5 t ha^{-1} from 1992 to 2001. However, the average difference between simulated potential yield and the highest recorded yields of IR72 grown in replicated agronomic trials under optimum crop management systems at the IRRI Research Farm was about 0.6 t ha^{-1} for 1992-2001 (see figure). These results suggest that improved crop managment has effectively closed the yield gap between simulated potential yield and actual yield. In 1992, 1994, 1996, and 2001, the model estimated the yield potential of IR72 very accurately. The model also simulates the variation in yield over years very well.

The smaller yield potential in the 1998-2001 period is also evident in the simulations (see figure). The highest yield of IR72 in the 1998-2001 period was reduced by 17% compared with the highest yield of IR72 in the 1992-97 period. The simulation model estimated that the climatic yield potential in 1998-2001 was, on average, 12% lower than the yield potential in 1992-97. Therefore, the recent decline trend in grain yield at the IRRI Research Farm was not related to crop management or varietal performance. Reduced solar radiation and increased nighttime temperature were mainly responsible for the yield decline. Furthermore, yields at the IRRI Research Farm are still close to the climatic potential level.

Conclusion

The trends in the highest actual yield of irrigated rice obtained at the IRRI Farm since 1992 can be well explained by the ecophysiological model ORYZA1 for potential production. Before 1992, there was an obvious yield gap of 3 t ha^{-1} between potential and actual yields, which apparently resulted from N limitation (Cassman et al 1993, Kropff et al 1993, Dobermann et al 2000). A much smaller yield gap was observed in recent 10 years after 1992, which apparently resulted from the effects of yield-reduc-



Observed and simulated yields at IRRI for the best entry in the long-term continuous cropping experiment (LTCCE) (Dobermann et al 2000) and for the highest yield recorded in IR72 in the dry season from 1992 to 2001 (Peng et al 2003).

ing factors such as pests and diseases. We believe it is useful to use the ORYZA1 model (or other well-validated rice simulation models) as a useful research tool to estimate the yield gap in experiments at IRRI and at other locations where strategic research is conducted on the effects of crop management practices and environmental conditions on rice yields.

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Detection of simple sequence repeat markers associated with resistance to whitebacked planthopper, *Sogatella furcifera* (Horvath), in rice

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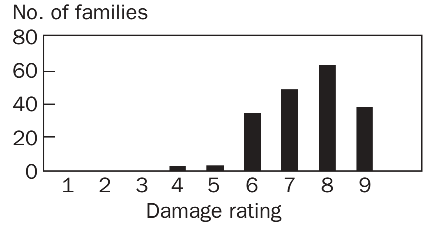
The whitebacked planthopper (WBPH), *Sogatella furcifera* (Horvath), is a serious insect pest that causes severe yield losses in rice-growing areas in tropical Asia. Through classical genetic analysis, six major genes conferring resistance to WBPH have been discovered in rice germplasm: *Wbph1*, *Wbph2*, *Wbph3*, *wbph4*, *Wbph5* (Khush and Brar 1991), and *Wbph6*(t) (Ma et al 2001). Using molecular markers, *Wbph1* and *Wbph6*(t) have been located in linkage groups 7 (McCouch 1990) and 11 (Ma et al 2001), respectively. In addition to these major genes, quantitative trait loci (QTLs) associated with quantitative resistance to WBPH have also been mapped across rice mapping populations. A major QTL for tolerance for WBPH was mapped on linkage group 11 in a doubled-haploid (DH) mapping population derived from IR64/Azucena (Kadirvel et al 1999). A major QTL for antibiosis based on ovicidal response was detected on linkage group 8 in a recombinant inbred population (RIL) derived from Asominori/IR24 (Yamasaki et al 1999). Two more QTLs for ovicidal response of WBPH were detected in a DH population derived from Zaiyeging 8/Zing 17 (Sogawa et al 2001). The search for QTLs conferring resistance to WBPH across mapping populations would help breeding programs develop cultivars with durable resistance to WBPH. Here we report our attempt to detect simple sequence repeat (SSR) markers associated with quantitative resistance to WBPH involving an F_3 population derived from a cross between Basmati 370 and ASD16.

For a phenotyping experiment, WBPH was mass-reared on susceptible rice variety Taichung Native 1 (TN1) following the method of Heinrichs et al (1985). A total of 262 F_3 families of Basmati 370/ASD16 were screened along with their parents at the seedling level using the standard seedbox screening test (SSST) (Heinrichs et al 1985). Varieties TN1 and PTB33 were used as susceptible and resistant checks, respectively.

In brief, 30 pregerminated seeds of each F_3 family were sown 3 cm apart in 50-cm rows in 50 × 50 × 10 cm^3 wooden boxes. One row each of susceptible check TN1 and resistant check PTB33 were sown at random in all the seed boxes. Ten days after sowing (DAS), the seedlings were infested with first- to third-instar nymphs of WBPH at the rate of approximately five to eight nymphs per seedling. After infestation, the wooden seed boxes with seedlings were covered with wire mesh wooden cages. The test plants were observed daily for damage by WBPH. Damage rating of the test lines was done on an individual plant basis when 90% of the plants in the susceptible check row were killed. The test lines were graded using the *Standard Evaluation System for Rice* (SES) scale (IRRI 1996).

Seedling screening showed that Basmati 370 was moderately resistant (damage rating of 3.70) and ASD16 was susceptible (damage rating of 7.70) to WBPH. The F_3 families showed considerable variation in seedling resistance to WBPH, with damage ratings ranging from 3.94 to 9.00 and a mean damage rating of 6.91. The frequency distribution of phenotypic values of F_3 families displayed the presence of quantitative variation in resistance to WBPH in the mapping population (see figure). However, the frequency distribution skewed toward susceptibility.

An SSR marker data set for the Basmati 370/ASD16 F_3 population was developed by surveying 192 F_3 families with 60 polymorphic SSR markers. Single-marker analysis was performed using one-way ANOVA to identify putative SSR markers associ-



Frequency distribution of phenotypic values of F_3 families.

ated with resistance to WBPH using marker-phenotypic data from 192 out of 262 F_3 families. Marker trait association revealed that 6 out of 60 polymorphic SSR markers had association with resistance to WBPH in this mapping population. The identified markers were RM282 (linkage group 3), RM178 (linkage group 5), RM2, RM248, and RM351 (linkage group 7), and RM313 (linkage group 12) (Table 1). Two-way interactions between the putative SSR markers were tested using the SAS package (SAS 1985) and the interacting marker pairs—RM2/RM282 and RM248/RM282—were identified (Table 2). Based on the association of these putative SSR markers with WBPH resistance, we could establish the possibility of QTLs for WBPH resistance on linkage groups 3, 5, 7, and 12. The two-way interaction analysis indicated a possible epistatic interaction between the QTLs identified on linkage groups 3 (RM282) and 7 (RM248). We are in the process of fine mapping these QTLs in a recombinant inbred population of Basmati 370/ASD16 (F_9 generation) using an SSR marker-based linkage map.

Table 1. Putative SSR markers linked with resistance to WBPH in Basmati 370/ASD16 F_3 population.

Marker	Linkage group	F (calculated)[a]	*P* value	F (critical)
RM282	3	4.716	0.010	3.045
RM178	5	5.301	0.005	3.046
RM2	7	3.310	0.038	3.049
RM248	7	4.397	0.013	3.049
RM351	7	6.315	0.002	3.045
RM313	12	3.469	0.033	3.045

[a]Calculated using single-factor ANOVA.

Table 2. Two-way interactions between putative SSR markers associated with resistance to WBPH in Basmati 370/ASD16 F_3 population.

Pair of linked markers	R^2	F value	Probability
RM2/RM178	0.125	2.500	0.089
RM2/RM248	0.083	0.450	0.772
RM2/RM282	0.135	2.470	0.047
RM2/RM313	0.102	1.690	0.154
RM2/RM351	0.122	1.700	0.153
RM178/RM248	0.094	0.220	0.927
RM178/RM282	0.115	0.700	0.594
RM178/RM313	0.095	0.610	0.657
RM178/RM351	0.127	0.960	0.431
RM248/RM282	0.138	2.790	0.028
RM248/RM313	0.089	0.550	0.696
RM248/RM351	0.152	0.110	0.978

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Rice covers much of Asia, so improved varieties that need less pesticide leave a cleaner, greener environment.

Vivek Dhan 82: a high-yielding, blast-resistant irrigated rice variety for the Indian Himalaya

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Rice is grown on about 1.44 million ha of mountain ecosystem in the Indian Himalaya, with total production and productivity of 2.52 million t and 1.75 t ha^{-1}, respectively. The Indian Himalaya region, composed of two geographically distinct flanks, the northeastern and the northwestern, represents a wide range of diversity in agroclimatic conditions such as soil, temperature, rainfall, and altitude. The prevalence of suboptimum temperature throughout the life cycle of the rice plant prolongs its maturity duration. In addition, the hills are known to be a hot spot for rice blast. Tolerance for low-temperature stress and resistance to blast are thus considered essential for developing new varieties that can, in turn, improve rice productivity of the hill ecosystem.

To develop a rice variety with resistance to blast and tolerance for low-temperature stress, a cross (VR1023) was made in 1986 between VL Dhan 221 (a short-duration, blast-resistant variety for the rainfed uplands) and UPR82-1-7 (genotype with good grain and better plant type). Promising uniform lines that were selected using pedigree methods were tested for yield and other ancillary attributes for two consecutive years at the experiment farm in Hawalbagh (1,250 m asl) before being nominated to the All-India Coordinated Testing under initial varietal trials (early hills) as IET15473 in 1997. On the basis of better yield performance in the hill zone, it was identified for release by the All-India Annual Rice Workshop and subsequently released by the CRVC in 2001 as Vivek Dhan 82 for cultivation in the hills and mountain areas of Uttaranchal (UA), Himachal Pradesh (HP), and Meghalaya states. This variety gave an average yield of 4.94 t ha^{-1}, compared with the national check K39's 3.35 t ha^{-1}, the regional check K448-1-2's 3.6 t ha^{-1}, and the local check's 4.26 t ha^{-1} in coordinated trials conducted at different hilly sites of UA, HP, and Meghalaya (see table).

Vivek Dhan 82 is a semitall (115–120 cm) variety and requires 90 d to flower in mid-altitude areas such as Hawalbagh (UA), Malan (HP), and Barapani (Meghalaya) and 105–110 d in higher elevation locations such as Katrain (HP). It has well-exserted panicles, is awnless and straw-colored, and has long bold (L/B, 2.55) grains with 70.6% milling recovery, intermediate gelatinization temperature, and good kernel elongation ratio (1.63). The variety also showed resistance to or tolerance for major biotic stresses of the region (e.g., leaf and neck blast disease and insects such as stem borer and leaffolder).

The variety was also tested under the Frontline Demonstration Program in farmers' fields at Lakhanari, Rait, Khari, and Palrigarh villages in Almora District (UA) during the 2002 kharif (wet) season. The yield of Vivek Dhan 82 (4.2 t ha^{-1}) was higher than that of local varieties (3.2 t ha^{-1}) in the region. The variety is becoming popular because of its higher yield, better straw yield (required for animal feed), and tolerance for diseases and insect pests prevailing in the recommended areas of cultivation.

Yield performance of Vivek Dhan 82 in the All-India coordinated trials in the hills of Uttaranchal, Himachal Pradesh, and Meghalaya.

Genotype	Grain yield (t ha^{-1})				Yield gain (%)
	1997	1998	1999	Mean	
Vivek Dhan 82	4.92	4.58	5.21	4.94	–
K39 (national check)	1.82	3.84	3.57	3.35	47.3
K448-1-2 (regional check)	–	–	3.60	3.60	45.5[a]
Local check	3.88	4.58	4.16	4.26	15.8

[a]Based on 1999 only.

Santosh—a high-yielding variety for the rainfed lowland of Bihar, India, developed through participatory breeding

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The rainfed lowland is a predominant rice ecology in Bihar (2.7 million ha). As it is monsoon-based, sowing and transplanting of rice are invariably delayed. The crop also faces flood and drought, singly or in combination, at any growth stage. Because of these constraints, the high-yielding varieties developed for this ecology through on-station efforts are not widely adopted. Traditionally, to develop varieties adapted to this ecology, photoperiod-sensitive cultivars are grown. A participatory approach began in 1995 at RAU. The program was further strengthened when an IRRI-sponsored participatory breeding project was launched in 1998. From the beginning, farmers were partners in varietal selection.

An on-farm research trial consisting of 12 improved varieties and advanced breeding lines (including local checks) that differed in height and growth duration was conducted at three representative sites in farmers' fields. Of these materials, four entries were selected, mainly on the basis of high yields, and were included in large-scale multilocation on-farm trials. A survey conducted under the Farmers' Participatory Breeding (FPB) Project found that RAU 1306-4-3-2-2, a line included in the 1995 on-farm trial, was already being grown in several villages. Farmers liked its excellent grain and cooking quality and tolerance for submergence and drought. It is about 15 d earlier than some popular local cultivars such as Bakol. This entry was thus included in the ongoing multi-location on-farm trials to assess its performance in farmers' fields. All the entries were evaluated at the vegetative and reproductive stages and a relative ranking, by both scientists and farmers, was made. RAU 1306-4-3-2-2 was rated the best by farmers.

RAU1306-4-3-2-2 was entered in the All-India Coordinated (ACRIP) and state varietal trials as IET15773. The performance data formed the basis of its release. In the ACRIP trials, its yield ranged from 2.7 to 5.3 t ha^{-1} and its average yield was 4.0 t ha^{-1} (the national check yielded 3.5 t ha^{-1}) (Table 1). In state varietal trials at different locations during the

Table 1. Yield (t ha^{-1}) of RAU1306-4-3-2-2 (IET15773) under an initial varietal trial with shallow water at different coordinating centers, 1997 kharif.

Location	RAU1306-4-3-2-2	Salivahan (national check)	Local check	CD at 5%	CV (%)
Jeypore	4.6	4.1	3.5	13.3	16.1
Chinsurah	3.5	3.5	4.0	7.8	11.7
Kharagpur	3.5	5.0	4.0	11.7	14.9
Pusa	4.1	3.3	2.7	11.2	17.0
Ranchi	2.7	6.2	1.7	9.3	19.7
Varanasi	4.2	3.4	3.2	14.5	23.4
Raipur	3.9	2.6	3.7	10.8	17.8
Titabar	3.8	5.0	4.1	6.0	7.6
Karimganj	3.8	3.7	4.0	5.5	8.5
Arundhati Nagar	5.3	4.4	5.4	2.7	13.6
Mean	4.0	3.5	3.6	–	–

Table 2. Yield (t ha^{-1}) of RAU1306-4-3-2-2 in on-station varietal trials at Patna, Pusa, and Sabour.

Year/location	RAU1306-4-3-2-2	Rajshree	Mahsuri	CD at 5%	CV%
1993[a]					
Patna	2.6	2.0	3.0	8.84	18.6
Pusa	2.8	1.8	1.8	6.87	19.3
Sabour	3.5	1.4	1.9	7.70	21.4
1994					
Patna	6.0	–	1.3	–	–
Pusa	7.2	5.0	2.4	9.16	10.46
Sabour	3.8	1.6	1.5	8.94	30.89
1995					
Patna	5.5	3.7	3.2	10.2	19.2
Pusa	4.7	3.3	2.7	9.5	20.0
Sabour	4.2	3.3	2.8	–	24.4
1996					
Patna	4.8	3.8	2.9	11.5	21.5
Pusa	4.4	5.1	4.2	9.2	17.3
Sabour	4.5	3.1	–	–	23.5
Pooled mean	4.5	3.1	2.7	–	–

[a]Drought year.

1993-96 wet seasons, its average yield was better than that of popular check varieties Rajshree and Mahsuri (Table 2). In 18 on-farm trials conducted in 1999 and 2000, the mean yield of RAU 1306-4-3-2-2 (4.4 ± 0.5 t ha^{-1}) was higher than that of Rajshree (4.2 ± 0.4 t ha^{-1}) and the farmers' variety Bakol (3.9 ± 0.4 t ha^{-1}). RAU 1306-4-3-2-2 outyielded Bakol at 15 out of 18 sites.

Our survey revealed that, before its release, many farmers were growing RAU 1306-4-3-2-2 in both Malinagar and neighboring villages. In Malinagar village, it covered about 40% of the rainfed lowland and medium land area. Farmers preferred this variety because of its high yield, its excellent grain and eating quality, and its duration. In recent times, quality has become a deciding factor in varietal selection and adoption.

RAU 1306-4-3-2-2 was released by the RAU Research Council in 2001 as Santosh (meaning "satisfaction"). It is tall (130 cm) and nonlodging and has erect leaves, long panicles, and brown husk. It can tolerate zinc deficiency and is adapted to delayed planting. Availability of seed, though, was a major constraint. However, with its release, seed production is expected to increase.

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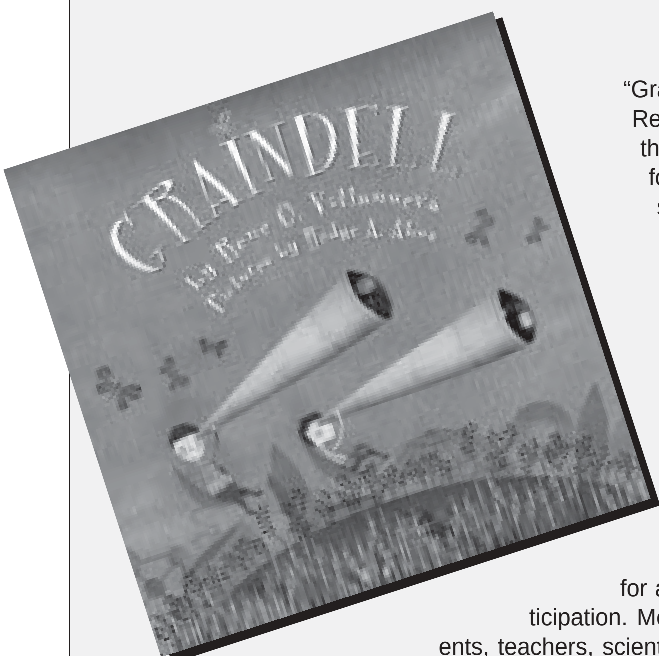
IRRI launches first children's storybook



"Graindell" is a children's storybook published by the International Rice Research Institute (IRRI). Written by renowned Filipino children's author Rene O. Villanueva, the book captures the organization's goal for all the children of the world—a "home for tomorrow," a progressive community where no one will go hungry. Through this first title in a series of children's publications, IRRI introduces its future stakeholders to important issues relating to rice, "the grain of life," food to half the world's population, especially in Asia.

Graindell, "the planetoid shaped like a little eye," tells the story of two friends, Abu and Thor, who share a common dream—to turn their home into the greatest place to live. The simple, yet moving, tale comes alive with the masterful renderings of Redge Abos, a young and talented artist from *Ilustrador ng Kabataan* (INK), in watercolor, combined with digital technology.

With the release of this first children's storybook, IRRI launches the "Graindell Community," which espouses the call for a dynamic, well-developed countryside through multisectoral participation. Membership is open to children and their stewards, including parents, teachers, scientists, children's storywriters and illustrators, and other concerned citizens.

The members of the "Graindell Community" converge at the educational Web site, Graindell.com, where IRRI's own scientists lend their expertise to build a popular knowledge bank on rice, against the backdrop of science, food and nutrition, environment, arts and culture, literacy, and community participation. The site teaches children to "aspire, persevere, and achieve" through games, instructional materials, and interactive learning exercises with other children, as well as their stewards.

Graindell is IRRI's first project for the United Nations International Year of Rice to be celebrated in 2004.

The story of "Graindell" celebrates what IRRI is all about. It portrays the organization's endeavor to create a new generation of rice farmers and consumers who will embrace the traditional wisdom of farm life, understand the need for new and creative technology, and work together for a self-sufficient and well-developed society. By involving children now, they can march fearlessly into the future, knowing that "a home for tomorrow" is not only possible—it is achievable.

Please visit www.graindell.com <http://www.graindell.com> to sign up, get more information, and contribute content to the site.

Effects of methanol extracts from *Ophiopogon japonicus* on rice blast fungus

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Previous studies showed that dwarf lilyturf (*Ophiopogon japonicus* Ker-Gawl.) (Izawa 1967, Kishima 1963) contains allelopathic chemicals, which inhibited the germination and initial growth of three weeds—barnyardgrass (*Echinochloa crus-galli* L.), monochoria (*Monochoria vaginalis* Presl), and smallflower umbrella (*Cyperus difformis* L.) (Lin 2001). This study determined whether methanol extracts of dwarf lilyturf have inhibitory effects on rice blast fungus *Pyricularia grisea*.

Fresh roots and root tubers of dwarf lilyturf plants were washed with distilled water and oven-dried at 50 °C for 48 h. About 100 g of dried samples were cut into 1-cm-long pieces and ground in a juice mixer for 15 min. Eight grams of dry powder were soaked in 80 mL 70% methanol solution at 5 °C for 24 h and filtered through No. 2 filter paper (Toyo Roshi Kaisha Ltd., Japan). The supernatant was sufficiently concentrated and evaporated to a solid state through a rotary vacuum evaporator (Tokyo Rikakikai Co., Ltd., Japan) and dissolved in 10 mL sterile distilled water used as original solution. Then, 1/2, 1/4, and 1/8 dilutions were prepared. One mL each of these doses was blended with 9 mL of 0.8% potato dextrose agar (Wako Pure Chemical Industries, Ltd., Japan) culture solution and placed in a 9-cm petri dish to give a final concentration of 1/10, 1/20, 1/40, and 1/80 of the original solution. The 0.01 mg spores of two isolates of *P. grisea* (MAFF305480 and MAFF101002), which mainly occur in Miyazaki Prefecture, southern Japan, were inoculated in the center of the petri dish. The colony diameters of the mycelial plugs were measured 10 d after being kept in a growth chamber with 4,000 lux artificial light (0700–1900) at –25 °C. The control was the same as the treatments, except that distilled water was used instead of an extract. No fungal contamination was observed during the whole experiment. Five treatments, including the control, were arranged in a completely randomized design with three replications. Comparisons of all treatments were made at the 0.05 probability level using the least significant difference method. Inhibitory percentage was calculated using the formula [(control value – treatment value)/control value] × 100.

The results shown in Figures 1 and 2 indicate that methanol extracts from dried powder of dwarf lilyturf inhibited the mycelial growth of the two isolates of *P. grisea*. In particular, the extract with 1/10 concentration completely inhibited mycelial growth of both MAFF305480 and MAFF101002, whereas the 1/20 concentration inhibited mycelial growth of MAFF305480 and MAFF101002 by 100% and 81%, respectively. The results suggest that the dwarf lilyturf plants have inhibitory potential and could be used as a biological fungicide to control rice blast. We have identified and isolated six allelopathic chemicals from methanol extracts of dwarf lilyturf plants (unpubl. data): *o*-hydroxybenzoic acid; 4-hydroxy-3-methoxybenzoic acid; 4-hydroxy-3,5-dimethoxy benzoic acid; 3,5-dimethoxy-4-hydroxycinnamic acid; syringaldehyde; and ρ-hydroxybenzoic acid. We plan to evaluate the efficacy of these extracts in controlling rice blast in the field.

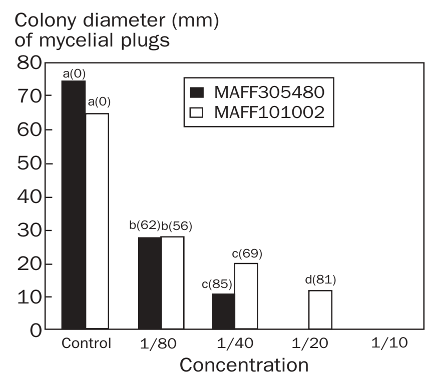

Fig. 1. Effects of methanol extracts from dwarf lilyturf on colony diameter of inoculated *P. grisea* in vitro. (Numbers in parentheses indicate inhibitory percentage; different letters indicate significant diffrences at 5% between treatments within the same isolate.

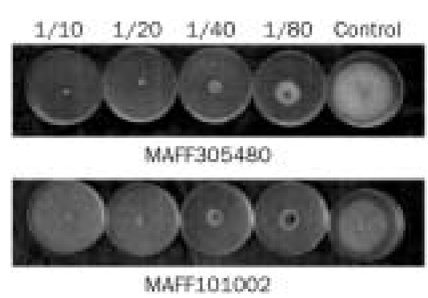

Fig. 2. Effects of methanol extracts from dwarf lilyturf plants on mycelial growth of *P. grisea*.

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Fingerprinting the rice isolates of *R. solani* Kuhn using RAPD markers

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The genetic differences underlying *Rhizoctonia solani* populations provide a useful means for examining the nature and spread of the population within the rice system. So far, no attempt has been made to define variability in relation to spatial distribution and no information is available on the amount of variability in *R. solani* within the field. Many anastomosis groups are subdivided on the basis of the cultural, virulence, molecular, biochemical, immunological, and other characteristics into intraspecific groups (ISGs) (Ogoshi 1987). The most convincing validation of AG and ISG concepts has come from molecular systematic studies (Vilgalys and Cubeta 1994). Our study was undertaken to (1) analyze the interfield variability within 46 Indian rice isolates of *R. solani* collected from two fields, one each at Seola-Kala, Dehradun District (hilly region, 24 isolates), and Nagina, Bijnore District (plain region, 22 isolates), for cultural and morphological characteristics, aggressiveness, anastomosis behavior, nuclear staining, and molecular characterization by RAPD analysis; (2) assess the agreement among five methods in differentiating the isolates; and (3) study the extent and possible factors responsible for intrafield variability in rice. This is the first attempt to define intrafield variability among *R. solani* isolates that cause sheath blight in rice.

Of 22 primers that were screened, the following eight were selected for amplifying DNA of all the isolates: T11 = 5′-GTCCATTCAGTCGGTGCT-3′; T13 = 5′-GAATGCCTTC CAAGCCGGT-3′; C15 = 5′-GGTGCCACGAGTAATC-3′; G16 = 5′-CCAGTCTTC GTAGAGAATCG-3′; T19 = 5′-GTAAAACGACGGCCAGT-3′; C20 = 5′-ATGGATCCGC-3′; G21 =5′-GAGTACGTGC TCGCTCG ATG-3′; and C22 = 5′-TGGGTCGAGGGGTTC-3′. Amplified polymerase chain reaction products were separated on agarose gel (Fig. 1). A dendrogram was constructed using Jaccard's similarity coefficient and UPGMA clustering using NTSYS-PC version 2.11a (Rohlf 2000). The cut-off point to decide the number of clusters was determined using canonical discriminant function analysis by SPSS Software Version 10.

All isolates were multinucleate and shared typical characteristics with *R. solani*. They exhibited varying degrees of virulence on Pusa Basmati 1 and, on the basis of the disease severity (lesion length), could be classified as highly virulent (2), moderately virulent (7), less virulent (33), and avirulent (40). All isolates gave two (incompatible fusion) or three types of anastomosis reaction (compatible fusion) with the tester isolate of *R. solani* (N15) belonging to AG-1 IA.

The dendrogram, constructed using 88 polymorphic bands obtained with eight primers and 41 isolates, was divided into seven clusters at 0.125 similarity level (Fig. 2). No amplification was obtained with isolates N3, D5, D22, D23, and D24. The isolates N18 (crushed and mycelial aggregate-type sclerotia) and N16 (macro sclerotia) were present independently at the 12.5% similarity level. Among isolates of cluster 1 (N1, N9, N13, N14, N15, N20, N21, N22, and D12), similarity values ranged from 13.7% to 32.5%, whereas, among isolates of cluster 2 (D1, D3, D6, D7, D10, D11, D15, D16, D17, D18, D19, D20, and N17), cluster 3 (N8, N19, D2, and D13), cluster 4 (N6, N11, and N12), cluster 5 (D9, D14, and D21), cluster 6 (N2, D4, and D8), and cluster 7

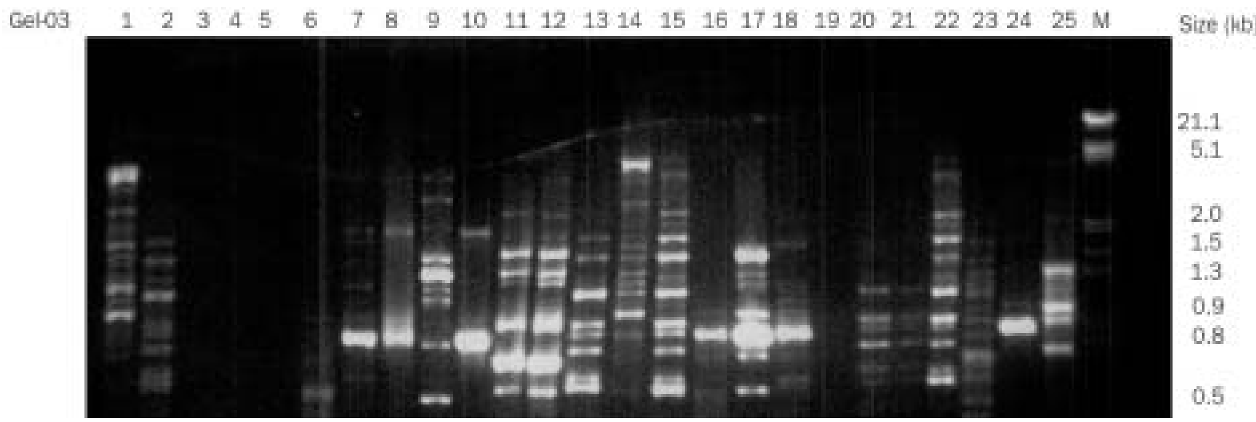

Fig. 1. Agarose gel showing PCR amplification products of 25 isolates obtained with the primer T13. Numbers on the right indicate band size in kilobase pairs. Lanes 1–22 = Nagina isolates (N1 to N22); lanes 23–25, Dehradun isolates (D1 to D3), and M = molecular weight marker, lambda *Hind*III/*Eco*RI double-digested.

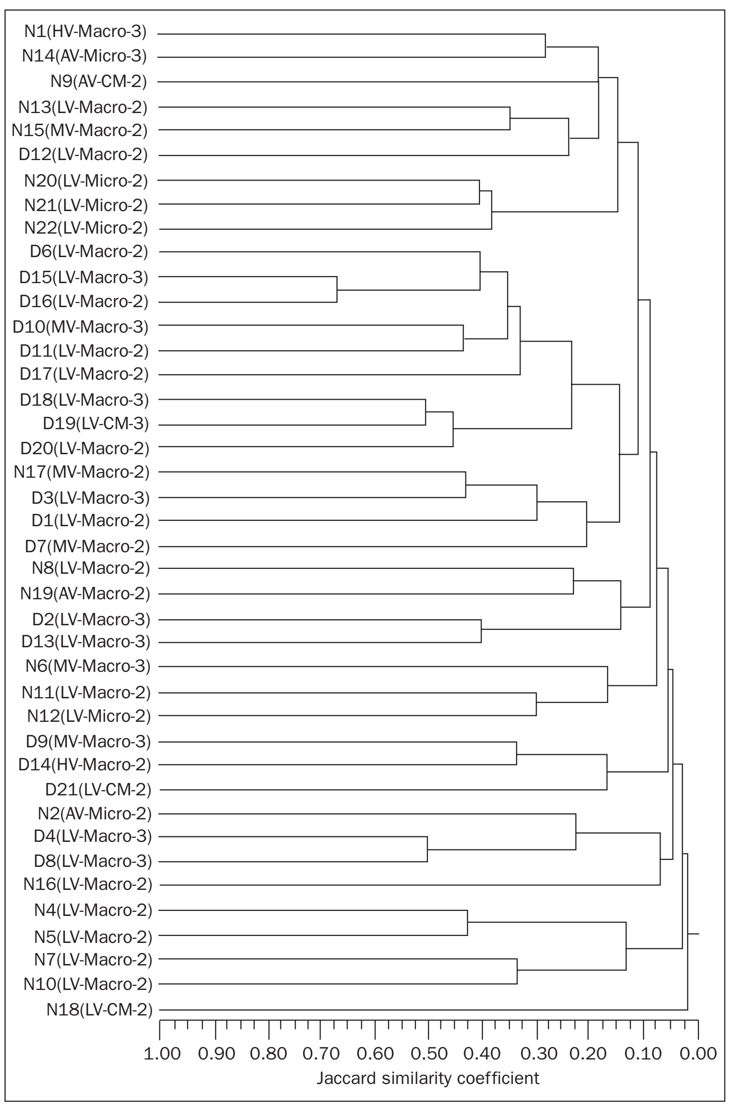

Fig. 2. Dendrogram of 41 rice isolates of *Rhizoctonia solani* revealed by UPGMA cluster analysis of genetic similarities based on RAPD data of 88 fragments amplified with 8 primers. N1 to N22 = Nagina isolates and D1 to D24 = Dehradun isolates. HV = highly virulent, MV = moderately virulent, LV = less virulent, and AV = avirulent. Macro = macro sclerotia, micro = micro sclerotia, and CM = crushed and mycelial aggregate type of sclerotia. 3 = 3-type anastomosis reaction (compatible fusion) and 2 = 2-type anastomosis reaction (incompatible fusion).

(N4, N5, N7, and N10), the similarity values ranged from 13.7% to 74.5%, 12.5% to 40%, 15% to 30%, 15% to 32.5%, 12.5% to 50%, and 13.80% to 42.5%, respectively. Distinct subclusters were detected within clusters 1 and 2, indicating a more complex pattern of genetic variation. In contrast, isolates of clusters 3, 4, 5, 6, and 7 were less differentiated into marked subclusters. The micro sclerotia-forming isolates (N20, N21, and N22) formed a distinct subcluster within cluster 1 at 35% similarity level. All isolates belonging to cluster 7, which were isolated from Nagina, were less virulent on rice and depicted two types of anastomosis reaction.

The lack of a perfect state, wide intrafield variability, and compatible fusion among morphologically and virulent-wise dissimilar isolates (D19 and N14), demonstrated for the first time during this investigation, indicate heterokaryosis as a major mechanism for creating intrafield variability. Isolate-specific primers open up the possibility to use RAPD to study population dynamics and survival of *R. solani* in the soil and polymorphism in the *R. solani* complex in rice.

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Is the trap barrier system with a rice trap crop a reservoir for rice insect pests?

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In the Banaue rice terraces, we monitored the rice arthropod dynamics in a rice trap crop planted inside (1) a trap barrier system (TBS + TC), (2) surrounding rice crops 25, 50, 100, 200, and 400 m away from the TBS + TC setup, and (3) those grown in areas farther away (> 1,000 m) and where the TBS + TC system was not introduced.

Rice is planted once a year in Banaue, with seeds sown on seedbeds in late November and December. The area is planted to Lacoop, which is a photoperiod-sensitive traditional rice variety with 6-mo maturity. Lacoop was also planted inside the TBS 1 mo in advance of the farmers' main crop. One of each TBS + TC setup was strategically established in terraced fields adjacent to the farmers' residences, creeks, and forest on 21 Dec 2002. This was done to lure rats from possible source habitats to the TBS + TC early in the rice cropping season, thereby reducing the number of breeding rats in the main season.

The main purpose of quantifying rice arthropod dynamics and diversity was to provide information on the TBS + TC technology to cooperating farmers, who need to validate its role in the development of an ecologically sustainable rodent management program. During farmers' meetings, concerns about TBS + TC serving as a reservoir for rice insect pests were raised. The farmers feared that this would cause greater damage to the surrounding rice crops.

Rice arthropods were sampled using standard insect sweep nets. Each sweep net sample was composed from 10 strokes. Each TBS + TC setup was sampled 12 times starting on 18 Feb 2003. The rice crops surrounding the TBS + TC and those in non-TBS+TC areas were sampled at various distances four times each, starting on 8 May 2003. In all these areas, samplings were done at weekly intervals with four samples on each sampling occasion; pooled values were presented for each sampling date.

Rice arthropods were sorted and identified on the basis of

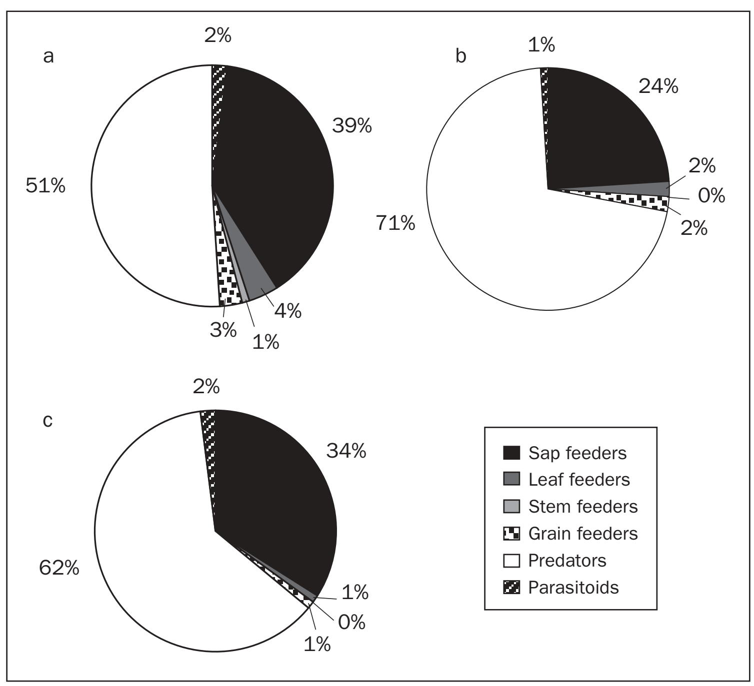

Fig. 1. Rice arthropod composition in (a) TBS + TC, (b) surrounding rice crops 25–400 m away from TBS + TC, and (c) in non-TBS + TC rice-cropped areas, Banaue rice terraces, Ifugao Province, Philippines.

functional guilds: herbivores (sap feeders, leaf feeders, stem feeders, and grain feeders) or beneficials (predators and parasitoids).

The most abundant rice herbivores encountered were sap feeders (green leafhoppers, whitebacked planthoppers, and brown planthoppers). They comprised 39%, 24%, and 34% of the total rice arthropod composition inside the TBS + TC, rice crops outside the TBS + TC, and rice crops without the TBS + TC, respectively (Fig. 1). No hopperburn was observed. Banaue farmers did not use inorganic fertilizers and synthetic pesticides, and this may explain why none of the herbivores (sap feeders, leaf feeders [larvae of leaffolders and whorl maggots, and short-horned grasshoppers], stem feeders [larvae of lepidopterous stem borers], and grain feeders [rice earhead bugs]) caused economic crop losses. In addition, more than 50% of the total rice arthropod complex was found to be beneficial arthropods (mirid bugs, nonweb- and web-spiders, and parasitoids) (Fig. 1). In most instances, the ratio between herbivores (phytophages) and beneficials (predators and parasitoids) in TBS + TC, at various distances from TBS + TC, or in non-TBS + TC was in favor of the beneficial insects, indicating a good balance of natural control mechanisms in the rice ecosystems of the Banaue rice terraces (Fig. 2). Hence, in such systems, we can safely conclude that the use of TBS + TC for rodent pest management would not result in economic crop losses from rice insect pests.

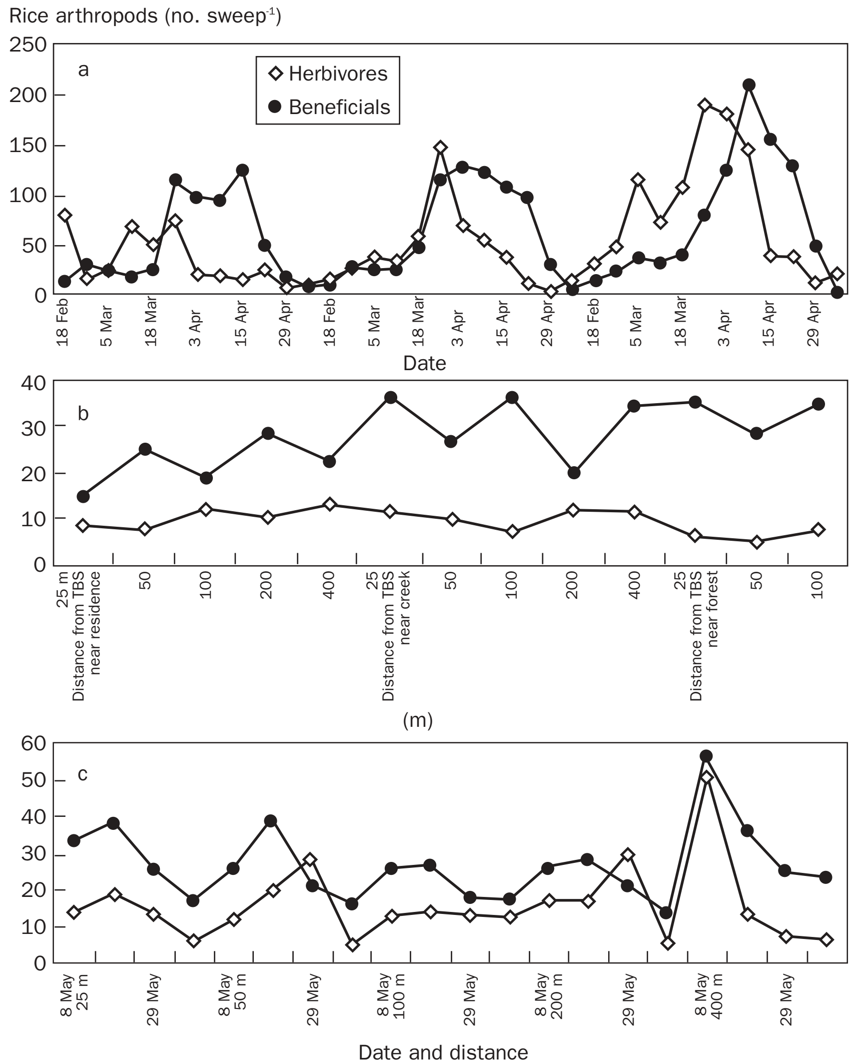

Fig. 2. Dynamics of rice herbivores and beneficials in (a) TBS + TC, (b) at fixed distances away from TBS + TC, and (c) at fixed distances in non-TBS + TC rice crops, Banaue rice terraces, Ifugao Province, Philippines.

Screening of rice genotypes for resistance to leaffolder, *Cnaphalocrocis medinalis* Guenée, and stem borer, *Scirpophaga incertulas* Walker

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Leaffolders (LF) and stem borers (SB) are destructive rice pests in Uttar Pradesh. LF and SB infestations occur in August and continue until crop maturity. The pests can be avoided by planting resistant varieties. We screened 30 aromatic rice genotypes for resistance to LF and SB in the field at CRS, Masodha, Faizabad, during 2001 and 2002 kharif. Each test entry was planted in 12 × 2-m plots at 20 × 15-cm spacing with four replicates. All recommended crop management practices, except for plant protection measures, were followed. Infestation was recorded by counting the total number of leaves and the number of infested leaves (for LF) and the total number of tillers and damaged tillers (for SB) from 20 randomly selected hills of each genotype. NDR6175, NDR6093, and NDR6232 were found to be resistant, 10 genotypes were moderately resistant, 15 were moderately susceptible, and two were susceptible to LF. Six genotypes were moderately resistant, 20 were moderately susceptible, and four were susceptible to SB (see table).

Reaction of rice genotypes to LF and SB 2001 and 2002 kharif.

Genotype	LF incidence (% infested leaves hill^{-1})				SB incidence (% infested tillers hill^{-1})			
	2001	2002	Mean	Reaction[a]	2001	2002	Mean	Reaction
NDR6175	6.25	0	3.1	R	3.3	0	1.6	MR
NDR6160	10.7	3.6	7.1	MR	4.3	5.2	4.7	MR
NDR6048	15.2	9.1	12.1	MS	9.9	8.0	8.9	MS
NDR637	16.1	9.7	12.9	MS	11.1	9.0	10.0	S
NDR637	–315.4	11.1	13.3	MS	4.3	11.9	8.1	MS
NDR6093	3.6	0	1.8	R	0	5.0	2.5	MR
NDR117	11.5	7.7	9.6	MR	8.7	10.1	9.4	MS
NDR6164	7.1	3. 5	5.3	MR	7.1	8.5	7.8	MS
NDR6166	15.4	3.9	9.6	MR	6.5	9.1	7.8	MS
NDR6168	14.3	11.1	12.7	MS	5.4	9.1	7.3	MS
NDR6207	7.4	6.1	6.7	MR	3.7	7.1	5.4	MS
NDR6208	11.8	8.6	10.3	MS	8.8	8.8	8.8	MS
NDR6222	9.1	13.6	11.4	MS	9.1	4.6	6.8	MS
NDR6223	6.1	15.4	10.7	MS	3.0	0	1.5	MR
NDR6224	12.0	11.5	11.8	MS	11.5	7.7	9.6	MS
NDR6225	9.7	12.9	11.3	MS	9.6	9.6	9.6	MS
NDR6230	11.8	14.7	13.2	MS	8.1	7.2	7.6	MS
NDR6232	4.0	3.6	3.8	R	0	6.2	3.1	MR
NDR6233	4.6	9.1	6.9	MR	8.1	7.6	9.8	MS
NDR6237	8.7	8.7	8.7	MR	4.3	11.9	8.1	MS
NDR6239	14.3	10.7	12.5	MS	6.3	9.8	8.0	MS
NDR6234	8.0	4.0	6.0	MR	5.4	9.1	7.3	MS
NDR625	7.7	11.5	9.6	MR	8.1	7.9	8.0	MS
NDR6236	14.3	11.1	12.7	MS	11.9	8.8	10.3	S
Pusa Basmati	17.2	13.8	15.5	S	11.0	8.9	9.9	MS
T. Basmati	13.3	11.1	12.2	MS	10.5	1.1	10.8	S
T3	14.9	16.1	15.5	S	11.6	2.5	12.0	S
K. namak	10.7	7.7	9.2	MR	7.1	9.3	8.2	MS

[a]MR = moderately resistant, MS = moderately susceptible, S = susceptible, R = resistant.

Reduction in chemical use following integrated ecologically based rodent management

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Rodents generally cause chronic preharvest losses of 5–10% in rice and, in some regions, the problem is escalating (Singleton 2003). Impacts of pests on smallholder rice farmers also have important social and environmental dimensions (Heong 1999). Farmers often use inappropriate methods in their desperate attempts to reduce the impacts of rodents. This includes the use of broad-spectrum poisons such as endosulfans, organophosphates, and carbamates. Occasionally, these are mixed with used engine oil before applying them to flooded rice crops (Sudarmaji et al 2003). These chemicals and their inappropriate use are of major environmental concern. Another management action is the use of power mains to electrocute rats in flooded rice fields. This has led to deaths of people in the Philippines and Vietnam and therefore has major social implications.

Since 1996, there has been a concerted effort in Southeast Asia to develop an integrated package of ecologically based methods to manage rodent pests in lowland irrigated rice agroecosystems. This led to the development of village-level studies in West Java, Indonesia (Cilamaya; 1999-2002), and in the Red River (Vinh Phuc; 2000-02) and Mekong River deltas in Vietnam (Tien Giang and Soc Trang; 2001-02). We assessed whether these integrated practices lessened the impact of rats economically and environmentally and whether the involvement of smallholder farmers in the study influenced their perceptions and practices of rodent management. This paper reports on one element of this study: the use of chemicals, plastic exclusion barriers, and electrocution by individual farmers after they had participated in a community-based program of integrated rodent management.

Each region had two treated and two untreated villages where lowland irrigated rice was grown on more than 80–120 ha. Before these farmer participatory studies, 30–100 farmers from each village were interviewed on their knowledge, attitudes, and practices of rat control (see Escalada and Heong 1997 for details). The integrated management actions were taken for 3 years in West Java, 3 years in the Red River Delta, and 1.5 years in the Mekong River Delta. At the completion of the study, the farmers were interviewed again to assess changes in their perceptions and practices.

In West Java, the rice field rat, *Rattus argentiventer*, is the dominant rodent pest. In both the Red River and Mekong River deltas in Vietnam, the rice field rat is the most common species, but the lesser rice field rat, *R. losea*, also occurs in moderate densities. Although this study was conducted in different countries and regions, chemical control was the most common method used to manage rats in lowland irrigated rice crops (see table). Interestingly, the chemicals used are often those not registered for killing rodents: endosulfan plus oil in Indonesia (100% of farmers in a village used it in 1999 and 88% in 2002) and a Chinese "rodenticide" in Vietnam (37% of farmers in Soc Trang used it in 2001). From our experiences, farmers tend not to report their use of power mains to electrocute rats because it is banned in Indonesia and Vietnam. We were therefore surprised that approximately 40% of the farmers regularly used this method in Soc Trang Province. Another method of environmental concern is the widespread use of plastic fences to physically exclude rats from crops in the Red River Delta. The environmental issue is the disposal of the plastic, which is discarded after two crop seasons. An alternative we recommended was to convert a few of their plastic fences to trap-barrier systems (TBS) (Singleton et al 1998), which achieve two purposes. First, only one TBS per 10 ha is required as part of the integrated management practices for rodents, which reduces markedly the amount of plastic in the fields. Second, given that the average farm size is less than 2 ha, the wider coverage of a TBS encourages a community approach to rodent management.

After the participation by farmers from treatment villages in integrated ecologically based management of rodents, the follow-up surveys highlighted a major decline in actions that are of concern socially and environmentally (see table). In treatment villages in West Java, 49% fewer farmers used rodenticides, which was significantly lower than in an untreated village ($\chi^2 = 7.2$, $P < 0.01$, df = 1). Also, the use of endosulfan plus sump oil fell by 28% ($\chi^2 = 11.2$, $P < 0.001$, df = 1; see table 1). In treatment villages in the Red River Delta, 66% fewer farmers used rodenticide, which was significantly lower than in untreated villages ($\chi^2 = 11.4$, $P < 0.001$, df = 1). Also, the use of plastic barriers fell by 72% compared with only a 7% reduction in untreated villages ($\chi^2 = 46.2$, $P < 0.001$, df = 1). In treatment villages in the Mekong River Delta, 24% fewer farmers used rodenticides during a period when 16% more farmers used them in the untreated villages ($\chi^2 = 7.23$, $P < 0.01$, df = 1). The use of electrocution in Soc Trang fell considerably in both villages probably because farmers at both sites were advised that it was an unsafe and illegal practice.

These studies clearly support the strong social and environmental benefits for smallholder farmers if they work together at a village level to implement an integrated package of ecologically based methods to manage rodent pests in lowland irrigated rice agroecosystems. We recognize the sociological challenges associated with sustaining a community approach to rodent management (Morin et al 2003) and the current findings provide a strong impetus for overcoming these challenges.

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Changes in use by smallholder farmers of chemicals, plastic fencing, and electrocution to control rat populations in lowland irrigated rice crops in West Java, Indonesia, and the Red River and Mekong River deltas in Vietnam. Farmers in treatment villages applied integrated management of rodents.[a] Those in untreated villages used traditional methods for managing rodents. (n) = number of farmers surveyed.

Management action for rats	Region	Pre-treatment survey		Post-treatment survey			
		Treatment villages[a]	Untreated villages	Treatment villages		Untreated villages	
		% farmers	% farmers	% farmers	% change	% farmers	% change
Rodenticides	West Java	95 (60)	98 (60)	46 (50)	–49	88 (50)	–10
	Red River Delta	85 (60)	77 (60)	19 (120)	–66	50 (120)	–17
	Mekong River Delta	61 (200)	69 (200)	37 (200)	–24	85 (200)	+16
Oil plus endosulfan	West Java	80 (60)	70 (60)	52 (50)	–28	100 (50)	+30
Plastic exclusion barriers	Red River Delta	75 (60)	90 (60)	3 (120)	–72	83 (120)	–7
Electrocution	Mekong River Delta						
	Soc Trang	42 (100)	39 (100)	7 (100)	–35	8 (100)	–31

[a]Integrated ecologically based management began in the treatment villages in West Java in November 1999 (pre-treatment survey September 1999; post-survey September 2002); in the Red River Delta in February 2000 (pre-survey September 2000; post-survey July 2002); in the Mekong River Delta in April 2001 (pre-survey March 2001; post-survey April 2002).

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First report of narrow brown leaf spot disease of rice in West Bengal, India

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During the 2001 wet season (Jun-Nov), the popular, high-yielding, and widely adapted cultivar Swarna was observed to have many linear red-brown spots. These had light-colored margins and light brown to gray centers. Observed on leaves during the later (dough and mature grain) growth stages, the spots were restricted between the veins. The experimental plots of the rice-wheat system of the Rice Research Station, Chinsurah, were exposed to these weather conditions: mean maximum temperature, 32 °C; mean minimum temperature, 25 °C; relative humidity, 98%; and rainfall, 942 mm. A similar type of lesions was also found on the leaf sheaths, pedicels, and glumes. The lesions were 2–10 × 0.5–1 mm and they coalesced to form long, threadlike brown lesions parallel to the veins on the entire leaves.

A preliminary microscopic study of the 20-d-old fungal colony revealed that the conidiophores emerge from host stomata; are pale brown, geniculate, in clusters of 3–5, and uniform in color; have three or more septa; are irregular in width and have rounded tips; and the old scarps are rounded on conspicuous shoulders or on short peg-like protrusions, measuring 80–140 × 4–6 mm. Conidia were light olive and cylindrical to subclavate, with 3–10 septa, an obeonic base, blunt tips, in whorls of 3–4 on the conidiophore tip and measuring 15–60 × 3–5 mm. Conidia produced in rice-straw agar-culture media were hyaline. These confirmed that the fungus is *Cercospora janseana* (Racib.) O. Const. and it causes narrow brown leaf spot (NBLS) or cercospora leaf spot disease.

Pathogenicity tests were done on Swarna during panicle emergence. The plants were sprayed with spore suspension (8 × 10^4 spores mL^{-1} water) in late afternoon, then covered with a polythene sheet to preserve the moisture. The plants were surface-irrigated profusely by using tube-well water. Typical NBLS symptoms appeared within 21–25 d after inoculation. This is the first report of this disease from the state of West Bengal, India.

The affected leaf area was only 5%. As such, the incidence was not considered to be serious but close monitoring is necessary to prevent its spread.

Effect of organic farming on management of rice brown planthopper

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In southern India, brown planthopper (BPH) *Nilaparvata lugens* takes a heavy toll on rice production. It directly causes damage and acts as a vector of many diseases. An experiment involving a cultural method of control was conducted using synthetic fertilizers and biofertilizers. Biofertilizers are becoming popular as a cheap and safe alternative to conventional chemical fertilizers (Sharma 2001).

The experiment was laid out in a completely randomized block design in the insectary. Test variety ADT36 was planted in pots with wetland soil collected from the field. There were nine treatments (1: 100-50-50 kg NPK ha^{-1}, 2: 120-50-50 kg NPK ha^{-1}, 3: 2 kg azospirillum ha^{-1}, 4: 500 kg azolla ha^{-1}, 5: 100-50-50 kg NPK ha^{-1} + 2 kg azospirillum ha^{-1}, 6: 100-50-50 kg NPK ha^{-1} + 500 kg azolla ha^{-1}, 7: 120-50-50 kg NPK ha^{-1} + 2 kg azospirillum ha^{-1}, 8: 120-50-50 kg NPK ha^{-1} + 500 kg azolla ha^{-1}, 9: untreated check [12.5 t farmyard manure ha^{-1}]) and each treatment was replicated thrice. Five hills were maintained per plot. Inorganic and organic fertilizers at the computed doses were applied in the respective treatments and the soil was thoroughly mixed.

Ten second-instar nymphs were released at 15 d after treatment (DAT) in each treatment and the population recorded for two generations. Five hills were selected in each treatment. The total number of tillers and productive tillers was observed. Plant height was measured from the ground level to the tip of the longest leaf and expressed in cm at the time of last observation. Grain yield was recorded.

The combination of inorganic fertilizer (120-50-50 kg NPK ha^{-1}) and azospirillum resulted in the lowest population of BPH (26.66 $hill^{-1}$) when compared with 120-50-50 kg NPK ha^{-1} alone (62 $hill^{-1}$), followed by the combination of 120-50-50 kg NPK ha^{-1} and azolla (33 $hill^{-1}$) in the first generation (Table 1). A similar trend was evident in the second generation.

When azospirillum and azolla were applied alone, the BPH population was 43 $hill^{-1}$ and 47 $hill^{-1}$, respectively, in the first generation. When synthetic fertilizer was applied alone, the populations were bigger in both generations.

Application of 120-50-50 kg NPK ha^{-1} + azolla and 120-50-50 kg NPK ha^{-1} + azospirillum resulted in the highest tiller production, 1,000-grain weight, and grain yield (Table 2). With higher doses of azolla, productive tillers were 11 $hill^{-1}$, plant height was 71.96 cm, 1,000-grain weight was 21.38 g, and yield was 4,091.33 kg ha^{-1}. The corresponding numbers for azospirillum were 10.33 $hill^{-1}$, 66.80 cm, 22.56 g, and 4,113.66 kg ha^{-1}. The lowest yield was obtained from plots treated with inorganic fertilizer alone.

Organic farming is a recent approach that aims to conserve natural resources and protect the environment. BPH populations were low in plots treated with organic amendments along with synthetic fertilizers. This supports the findings of Kajimura et al (1995) who noted low densities of BPH and whitebacked planthop-

Table 1. BPH populations on rice variety ADT36 in response to application of organic and inorganic fertilizers.[a]

Treatment	Generation	
	First	Second
100-50-50 kg NPK ha^{-1}	52.66 (7.25) d	73.34 (8.56) d
120-50-50 kg NPK ha^{-1}	62.00 (7.86) d	88.34 (9.39) d
2 kg azospirillum ha^{-1}	43.0 (6.55) cd	58.33 (7.63) c
500 kg azolla ha^{-1}	47.0 (6.84) cd	62.67 (7.91) cd
100-50-50 kg NPK ha^{-1} + 2 kg azospirillum ha^{-1}	38.3 (6.18) bc	48.33 (6.94) b
100:50:50 kg NPK ha^{-1} + 500 kg azolla ha^{-1}	39.0 (6.23) bc	48.66 (6.97) b
120:50:50 kg NPK ha^{-1} + 2 kg azospirillum ha^{-1}	26.66 (5.15) a	39.00 (6.24) a
120:50:50 kg NPK ha^{-1} + 500 kg azolla ha^{-1}	33.00 (5.74) b	45.33 (6.73) b
12.5 t farmyard manure ha^{-1}	49.66 (7.04) cd	67.66 (8.22) cd

[a]Mean of three replications. Numbers in parentheses are square root-transformed values. In a column, means followed by the same letter(s) are not significantly different at P = 0.05 by Duncan's multiple range test.

Table 2. Growth and yield characteristics of rice variety ADT36 as affected by application of organic and inorganic fertilizers and biofertilizers.[a]

Treatment	Total tillers $hill^{-1}$ (no.)	Productive tillers $hill^{-1}$ (no.)	Plant height (cm)	1,000-grain weight(g)	Grain yield ($t\ ha^{-1}$)
100-50-50 kg NPK ha^{-1}	10.66 c	7.33 c	52.46 c	18.5 bc	3.4 d
120-50-50 kg NPK ha^{-1}	12.33 b	9.66 ab	56.46 bc	19.66 abc	3.6 c
2 kg azospirillum ha^{-1}	12.66 b	9.00 b	53.43 c	19.66 abc	3.5 cd
500 kg azolla ha^{-1}	13.00 b	9.33 b	59.50 bcd	19.1 abc	3.4 d
100-50-50 kg NPK ha^{-1} + 2 kg azospirillum ha^{-1}	12.66 b	9.66 ab	66.93 abc	21.73 a	3.9 b
100:50:50 kg NPK ha^{-1} + 500 kg azolla ha^{-1}	12.33 b	9.66 ab	67.63 ab	21.23 a	3.9 b
120:50:50 kg NPK ha^{-1} + 2 kg azospirillum ha^{-1}	14.33 a	10.33 ab	66.80 abc	22.56 a	4.1 a
120:50:50 kg NPK ha^{-1} + 500 kg azolla ha^{-1}	14.66 a	11.00 a	71.96 a	21.38 a	4.1 a
12.5 t farmyard manure ha^{-1}	12.33 b	9.33 b	64.13 abc	20.66 ab	3.6 c

[a]Mean of three replications. In a column, means followed by the same letter(s) are not significantly different at $P = 0.05$ by Duncan's multiple range test.

per in organically farmed fields and those with low N content. Chino et al (1987) reported that asparagine content of plant phloem sap was significantly lower under organic cultivation, thereby adversely affecting the feeding activity of BPH. Plots treated with 120-50-50 kg NPK ha^{-1} had significantly higher levels of BPH (Table 1). But BPH levels in azolla plots were not significantly different from those in control plots (with farmyard manure).

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The effect of nitrogen on rice grain iron

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Previous studies have shown that iron (Fe) content of rice grain may vary widely among rice genotypes (Senadhira et al 1998, Prom-u-thai and Rerkasem 2001). In addition, grain Fe may also be affected by environmental and management conditions. This experiment measured grain Fe concentration in five rice genotypes (KDML 105, IR68144, Ubon 2, Basmati 370, and RD6) grown under three levels of N (0, 60, and 120 kg N ha^{-1}). The field experiment was in a split-plot design with three replications. Basal fertilizer consisted of 6.6 kg P and 12.4 kg K ha^{-1}. The basal fertilizer and half of the N were applied at transplanting and the other half of N was applied after 4 wk. Fe concentration was determined in mature grain, as unhusked (whole grain with palea and lemma intact) and brown rice (palea and lemma removed), husk (palea and lemma), and polished grain (30 s) by dry-ashing and atomic absorption spectrometry (Emmanuel et al 1984).

In all five genotypes, grain yield increased slightly with the application of 60 kg N ha^{-1}, but there was no further effect of increasing N to 120 kg ha^{-1} ($P<0.05$) (Table 1). Nitrogen fertilizer generally increased N content of the rice grain (Table 2). On the other hand, grain Fe concentrations in the five genotypes were affected differently by N rates (Table 3). The Fe concentration in unhusked KDML 105, IR68144, Ubon 2, Basmasti 370, and RD6 increased

Table 1. Grain yield ($t\ ha^{-1}$) of five genotypes grown at three levels of nitrogen (0, 60, 120 kg N ha^{-1}).

Genotype	Grain yield ($t\ ha^{-1}$)		
	0 kg N	60 kg N	120 kg N
KDML 105	3.6	4.0	3.8
IR68144	2.7	4.7	3.9
Ubon 2	4.1	4.0	3.7
RD6	3.1	3.4	3.3
Basmati 370	3.7	3.3	3.4
	3.2 a	3.8 b	3.6 b
Analysis of variance			
P (genotypes [G])	ns		
P (N)	<0.05		
P (G × N)	ns		
LSD (N, 0.05)	0.4		

Table 2. The N concentration (% N) in unhusked rice of five genotypes grown under three levels of N (0, 60, and 120 kg ha^{-1}).

Genotype	Grain N concentration[a] (%)		
	0 kg N	60 kg N	120 kg N
KDML 105	1.3 aA	1.6 aB	1.8 bB
IR68144	1.5 aA	1.6 aA	1.9 bcB
Ubon 2	1.5 aA	1.6 aA	2.0 cB
RD6	1.3 aA	1.6 aB	1.8 bB
Basmati 370	1.3 aA	1.5 aA	1.5 aA
Analysis of variance			
P (Genotype [G])	<0.01		
P (N)	<0.01		
P (G × N)	<0.01		
LSD (N, 0.05)	0.30		
LSD (G, 0.05)	0.20		

[a]Lower case for comparison of genotype effect, upper case for comparison of N effect.

Table 3. The Fe concentration (mg kg^{-1}) in unhusked, brown rice, husk, and polished grain (white grain) at 30 and 60 s of five genotypes grown under three levels of N (0, 60, and 120 kg ha^{-1}).[a]

Genotype	N (kg ha^{-1})	Fe concentration (mg Fe kg^{-1})			
		Unhusked	Brown rice	White rice[b]	Husk
KDML 105	0	13.0	7.8 a	7.9 a	36.0 a
	60	14.6 ab	8.2 a	7.2 a	32.6 a
	120	16.1 b	8.8 a	7.3 a	37.4 a
IR68144	0	15.8 a	13.5 a	12.3 b	37.9 a
	60	17.2 a	13.0 a	13.6 b	38.3 a
	120	21.1 b	13.1 a	10.0 a	48.6 a
Ubon 2	0	13.8 a	9.3 a	4.6 a	42.7 a
	60	13.6 a	8.1 a	8.8 b	44.8 a
	120	13.5 a	8.3 a	6.5 ab	48.5 a
RD6	0	15.2 a	8.2 a	5.1 a	39.8 a
	60	15.8 b	8.3 a	10.3 b	51.3 a
	120	18.3 b	9.0 a	8.2 b	44.2 a
Basmati 370	0	15.6 a	10.8 a	7.6 a	35.8 a
	60	16.3 a	12.1 ab	6.5 a	37.5 a
	120	18.3 b	12.4 b	10.2 b	47.3 b
Analysis of variance					
P (G)		<0.01	<0.01	<0.01	<0.01
P (N)		<0.01	ns	<0.05	<0.05
P (G × N)		<0.05	<0.05	<0.01	<0.05
LSD (0.05)		2.6	1.5	2.3	11.5

[a]LSD used to compare differences in the same genotypes at different treatments. [b]Polished for 30 s.

with the application of 120 kg N ha^{-1}. Nitrogen had no effect on Fe in unhusked grain of Ubon 2. Much higher concentrations of Fe were found in the rice husk compared with the rest of the grain. Nitrogen levels had no effect on Fe concentration in brown rice and husk. However, in the brown rice of Basmati 370, it was increased with 120 kg N ha^{-1}. To produce white rice, the mill normally polishes brown rice for about 30 s. In this study, we found that grain Fe concentration generally declined after polishing, indicating that a high proportion of Fe is contained in the bran. For Ubon 2 and RD6, grain Fe in white rice from 60 kg N and 120 kg N applications was twice as much as with 0 N. There was a similar, although slightly less, effect of N in Basmati 370. In IR68144, the grain Fe in white rice with 120 kg N was slightly less than with 0 N and 60 kg N, but in KDML 105, the grain Fe in white rice showed no response to N. However, the grain Fe in unhusked, brown, and white rice was not correlated with the grain N in rice grain and grain yield at three levels of N application.

Different parts of the rice grain—the husk, the bran, and the endosperm—appeared to contain Fe at different concentrations and their Fe contents responded differently to N fertilizer. The effect of N fertilizer on grain Fe appeared to be mostly in the husk. The Fe concentration in unhusked rice was only weakly correlated with that in brown rice (r = 0.66) and white rice (r = 0.42).

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Influence of irrigation, nutrient management, and seed priming on yield and attributes of upland rice

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The productivity of upland rice is very low because of a host of problems, among which soil moisture stress, poor native soil fertility, and high weed infestation are the most important ones. Under upland situations, moisture stress is likely to occur during any of the growth stages of the crop, which may adversely affect growth and yield. Presowing treatment improves germination, promotes plant and root growth, and increases crop survival under water-stress conditions. A field experiment was conducted at the Instructional Farm in Vellayani of Kerala Agricultural University, India, during the late first crop season of 1999 to examine the response of upland rice to different levels of irrigation, nutrient management, and seed priming.

Soil characteristics at the trial site were a sandy clay loam texture, organic C 1.7% (Walkley and Black's rapid titration method, Jackson 1973), pH 4.8 (pH meter with glass electrode, Jackson 1973), and available N, P_2O_5, and K_2O of 238 (alkaline potassium permanganate method, Subbiah and Asija 1956), 32.8 (Bray 1 method, Jackson 1973), and 160 kg ha^{-1} (ammonium acetate method, Jackson 1973), respectively. Treatments consisted of three irrigation levels (irrigation water [IW]/cumulative pan evaporation [CPE] ratio of 1.5 [I_1], 0.1 [I_2], and rainfed [I_3]; three nutrition levels (20-10-15 [F_1], 40-20-30 [F_2], and 60-30-45 [F_3] kg NPK ha^{-1}); and two seed priming methods (1% [S_1] and 2.5% (KCl) [S_2]. The experimental layout was a split-split-plot design with three replications: irrigation levels in main plots, nutrient management in subplots, and seed priming in sub-subplots. Irrigation was given to a depth of 50 mm. Upland rice variety Matta Triveni (PTB45) was dibbled at a spacing of 20 × 10 cm. This variety was released from RARS, Pattambi, Kerala. It has a duration of 95–105 d. The grains are red, long, and bold.

Irrigation was scheduled 1 wk after sowing, according to the treatment. N was applied in three equal splits—i.e., basal, at tillering, and at panicle initiation. The rice seeds were immersed in 1.0% and 2.5% KCl solution for 15 h and dried before pregermination. The total quantity of water received by irrigation treatments I_1, I_2, and I_3 during the cropping period was 544, 456, and 214 mm, respectively. The area of the experimental site has a humid tropical climate. The mean rainfall received during the cropping period was 422 mm. The mean annual maximum and minimum temperatures were 32.2 and 23.1 °C, respectively. The mean relative humidity was 82%.

The number of productive tillers $hill^{-1}$ and the number of spikelets $hill^{-1}$ were influenced by irrigation and nutrient treatment only. Treatment levels I_1 and F_3 recorded the highest values for both these attributes (Table 1). Panicles produced by plants subjected to a rainfed situation often failed to emerge and had a high percentage of sterile spikelets.

The data showed that both irrigation and nutrient levels had a significant influence on the

Table 1. Response of upland rice to different levels of irrigation, nutrient management, and seed priming at the Instructional Farm, Vellayani, Kerala, India.

Treatment[a]	Productive tillers $hill^{-1}$ (no.)	Spikelets $panicle^{-1}$ (no.)	Filled grains $panicle^{-1}$ (no.)	Chaff percentage	1,000-grain weight (g)	Grain yield (kg ha^{-1})
Irrigation						
I_1	11	119	101	14	22.44	2676
I_2	9	116	101	13	21.58	2145
I_3	6	91	426	31	7.07	371
F (2, 4)	15.297*	6.771*	43.8**	511.67**	990.5**	2,163.2**
CD	2.715	22.82	20.69	4.97	0.351	101.8
Nutrients						
F_1	8	91	71	26	19.76	1299
F_2	8	115	87	30	20.65	1798
F_3	10	120	89	34	20.68	2094
F (2, 16)	6.426**	14.923**	7.649**	10.764**	83.5**	53.1
CD	1.61	12.12	10.23	4.03	0.154	165.1
Seed priming						
S_1	8	109	79	32	20.29	1736
S_2	9	109	85	28	20.30	1724
F (1, 34)	0.954	0.001	1.539	5.421*	0.194	0.036
CD	ns	ns	ns	3.584	ns	ns

[a]Irrigation levels: I_1 = irrigating the crop at an IW/CPE ratio of 1.5, I_2 = irrigating the crop at an IW/CPE ratio of 1.0, I_3 = rainfed; nutrition levels: F_1 = 20-10-15 kg NPK ha^{-1}, F_2 = 40-20-30 kg NPK ha^{-1}, F_3 = 60-30-45 kg NPK ha^{-1}; seed priming: S_1 = 1.0% KCl for 15 h, S_2 = 2.5% KCl for 15 h. * = significant at 5% level, ** = significant at 1% level.

number of filled grains panicle^{-1}. Irrigation treatments I_1 and I_2 were on a par with each other and were significantly superior to I_3. Similarly, F_2 and F_3 were on a par with each other and were significantly superior to F_1. The interaction I × F was significant and the treatment combination I_2 F_2 recorded the highest number of filled grains panicle^{-1} (Table 2).

Both the irrigation treatments I_1 and I_2 registered less chaff percentage compared with the rainfed treatment (Table 1). The nutrient level F_3 produced significantly higher values of chaff percentage than F_1 and F_2. A higher fertilizer dose increased vegetative growth, resulting in higher leaf area index, and this might have resulted in mutual shading, which affected photosynthesis and thus gave a high chaff percentage. The seed priming treatment S_2 recorded lower values of chaff. Lowest chaff percentage values were found in combinations I_1 F_1 and I_1 F_1 S_1.

Irrigation at the I_1 level recorded significantly higher 1,000-grain weight over I_2 and I_3. Similarly, the highest level of NPK (F_3) produced a higher 1,000-grain weight than F_2 and F_1. The interaction effect of I × F indicated that the highest level tested in the trial (I_1 F_3) gave the highest test weight and was on a par with I_1 F_2. Among I × F × S combinations, I_1 F_2 S_1 recorded the highest test weight and was on a par with I_1 F_2 S_2.

Data indicated that the factors irrigation and nutrition and the interaction I × F had a significant influence on grain yield. I_1 gave the highest grain yield (2,676 kg ha^{-1}), which was significantly superior to I_2 (2,145 kg ha^{-1}) and I_3 (371 kg ha^{-1}). I_1 recorded a yield increase of 24.8% in grain yield over I_2 (IW/CPE = 1.0). This increase in yield was due to the concomitant increase of the yield attributes at higher levels of irrigation. The drastic reduction in yield under moisture stress was mainly due to the increased number of unfilled grains panicle^{-1} rather than a reduction in panicle per unit area. Among the nutrient levels tested, F_3 recorded the highest grain yield of 2,094 kg ha^{-1}, which was significantly superior to the other two levels. Among I × F combinations, I_1 F_3 registered the highest grain yield of 3,223 kg ha^{-1}. This value indicates that good water availability and better nutrition result in higher yields and that seed priming has no influence. It is evident from the study that the crop responds to an irrigation level with an IW/CPC ratio of 1.5 and that an NPK level of 60-30-45 kg ha^{-1} helps attain maximum yield.

Table 2. Interaction effects of irrigation, nutrients, and seed priming on number of spikelets panicle^{-1}, number of filled grains panicle^{-1}, chaff percentage, 1,000-grain weight (g), and grain yield (kg ha^{-1}).[a]

Treatment	Spikelets panicle^{-1}(no.)	Filled grains panicle^{-1}(no.)	Chaff percentage	1,000-grain weight (g)	Grain yield (kg ha^{-1})
$I_1 F_1$	110	101	9.83	21.11	2,155
$I_1 F_2$	112	96	13.83	23.14	2,650
$I_1 F_3$	136	113	17.33	23.45	3,223
$I_2 F_1$	91	79	13	21.73	1,431
$I_2 F_2$	139	121	14.67	21.20	2,386
$I_2 F_3$	118	104	12.83	21.80	2,617
$I_3 F_1$	72	34	53.83	16.43	313
$I_3 F_2$	95	43	75.17	17.60	358
$I_3 F_3$	107	49	60.17	17.20	441
F(4, 16)	14.9**	4.37*	6.997**	53.616**	11.106**
CD	12.121	17.721	6.9	0.367	286.05
$I_1F_1S_1$	107	97	8.33	21.63	2,029
$I_1F_1S_2$	113	105	11.33	20.60	2,279
$I_1F_2S_1$	113	102	9.67	23.25	2,599
$I_1F_2S_2$	110	90	18	23.00	2,701
$I_1F_3S_1$	142	115	19	22.40	3,276
$I_1F_2S_2$	129	110	15.67	22.50	3,169
$I_2F_1S_1$	93	80	13.33	22.47	1,355
$I_2F_1S_2$	89	78	12.67	21.00	1,506
$I_2F_2S_1$	110	94	17.67	21.40	2,742
$I_2F_2S_2$	167	148	10.67	21.00	2,030
$I_2F_3S_1$	128	116	10.67	22.20	2,828
$I_2F_3S_2$	107	92	15	21.40	2,406
$I_3F_1S_1$	73	33	56	15.47	177
$I_3F_1S_2$	70	34	51.67	17.40	449
$I_3F_2S_1$	99	36	91.33	17.00	261
$I_3F_2S_2$	91	50	59	18.20	456
$I_3F_3S_1$	113	42	62.67	16.77	358
$I_3F_3S_2$	101	57	57.67	17.60	523
F(4, 34)	2.649	3.696*	4.173**	20.7**	1.461
CD	–	27.45	10.17	0.888	–

[a]* = significant at 5%, ** = significant at 1%.

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Effect of organic and inorganic P fertilizers on sustainability of soil fertility and grain yield in a rice-pulse system

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The use of indigenous rock phosphate (RP) as fertilizer is becoming increasingly important in India. The RP deposit in India was estimated to be about 260 t (Narayanasamy and Biswas 1998). Khasawnch and Doll (1986) reported that RP is as effective as water-soluble P fertilizer under suitable environments. As the availability of RP increases slowly and continuously when in contact with the soil, its effectiveness was two to three times more than that of triple superphosphate (Chien and Hammond 1988).

The application of RP with organic manure enhances the dissolution of RP in the soil and thus increases the plant availability of P. The organic acids produced during the decomposition of organic manure supply protons (W) for RP dissolution (Bagavathiammal and Mahimairaja 1999). In association with phosphate-solubilizing microorganisms and organic manure, RP could be used as a P source in many crops. The mechanism behind the solubilization of P from RP by microorganisms is related to the production of organic acids and chelating substances (Datta et al 1982). The residual effect of RP is more pronounced in the presence of organic manure in a rice-rice cropping system (Panda 1989). Roy et al (1997) found that in Udic Ustochrepts, rice yield and soil enrichment could be improved by using Mussoorie RP (MRP) incorporated with legume straw and phosphobacteria (PB) *(Bacillus polymyxa* and *Pseudomonas striata)* in neutral to slightly alkaline soils. Because not much work on the effectiveness of Rajphos (Udaipur RP, a product of Rajasthan Mines and Minerals Ltd., Udaipur, India) as a source of P was done, we evaluated its agronomic effectiveness along with other sources of P. The study aimed to determine the effect of organic manure and biofertilizer on the effectiveness of Rajphos and to examine the residual effect of Rajphos application in rice soil. Different inorganic P fertilizers were used with organic manures (e.g., green leaf manure, [GLM] was pungam leaf *Pongamia glabra)* and biofertilizer-phosphobacteria. The yields of rice and blackgram and soil fertility changes were noted.

The field experiments were conducted in 1996-97 at the TNAU Soil Science Department in Coimbatore. Soil is a clay loam alluvial with pH 7.86, EC 0.48 dS m^{-1}, 0.42% organic C, 183 kg $KMnO_4$-N ha^{-1}, 17.8 kg Olsen P ha^{-1}, and 543 kg NH_4OAcK ha^{-1}. The average total P (dry weight basis) was 7.2%, 8.3%, 20.1%, and 0.17% in Udaipur RP (Rajphos), MRP, diammonium phosphate (DAP), and GLM, respectively. The treatments were replicated three times in a randomized block design. Short-duration rice variety ADT36 (110 d) was planted in the first week of December every year using 15 ¥ l0-cm spacing. Freshly collected leaves of *P. glabra* were incorporated at 6.25 t ha^{-1} (equivalent to 1.875 t ha^{-1} on a dry weight basis) into the field 1 wk before transplanting. Phosphobacteria as biofertilizer were applied at 2 kg ha^{-1}. The phosphobacterial inoculant was prepared with lignite as a carrier. Rock phosphates and other fertilizers were applied as basal 3 d before transplanting. Recommended doses of N (120 kg ha^{-1}) as urea and K (41.5 kg ha^{-1}) as muriate of potash were applied in four equal splits at initial, tillering, panicle initiation, and flowering stages. Plots were irrigated and 25-d-old rice seedlings were transplanted in the puddled field. Other cultivation practices such as weeding (four times) and plant protection measures (two times) were carried out. The crop was harvested at maturity and its yield recorded. Postharvest soil samples after rice were analyzed for Olsen P with 0.5 M $NaHCO_3$ (pH 8.5) as extractant. Representative soil samples were collected at 0-15-cm depths, air-dried, sieved through a 2-mm sieve, and analyzed.

At first, the highest grain yield of rice was obtained with DA, followed by the RPs (Table 1). Though MRP contains relatively higher total P content (8.3%) than Rajphos (7.2%), the latter appeared to perform relatively better in rice soil than the former. However, MRP and Rajphos were on a par at the 5% level. This may be due to the differences in chemical composition and varying dissolution patterns of P from these two RPs. Rajphos, up to 32.73 kg P ha^{-1}, performed as well as DAP, but it gave a higher rice yield than MRP at all levels. The addition of GLM at 6.25 t ha^{-1} and PB at 2 kg ha^{-1}, along with different sources of P, considerably increased yield, mainly by improving the dissolution and availability of P from the RPs. The combination of Rajphos at 21.82/32.73 kg P ha^{-1}, GLM, and PB resulted in higher grain yields, a value comparable with the sole application of DAP (21.82 kg P ha^{-1}) in the cropping sequence.

The application of Rajphos (32.73 kg P ha^{-1}) along with GLM + PB recorded the highest benefit-cost ratio of 2.7 (Table 2), which was followed by DAP (32.73 kg P ha^{-1} + GLM + PB; 2.5). The P buildup in the soil was significantly increased with the application of phosphatic sources in combination with GLM/PB (Table 3). The application of organic fertilizers, along with Rajphos, enhanced the solubility of Rajphos by producing organic acids, which, in turn, improved P availability at the later stages of crop growth and thus increased grain yield. The lower yield obtained by Rajphos alone might be ascribed to the slow release of P (and in less amount) from Rajphos in the available form (Rabindra et al 1986).

To examine the residual effect of Rajphos, a rice fallow summer crop of black gram (variety Co 5, 75-d duration) was sown on the same plots without further application of nutrients. The application of Rajphos at 32.73 kg P ha^{-1}, along with GLM applied to rice, recorded the highest residual black gram yield of 480 kg ha^{-1}, which was followed by Rajphos + GLM + PB (Table 4).

These results suggest that the combined application of Rajphos (up to 32.73 kg P ha^{-1}, GLM (6.25 t ha^{-1}), and PB (2 kg ha^{-1}) could be a substitute for inorganic phosphate fertilizers (particularly DAP) in a rice-pulse cropping system.

Table 1. Effect of different sources and levels of P on yield (kg ha^{-1}) of rice variety ADT36 (av of 2 y).[a]

Level (L) (kg P ha^{-1})	Sources (P)				
	RP	MRP	DAP	L mean	O mean
P alone					
10.91	4,051 c	3,955 c	4,241 c	4,082 C	
21.82	4,502 b	4,457 b	4,661 b	4,540 B	
32.73	4,952 a	4,757 ab	5,006 ab	4,905 A	
43.64	4,627 ab	4,907 a	5,302 a	4,945 A	
P mean	4,533 B	4,519 B	4,803 A		4,618 C
P + GLM (0)					
10.91	4,727 c	4,613 b	4,902 c	4,747 C	
21.82	5,066 bc	4,989 b	5,222 bc	5,092 B	
32.73	5,490 a	5,384 a	5,524 ab	5,466 A	
43.64	5,163 ab	5,569 a	5,799 a	5,510 A	
P + GLM (0) mean	5,122 B	5,139 B	5,362 A		5,204 A
P + GLM +PB (0)					
10.91	4,455 c	4,327 b	4,611 b	4,464 C	
21.82	4,817 bc	4,660 b	4,956 b	4,811 B	
32.73	5,277 a	5,060 a	5,377 a	5,238 A	
43.64	4,952 ab	5,192 a	5,514 a	5,219 A	
P + GLM +PB (0) mean	4,875 b	4,810 b	5,115 a		4,933 B

	SE	LSD (5%)
P	56	113
O	56	113
L	65	130
P × L	113	225
O × P	98	195
P × L × O	195	389

[a]Means followed by small letters are compared within the column. Means followed by capital letters are compared within the column (L & O) and across the row (P). RP = Rajphos, MRP = Mussoorie rock phosphate, DAP = diammonium phosphate, P = sources of P, L = levels of P, O = organic fertilizers such as GLM/phosphobacteria (PB).

Table 2. Effect of different sources and levels of P on benefit-cost ratio (BCR).

Treatment	BCR		
	P source	P source GLM	P source + GLM + PB
Control	2.0	2.1	2.2
RP at 10.91 kg ha^{-1}	2.3	2.4	2.4
RP at 21.82 kg ha^{-1}	2.4	2.4	2.5
RP at 32.73 kg ha^{-1}	2.5	2.5	2.7
RP at 43.64 kg ha^{-1}	2.2	2.3	2.3
MRP at 10.91 kg ha^{-1}	2.2	2.4	2.4
MRP at 21.82 kg ha^{-1}	2.3	2.4	2.4
MRP at 32.73 kg ha^{-1}	2.3	2.4	2.4
MRP at 43.64 kg ha^{-1}	2.2	2.4	2.3
DAP at 10.91 kg ha^{-1}	2.3	2.5	2.5
DAP at 21.82 kg ha^{-1}	2.4	2.5	2.5
DAP at 32.73 kg ha^{-1}	2.4	2.5	2.6
DAP at 43.64 kg ha^{-1}	2.4	2.5	2.5

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Table 3. Effect of different sources and levels of P on soil P (Olsen P) (kg ha^{-1}).[a]

Level (L) (P kg ha^{-1})	Sources (P)				
	RP	MRP	DAP	L mean	O mean
P alone					
10.91	8.98 b	8.82 ab	9.25 b	9.02 CD	
21.82	9.30 ab	9.12 ab	10.34 ab	9.59 BC	
32.73	10.43 a	9.64 a	11.26 a	10.44 A	
43.64	10.47 a	8.03 b	10.91 a	9.80 AB	
P mean	9.80 A	8.9 B	10.44 A		9.71 AB
P + GLM (0)					
10.91	9.30 b	9.78 a	9.72 bc	9.60 C	
21.82	9.82 ab	9.99 a	9.16 c	9.66 C	
32.73	10.95 a	10.60 a	10.91 ab	10.82 AB	
43.64	10.82 a	10.91 a	11.56 a	11.10 A	
P + GLM (0) mean	10.22 A	10.32 A	10.34 A		
P + GLM + PB (0)					
10.91	8.64 b	8.42 b	9.56 ab	8.87 B	
21.82	9.30 ab	8.73 b	8.68 b	8.90 B	
32.73	10.47 a	10.56 a	9.03 b	10.02 A	
43.64	10.56 a	8.86 b	10.65 a	10.02 A	
P + GLM + PB (0) mean	9.74 A	9.14 A	9.48 A		9.46 BC

	SE	LSD (5%)
P	0.19	0.38
O	0.19	0.38
L	0.22	0.44
P × L	0.38	0.76
O × P	0.33	0.66
P × L × O	0.66	1.31

[a]Means followed by small letters are compared within the column. Means followed by capital letters are compared within the column (L & O) and across the row (P). RP = Rajphos, MRP = Mussoorie rock phosphate, DAP = diammonium phosphate, P = sources of P, L = levels of P, O = organic fertilizers such as GLM/phosphobacteria (PB).

Table 4. Residual effect of different sources and levels of P on grain yield of Black gram variety Co 5 (av of 2 y).[a]

Level (L) (P kg ha^{-1})	Sources (P)				
	RP	MRP	DAP	L mean	O mean
P alone					
10.91	240 c	290 a	275 a	286 C	
21.82	323 b	215 b	170 c	236 D	
32.73	320 b	310 a	230 b	287 B	
43.64	385 a	297 a	280 a	321 A	
P mean	317 A	278 B	239 C		278 C
P + GLM (0)					
10.91	260 c	260 b	220 c	240	
21.82	360 c	270 b	320 b	317	
32.73	480 a	330 a	360 a	390	
43.64	365 b	310 a	320 b	332	
P + GLM (0) mean	366 ns	293 ns	305 ns		321 A
P + GLM + PB (0)					
10.91	230 c	270 b	280 c	260	
21.82	315 b	270 b	290 b	288	
32.73	390 a	360 a	310 b	353	
43.64	325 b	275 b	355 a	318	
P + GLM + PB (0) mean	315 ns	294 ns	309 ns		306 B

	SE	LSD (5%)
P	0.47	0.94
O	0.47	0.94
L	0.54	1.09
P × L	ns	
O × P	ns	
P × L × O	11	22

[a]Means followed by small letters are compared within the column. Means followed by capital letters are compared within the column (L & O) and across the row (P). RP = Rajphos, MRP = Mussoorie rock phosphate, DAP = diammonium phosphate, P = sources of P, L = levels of P, O = organic fertilizers such as GLM/phosphobacteria (PB), ns = nonsignificant.

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Participatory research on the effect of on-farm water management practices

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Irrigation facilities have been built for considerable areas of cropped land, but the desired level of output by way of increased irrigated area and agricultural production has not been achieved. This is mainly attributed to the wastage of water at certain reaches. As rice is a major consumer of irrigation water, much has to be done to improve water-use efficiency in rice fields and this is possible only through farmers' participation. Farmers generally have the impression that field-to-field flowing water is best for rice growth. They are reluctant to follow scientific recommendations in water management. (Scientific water management relates to maintaining the standing water at 1-2 cm from transplanting to tillering and 1-5 cm from tillering to 10 d before harvest.) Rice yield can be influenced by different water management practices such as continuous submergence (Mandal and Chatterjee 1984), varying levels of submergence at different growth stages (Thorat et al 1987), and shallow submergence (5 ± 2 cm) during the crop's entire growth cycle (Jha and Sahoo 1988). Our study aimed to evaluate the effect of scientific water management along with farmers' practices on rice cultivation and to demonstrate how farmer participation in the research program can enhance water management.

This study was conducted in the Ichannur subdistributory command of the Kuttiyadi Irrigation Project in Kerala, India, in the 1999-2000 summer seasons (Jan-May). The *field boothies* (canals below the subdistributory and above the outlet of the command area) were lined with concrete and the field and drainage channels laid out with the participation of the members of the Beneficiary Farmers' Association. These interventions ensured reliable water delivery in the command area. Even with this, farmers practiced only field-to-field flowing irrigation, which resulted in enormous wastage of water. To optimize water use, an experiment was set up in outlets 7 and 12 of the Ichannur subdistributory, where farmers' associations were active and initiated the experiment.

Rice variety Triveni (PTB38) was used in the study and a common nursery was raised. Nursery raising, transplanting, manure and fertilizer application, aftercare, and harvest were done following the recommendations of the Kerala Agricultural University. The treatments consisted of scientific water management (T_1) and the farmers' practice of water management (T_2). Scientific water management relates to maintaining standing water at 1-2 cm from transplanting to tillering and 1-5 cm from tillering to 10 d before harvest. It also involves complete drainage 1 d prior to N topdressing and irrigation 12 h after topdressing. Water is let into the field from the field irrigation channel, either through a siphon or small regulatory slots made for the purpose. The farmers' practice is letting water into the fields to maintain standing water of a convenient height (as decided by them) and adopting field-to-field irrigation.

In both outlets, two adjacent plots (about 10,000 m^2 each) were selected. There were thus two major plots for each treatment. Soil at the experimental site was clay loam with medium fertility and pH 5.3. Treatments were imposed accordingly and water depth was maintained using marking pegs distributed randomly to various portions in the field. Evaporation from the field was recorded using can evaporimeters. The quantity of water diverted to each plot was also recorded. Observation sites in each plot were fixed randomly at 10 different spots, each having an area of 1 m^2. From this area, 10 plants were selected for observation. Grain and straw yields were taken from the harvested produce. At harvest, plant height, number of tillers, and number of panicles were recorded. Grain yield and straw yield were recorded after drying to 14% moisture content. Water-use efficiency was calculated as the ratio of grain yield to total quantity of water used (expressed as kg ha^{-1} cm^{-1}). Statistical analysis was done using methods specified by Panse and Sukhatme (1978). The results on growth, yield, and yield attributes are presented in the table.

Plant height did not vary significantly in both years, indicating that this growth attribute is not influenced by differences in conditions under both flowing and standing water in the field.

Growth and yield attributes, grain yield, and water use of rice as influenced by water management treatments.

Attribute	1999			2000		
	T_1	T_2	CD (0.05)	T_1	T_2	CD (0.05)
Plant height (cm)	79.00	78.40	ns	76.80	78.70	ns
Tillers hill^{-1} (no.)	8.48	9.33	ns	9.46	8.44	ns
Panicles hill^{-1} (no.)	4.01	4.52	ns	4.53	4.37	ns
Grain yield (t ha^{-1})	2.33	2.42	ns	2.40	2.60	ns
Straw yield (t ha^{-1})	2.83	2.60	ns	3.01	2.90	ns
Water used (cm)	111.30	198.40	–	129.90	217.70	–
Water-use efficiency (kg ha^{-1} cm^{-1})	20.89	12.19	–	18.46	11.94	–

The number of tillers per hill (at harvest) likewise did not vary significantly. Similar results were noted for number of panicles. Grain yield showed a slightly increasing trend because of flowing water in both years, but there was no statistical difference between the two years. Straw yields under both water management treatments were on a par. There was a considerable difference in the total quantity of water used in the two water management practices during the 70-d growth period of the crop in the main field. During the first and second year of the study, the water used with scientific management was only 56% and 60% of that used with farmer management, and, since no yield increase was observed, this additional input of water was simply wasted. The farmers realized that they could have used this precious irrigation water to bring about a considerable area under cultivation. Water-use efficiency in both years was also considerably lower under the farmers' practice: 12 and 12 vs 21 and 18 kg ha cm^{-1}.

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Temporal variation in sugar exudation rate of hydroponically grown Pusa Basmati 1 at seedling stage

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Root exudates, along with dead root hairs, epidermal cells, and root caps, are a source of energy for the microbial community in the rhizoplane and rhizosphere. They aid in the mineralization of organic matter, nutrient cycling, and trace gas (CH_4, N_2O, etc.) production (Aulakh et al 2001). MacRae and Castro (1966), Marathe (1970), and Waschutza et al (1992) have identified raffinose, glucose, fructose, arabinose, ribose, and xylose in rice exudates. Glucose is the most abundant of all sugar exudates of plants in general (Boureau 1977). With growth of rice, the exudation of organic acids such as oxalic, succinic, aconitic, citric, malic, tartaric, and lactic acids substitutes for the exudation of sugars (Aulakh et al 2001, Boureau 1977). Root and shoot biomass was positively correlated with carbon exudation, suggesting that it is driven by plant biomass (Aulakh et al 2001). A decrease in exudation was observed by Vancura et al (1977) when the source of seedling nutrition shifted from stored substances in the seeds and the endosperm to photosynthesizing leaves. As the nutrient supply from the leaves increases, root exudation increases again and maintains a rising trend up to the time of flowering.

Our study was undertaken to estimate the sugar exudation rate of rice cultivar Pusa Basmati 1 during the seedling stage in a nutrient culture (Hoagland's solution). Pusa Basmati 1 is one of the most important rice varieties grown in India and in many other rice-growing Southeast Asian countries. The possibility of fitting the sugar exudation rate into mathematical functions was also explored.

Seeds of rice cultivar Pusa Basmati 1, obtained from the Division of Genetics of the Indian Agricultural Research Institute, were surface-sterilized by shaking with 70% ethanol for 2 min and then washing them thoroughly with sterile distilled water. Subsequently, the seeds were treated with 0.2% mercuric chloride solution for 30 min followed by repeated washing in sterile distilled water (MacRae and Castro 1996). The seeds were then allowed to germinate over moist filter paper in petri plates and allowed to grow for 96 h at 30 °C until the roots were conspicuous.

The seedlings were then transferred to cylindrical plastic containers (approx. 800 cm^3), containing Hoagland's solution (1/4 strength as described by Johnson et al [1957]). Four seedlings were fixed in four small apertures at the top of each container. The containers were filled with Hoagland's solution up to the brim so that roots of the growing seedlings remained immersed in solution. The solution in the containers was aerated at regular intervals with the help of an aquarium pump to supply oxygen for root respiration (Fig. 1). Although root respiration of rice under anaerobic conditions takes place mainly via oxygen supply through the aerenchyma, in transplanted rice culture seedlings remain in the nursery for around 25 d initially, where the soil is not puddled and remains primarily aerobic. To simulate this condition in the seedbed, the nutrient solution was aerated at regular intervals.

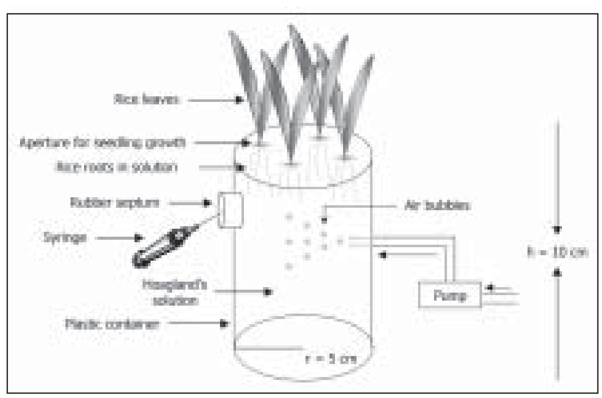

Fig. 1. Cultivating rice seedlings in nutrient solution.

Sugar content in the nutrient medium was estimated 3, 6, 9, 12, 15, 18, 21, and 24 d after seedlings were transferred into Hoagland's solution. Different types of sugars were not estimated separately but total sugar was determined. Nutrient solution (1 mL) was withdrawn into a glass syringe (2 mL) through a side port fitted with a rubber septum (Fig. 1) and was mixed with 5 mL of concentrated sulfuric acid and 1 mL of phenol solution (5% in water, w/v) in a test tube. The tube was shaken vigorously and kept for about 20 min before absorbance of the solution was recorded at 490 nm in a spectrophotometer (Electronic Corporation of India Ltd., New Delhi). Total sugar was determined from a standard curve prepared from sucrose standards (Dubois et al 1956). Eight sets of containers, each replicated three times, were kept for sugar estimation and destructive plant sampling. After each sampling, one set of containers was taken, from which solution containing the released sugars was drawn. All four seedlings were then washed and dried in an oven at 60 °C for 24 h and weighed. To calculate the sugar exudation rate, cumulative sugar exudation during each 3-consecutive-day period was used.

A completely randomized design was followed to carry out analysis of variance (Gomez and Gomez 1984). Each represented datum is a mean ± SD of three replications. Duncan's multiple range test was used to calculate the statistically significant differences among each pair of means. All these statistical analyses were done by using MSTAT-C software (version 1.41), developed by the Crop and Soil Science Department of Michigan State University, USA. The sugar exudation rate was curve-fitted by using MS Excel software (Microsoft Corporation, USA).

There was an increase in sugar exudation rate initially from 9.0 g kg^{-1} dry biomass d^{-1} on the 6th day. It declined from the 7th to the 9th day, and started increasing thereafter until 13.2 g kg^{-1} dry biomass d^{-1} was obtained on the 24th day (Fig. 2). The increase in root exudation rate during the first week was perhaps due to the nutrients derived from reserve substances in the seed endosperm. The transitional phase covering the transfer of nutrients from reserve substances to truly photosynthesizing leaves during the 2nd week is reflected in the low exudation rate of the sugars. When the true leaves had taken over from the 3rd week onward, exudation increased rapidly. The sugar exudation rate 24 d after root emergence had a significant correlation with plant biomass (r = 0.88) and can be best fit by a 5th-order polynomial equation ($R^2 = 0.99$).

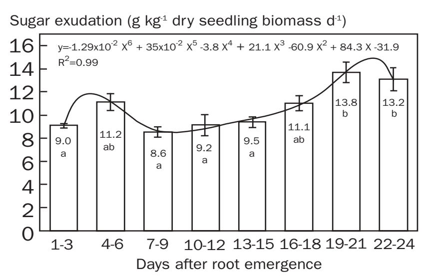

Fig. 2. Changes in the amount of sugar released by hydroponically grown Pusa Basmati I seedlings. Bars indicate mean ± SD of three replications; values followed by the same letters are not statistically different from each other according to Duncan's multiple range test.

It will be interesting to study the sugar exudation rate of hydroponically grown Pusa Basmati 1 in the following stages and to determine whether this rate follows any particular distribution. Although exudation may differ under field conditions, this study may help describe the sugar exudation behavior of Pusa Basmati 1 in nutrient cultures.

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Impact of pulse applications of herbicides on biomass of grasses and sedges and their effects on the yield and yield components of direct wet-seeded rice

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Because rice is a staple and an important export commodity for Pakistan, an economical and time-saving cultivation method becomes indispensable. This study aimed to develop a package of technologies to support direct seeding by identifying weed management strategies, establishing appropriate time and date of seeding, and promoting efficient application of herbicides.

An experiment using a split-plot design with three replications was conducted in 1999 and 2000. A subplot size of 5 × 3 m^2 was used in each treatment. Main plots were assigned to different herbicide application times (3, 6, and 9 wk after seeding [WAS]), whereas the subplots comprised four herbicides (Ronstar-12 L at 2 L ha^{-1}, Topstar-800 WG at 100 g ha^{-1}, Rifit-500 EC at 1 L ha^{-1}, and Acelor-50 EC at 250 mL ha^{-1}) with one control treatment. Fertilizers at 120-39.6-49.8 kg NPK ha^{-1} were used. Full doses of P and K and half of N were applied at the time of planting, while the remaining half of N was applied at panicle initiation. Pregerminated seeds of IR6 (100 kg ha^{-1}) were used. The soil is mostly silty clay. Annual precipitation (250–300 mm) mostly occurs in July and August. The 1999 experiments took place on a field where the previous crop was *Brassica napus*, while the 2000 experiments followed a wheat crop. Soil under the experiments during both years (1999-2000) had a pH of 8.2 and 8.5, respectively.

Rifit proved superior with higher rice and straw yields, number of panicles m^{-2}, number of spikelets $panicle^{-1}$, and 1,000-grain weight (g), and lower dry weed biomass (g m^{-2}) (Table 1) and sterility (%). Higher net income and benefit-cost ratios (BCR) were likewise obtained when it was applied at 3 WAS. Averaging over the time intervals

Table 1. Impact of variable times of herbicide application on biomass of grasses and sedges and their effects on yield and yield components of IRG, 1999 and 2000.

Item	Year	Herbicides					Application times		
		Ronstar	Topstar	Rifit	Acelor	Control	3 WAS[a]	6 WAS	9 WAS
15 DAA[b] (no. m^{-2})	1999	17.5 b	16.4 b	18.0 b	19.0 b	58.3 a	15.7 c	23.2 b	38.5 a
	2000	18.9 bc	18.0 c	19.3 bc	20.4 b	55.7 a	14.8 c	21.8 b	42.7 a
Dry weed biomass 15 DAA (g m^{-2})	1999	99.7 b	40.7 d	58.0 e	79.0 c	114.9 a	79.0 c	83.8 b	88.3 a
	2000	104.4 b	83.0 d	75.8 e	92.3 c	122.0 a	90.9 b	93.9 b	101.8 a
Tillers (no. m^{-2})	1999	261.6 a	262.9 a	268.3 a	260.3 a	236.2 b	262.4 NS	253.6	257.6
	2000	255.3 b	270.6 a	273.3 a	251.4 b	224.9 c	267.6 a	245.5 b	252.2 b
Panicles (no. m^{-2})	1999	231.2 b	237.2 b	256.0 a	235.7 b	195.1 c	241.7 a	223.5 b	227.9 b
	2000	229.0 c	276.5 a	279.5 a	260.2 b	220.3 d	256.5 NS	251.9	250.9
Rice yield (t ha^{-1})	1999	6.1 c	8.3 ab	8.7 a	7.7 b	5.1 d	7.5 NS	7.1	6.9
	2000	6.2 d	7.2 a	7.4 a	6.9 ab	5.2 c	6.7 NS	6.6	6.5

[a]WAS = weeks after seeding. [b]DAA = days after application of herbicides.

of herbicide application, Topstar was on a par statistically with Rifit for weed population, plant height, tillers m^{-2}, spikelets panicle^{-1}, 1,000-grain weight, and straw yield (data not shown). However, these herbicides did not differ statistically in terms of rice yield, harvest index (data not shown), and number of panicles during the second year of the trial. Rifit also resulted in significantly early maturing plants and higher BCR (2.33 in 1999 and 1.50 in 2000) at 3 WAS (data not shown). Topstar, Rifit, and Acelor at 3 WAS had 90.7% control of sedges and 86.3–86.5% control of grasses. Rifit gave the highest yields when applied at the same interval. Topstar resulted in significantly early maturing plants and gave higher BCR (1.74 in 1999 and 1.47 in 2000) at 9 WAS (data not shown). Rifit and Acelor also proved their efficacy against sedges, especially *Cyperus rotundus*. These results also confirmed the findings of Qazzafi (2000) and Awan et al (2001).

Rifit at 1 L ha^{-1} and Topstar at 100 g ha^{-1} are suitable for seeded rice. Best results are seen when Rifit is applied at 3 WAS.

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Table 2. Weed density of grasses and sedges as affected by herbicide application time and weed control effectiveness of selected herbicides, 1999 and 2000.

Herbicide used	1999						2000					
	3 WAS[a]		6 WAS		9 WAS		3 WAS		6 WAS		9 WAS	
	Grasses	Sedges	Grasses	Sedges	Grasses	Sedges	Grasses	Sedges	Grasses	Sedges	Grasses	Sedges
	Weed density[b] of grasses and sedges 15 DAA[c])											
Ronstar	4.0	4.7	6.7	8.0	13.0	16.0	3.4	5.0	5.6	8.0	16.8	18.0
Topstar	4.0	2.0	6.0	6.3	14.0	17.0	3.0	2.7	4.1	7.4	18.0	18.7
Rifit	5.3	2.0	10.3	6.0	14.0	16.0	4.5	2.5	8.0	7.2	18.0	17.7
Acelor	4.0	2.0	9.7	7.0	16.0	18.0	3.3	2.5	8.5	7.3	20.0	19.9
Control	29.2	21.4	29.3	26.7	30.0	38.1	22.2	24.9	26.8	26.6	32.6	34.0
	Effectiveness of herbicides[d] in controlling weeds											
Ronstar	86.3	78.2	77.2	70.0	56.7	58.1	86.3	78.4	79.8	69.1	48.5	47.0
Topstar	86.3	90.7	79.0	76.8	53.3	55.4	86.5	89.1	83.2	73.8	44.7	45.0
Rifit	81.8	90.7	65.0	77.1	53.3	58.1	79.8	89.9	69.1	74.1	44.7	47.9
Acelor	86.3	90.7	66.7	74.0	46.7	52.8	85.2	89.9	68.3	73.7	38.6	41.6

[a]WAS = weeks after seeding. [b]Density= % m^{-2}. [c]DAA = days after herbicide application.

$$^{d}\text{Effectiveness} = \frac{\text{Weed infestation in control plots} - \text{weed infestation in treated plots}}{\text{Weed infestation in control plots}} \times 100$$

Rice—the food that feeds almost half the planet on a daily basis—is going through a period of unprecedented change that presents both enormous opportunities and great challenges. The recent sequencing of the rice genome has provided us with more knowledge of the grain than we've had in its entire 2,000-year history. Such knowledge will be crucial in meeting the huge challenge of providing enough rice to feed all those who depend on it, while protecting the environment and our precious resources. That's why the United Nations has declared 2004 the International Year of Rice. The UN's Food and Agriculture Organization—working with partners such as IRRI—is firmly focused on making the world more aware that, without rice, there is no life.

Effect of nursery seeding date and phosphorus fertilization on rice seedling growth

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During rabi (Nov-Dec), the growth of rice seedlings in nurseries in some of the rice-growing areas in Andhra Pradesh, India, is poor due to the prevailing low temperature. The suppressed growth of seedlings caused by low temperature is described as cold injury (Shibata 1970). Also, absorption of phosphorus was most strongly inhibited at low temperature (<16 °C). The low concentration of P in soil solution P (2.5 times less) during cooler months necessitates the application of higher doses of P (Katyal and Venkatramaya 1983). Hence, there exists a need for producing vigorous seedlings through proper nursery management. A field study was conducted during the 2001-02 rabi season at College Farm, Rajendranagar, to evaluate the effect of low temperature and P fertilization on seedling growth of rice variety IR64. The treatments consisted of three dates of wet nursery sowing (20 Nov, 1 Dec, and 10 Dec) and four levels of P fertilization (0.5, 1.0, and 2.0 kg P_2O_5 100 m^{-2}). Soil was a sandy clay loam with pH 7.9, low in available N (223 kg ha^{-1}), and medium in P (17 kg ha^{-1}) and K (242 kg ha^{-1}). The experiment was laid out in a randomized complete block design (factorial) with three replications. Each nursery plot was 2 m × 3 m and was fertilized with a uniform dose of N and K at 1.0 kg 100 m^{-2}.

The time required for seeds to sprout increased with delay in sowing. Seeds sown on 20 Nov took 2 d to sprout, whereas those sown on 1 Dec and 10 Dec required 3 and 4 d, respectively (Table 1). This delay was due to a decrease in temperature inside the incubated seed lots from 29 °C on 10 Dec. The plumule and radicle lengths of sprouted seed at the time of sowing were considerably greater in the 20 Nov sowing than in the 10 Dec sowing. The shortest plumule and radicle were noticed with the 10 Dec sowing. The reduced plumule and radicle lengths were attributed to low emergence ability at lower temperatures (Inouye et al 1967).

With delay in sowing, the number of days required for emergence of the 1st, 2nd, and 3rd leaf increased (Table 2, see figure). However, P fertilization did not influence the emergence time of leaves. Root length and shoot dry weight recorded at 10, 20, and 30 days after sowing (DAS) were higher in the 20 Nov sowing than in the 1 Dec and 10 Dec sowings. Previously, the early growth rate of seedlings was found to increase with increasing temperature (Tanaka and Yamaguchi 1969). There was a positive relation between minimum temperature and root length and between seedling height and seedling weight, confirming that a temperature decline resulted in decreased growth of rice seedlings (see figure).

Fertilization with 2.0 kg P_2O_5 100 m^{-2} resulted in greater root length, seedling height, and shoot dry weight compared with 0.5 kg P_2O_5 and 1.0 kg P_2O_5 100 m^{-2}, though it was on a par with 1.5 kg P_2O_5 100 m^{-2} (Table 2). Application of P resulted in more vig-

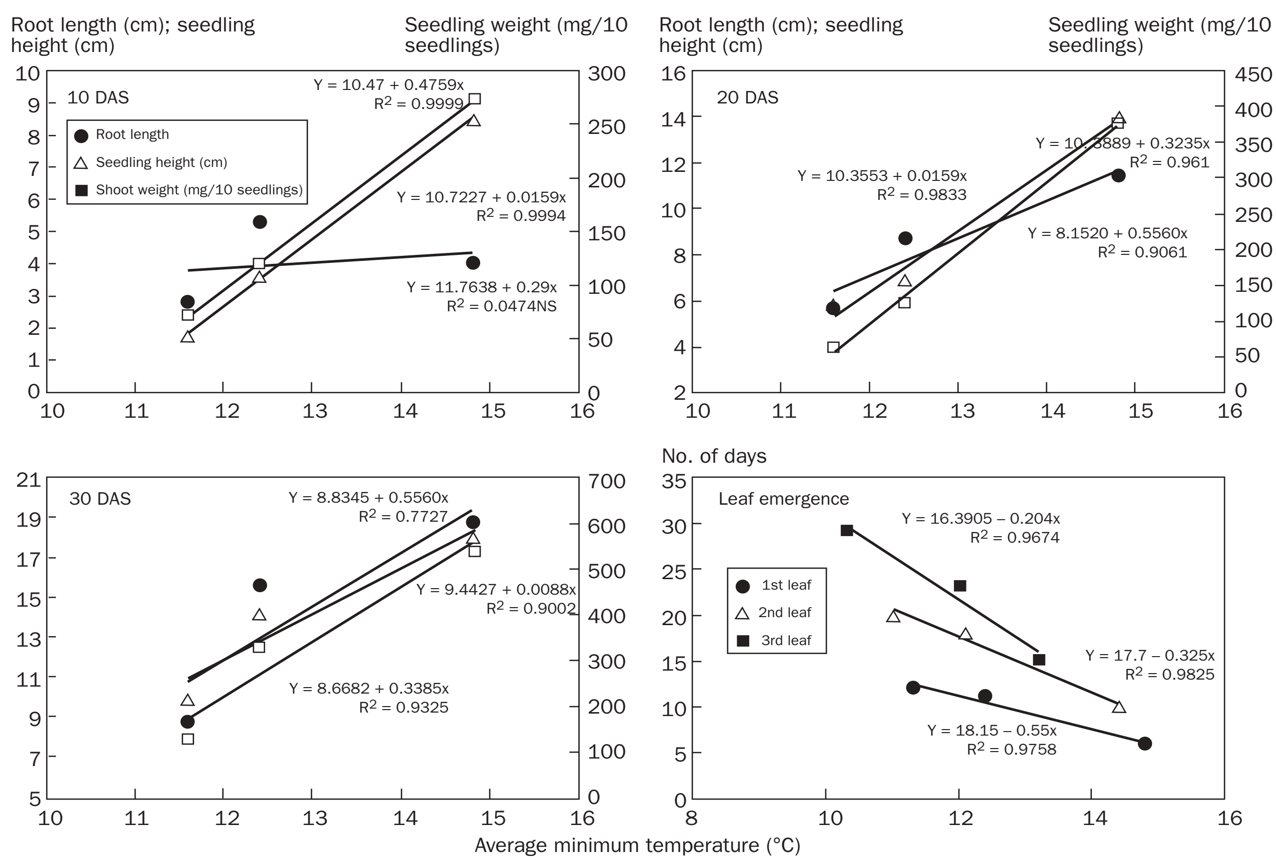
Table 1. Effect of dates of nursery sowing on days for sprouting and plumule and radicle length.

Date of nursery sowing	Atmospheric temperature: Initial 30-day range after sowing (°C)		Days required for sprouting	Temperature inside incubation at germination (°C)	Plumule length (mm)	Radicle length (mm)
	Max	Min				
20 Nov	27.7-31.7	8.1-18.0	2	29.0	3.20	21.6
1 Dec	26.7-31.7	8.1-15.9	3	24.5	1.43	6.0
10 Dec	26.2-31.7	6.3-18.1	4	24.2	0.77	5.7
SE				0.2	0.42	1.24
CD (*P* = 0.05)				0.7	1.21	3.74

orous roots as previously reported (Bhattacharya and Chatterjee 1978). Application of P at 18.9 kg P ha^{-1} was found to increase seedling dry weight (Anwarulla et al 1995). Delayed sowing drastically reduced root length, seedling height, and shoot dry matter because the low temperature caused slower vegetative growth (Kaneda and Beachell 1974). This is possibly due to re-

Table 2. Effect of nursery sowing date and P fertilization on growth of nursery seedlings.

Treatment	Days required for emergence of			Root length (cm) DAS			Seedling height (cm) DAS			Shoot dry weight (mg) 10 seedlings^{-1} DAS		
	1st leaf	2nd leaf	3rd leaf	10	20	30	10	20	30	10	20	30
Date of nursery sowing												
20 Nov	5.9	9.8	15.3	4.0	11.4	18.7	9.1	13.7	17.4	255	384	569
1 Dec	10.9	18.0	23.0	5.3	8.7	15.6	4.0	5.9	12.5	108	156	403
10 Dec	12.2	19.8	28.6	2.8	5.7	8.7	2.4	4.0	7.9	53	124	212
SE	0.2	0.2	0.3	0.2	0.3	0.4	0.2	0.3	0.2	10	11.82	12.25
CD (P = 0.05)	0.7	0.7	1.0	0.5	0.8	1.1	0.5	0.8	0.7	22	34.64	35.88
Levels of P_2O_5 (kg 100 m^{-2})												
0.5	10.0	16.4	22.8	3.4	7.2	12.9	4.1	6.8	11.8	92	170	309
1.0	9.7	15.8	22.8	3.8	8.5	14.1	4.8	7.4	12.1	117	197	364
1.5	9.7	15.3	22.0	4.3	9.3	14.7	6.1	8.2	13.0	167	247	448
2.0	9.3	15.8	21.8	4.7	9.5	15.6	5.6	9.0	13.5	181	270	459
SE				0.2	0.3	0.4	0.2	0.3	0.3	7	13.62	14.3
CD (P = 0.05)	ns	ns	nd	0.6	0.9	1.2	0.6	0.9	0.8	21	39.90	41.43



Effects of average minimum temperature on root length, seedling height, seedling weight, and days of leaf emergence 10, 20, and 30 days after nursery sowing.

duced mitotic activity in the cells of the vegetative shoot apex on account of the low temperature (Shimizu 1958). Application of P at higher levels resulted in better growth of seedlings, but this could not compensate for the positive effects of early sowing.

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NEW PUBLICATION

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Suggested citation:

Joshi, R. C., Baucas, N.S., Joshi, E. E. and Verzola, E. E. 2003. Scientific Information Database on Golden Apple Snail (*Pomacea* spp.). CD-ROM. Baguio: Department of Agriculture-Regional Field Unit-Cordillera Administrative Region (DA-RFU-CAR) in collaboration with Department of Agriculture-Philippine Rice Research Institute (DA-PhilRice), Agricultural Librarians Association of the Philippines (ALAP), and the Department of Agriculture-Cordillera Highland Agricultural Resource Management Project (DA-CHARMP).

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An improved direct-rice seeder

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Transplanting, a highly labor-intensive and costly method, can be substituted by direct seeding, which could reduce labor needs by more than 20%. Rice is either dry-seeded on well-prepared, dry/moist soil or wet-seeded on puddled soil. Current direct-seeder models drill seeds continuously at a seed rate higher than recommended and without consideration of desired seed-to-seed spacing. As the seed drum is emptied, the seeding rate increases steadily and steeply at the end and uniformity in seeding rate is not maintained. Hence, an improved direct-rice seeder that uniformly distributes seeds will be more useful in maintaining a uniform plant population in the field.

A test rig was developed and the influence of the machine and operational parameters—drum shape, drum diameter, number of seed-metering holes, diameter of seed-metering holes, and forward speed of operation—on the seeding rate of the drum seeder were investigated under laboratory conditions. Optimum results were obtained with a hyperboloid drum 200 mm in diameter with nine seed-metering holes each 10 mm in diameter, and a forward speed of 1.0 kph.

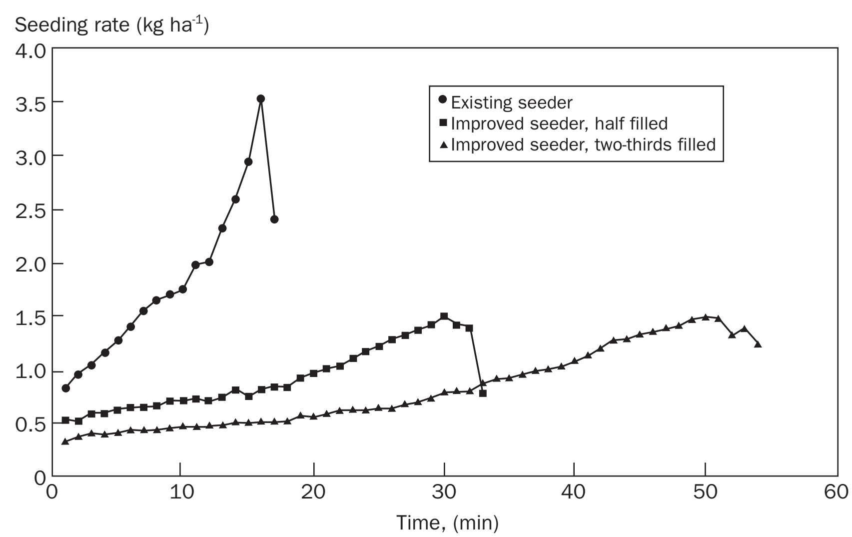
The percent variation in seed discharge of the prototype drum was reduced when the drum was filled to half of capacity. Baffles inside the seed drum reduced the variation, resulting in a more uniform seeding rate. The optimized drum was assembled to sow four, six, and eight rows of rice seeds and its field performance tested. It was found that the deviation from the recommended per-m^{-2} plant population using the prototype drum seeder was minimum, whereas the plant population was 2–4 times more with existing direct-rice seeders.

The prototype direct-rice seeders were tested with single and double ground wheels with and without furrow openers and using dry and soaked seeds. The direct-rice seeder wheel with double ground wheels reduced the slip percentage from 14.4 to 9.4, but it had difficulty turning. The use of soaked seeds using the improved seeder with furrow opener resulted in a higher yield of grain and straw.

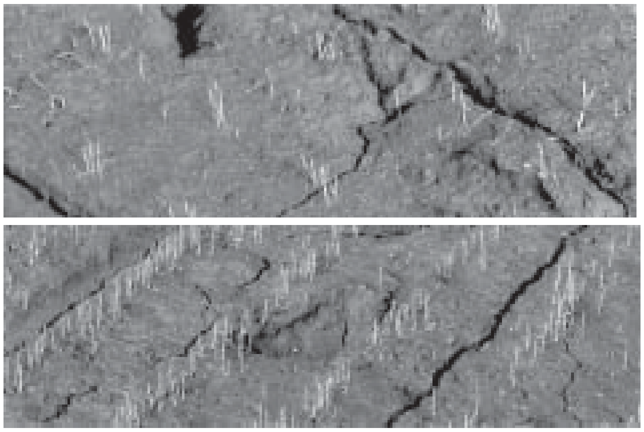
Field performance of the prototype direct-rice seeder and existing direct-rice seeder.[a]

Parameter	Improved direct-rice seeder	Existing direct-rice seeder
Plant population (no. m^{-2})	209	448
Tillers (no. m^{-2})	500 (50 DAS)[b]	659 (50 DAS)
	529 (75 DAS)	686 (75 DAS)
Productive tillers (no. m^{-2})	376	467
Grains $panicle^{-1}$ (no.)	126	96
Grain yield $panicle^{-1}$ (g)	205	1.99
Grain yield (t ha^{-1})	4.4	4.1
Straw yield (t ha^{-1})	6.0	4.9

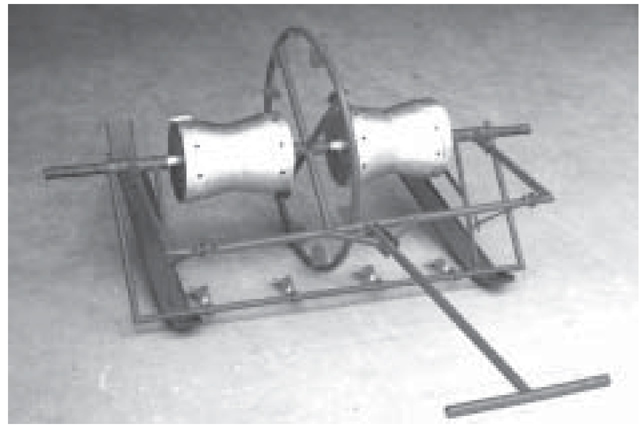
[a]Values indicate the maximum mean values of all treatments. [b]DAS = days after sowing.



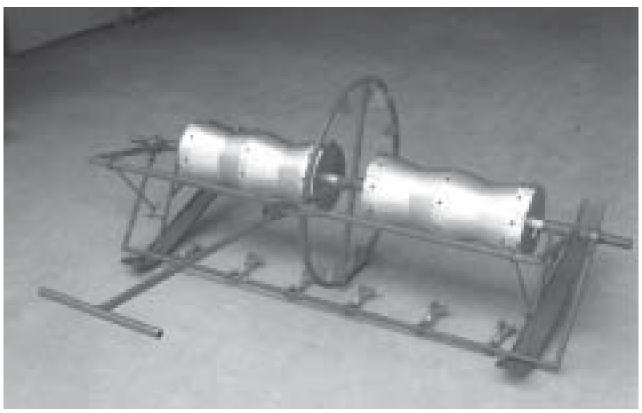
Comparison of seed discharge with respect to time between existing and improved direct-rice seeder.



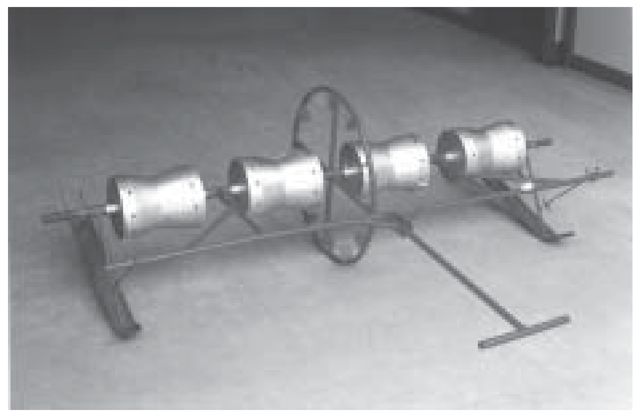
Crops sown with improved (top) and existing (bottom) direct-rice seeder.



Four-row improved direct-rice seeder.



Six-row improved direct-rice seeder.



Eight-row improved direct-rice seeder.

Yield performance under the rice *yaya* demonstration program in Sri Lanka: a case study

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Launched in 1997, the rice *yaya* (tract) demonstration program aimed to determine how farmers' rice yields could be further improved. The program involves extension activities to promote integrated crop management and the use of good-quality seeds and to provide credit and training facilities in selected locations across several districts in Sri Lanka. This study evaluated the impact of the rice yaya demonstration program on rice production. A field investigation was undertaken in one of the dry-zone rice-growing districts of southern Sri Lanka, Hambantota.

Field work was carried out in the irrigated areas of Hambantota District. Two farmer categories in the tract program, participants and nonparticipants (40 each), were interviewed at the end of the 2001 *yala* (dry) season (Apr-Aug). Current and past yield data were recorded. Table 1 shows the yield performance in the past seasons of both participants and nonparticipants.

During the past four seasons, the average yields obtained by program participants were higher than those of nonparticipants; the yield difference was more than 1.5 t ha^{-1}.

A comparison of the yield performance before and after the program indicated a shift to higher yield categories. In fact, the two upper yield categories (7.23 t ha^{-1} and above) were represented by 40% of the farmers after implementation of the program. Furthermore, none of the farmers had yields between 3.09 and 4.12 t ha^{-1}. Before the tract program, only 5% of the farmers were in the two highest yield categories, while 20% were in the lowest category. This implies that 40% of the program participants were in the two upper yield categories, in contrast to only 10% of the nonparticipants.

The study reveals that the extension program has made a positive impact on overall rice yield.

Table 1. Yield performance of selected farms in Hambantota District, 1998-2000.

Season[a]	Highest grain yield (participating farms)	Av yield (participating farms)	Av yield (nonparticipating farms)	Yield difference (t ha^{-1})
Yala (1998)	7.5	5.9	4.2	1.7
Maha (1998/99)	9.7	5.9	4.0	1.9
Yala (1999)	7.5	5.3	3.2	2.1
Maha (1999/2000)	7.9	5.9	3.2	2.7

[a]Yala = dry season from April to August. Maha = wet season from October to February.

Table 2. Yields obtained by participants and nonparticipants, 2001 yala.

Yield range (t ha^{-1})	% of participants		% of nonparticipants
	Before program	After program	
3.90–4.12	20	0	0
4.13–5.15	35	10	18
5.16–6.18	5	22	47
6.19–7.22	5	22	47
7.23–8.24	5	35	8
8.25–9.27	0	5	2

Agricultural extension and farmer needs for technology

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The accelerated Mahaweli Development Program is a major agricultural development effort for the dry zone of Sri Lanka. Through its agricultural extension component, innovations were introduced to rice farmers in the area. This study aimed to evaluate how effectively the agricultural extension system has introduced technologies to meet actual needs of farmers.

This study was carried out in Tambuttegame in the Mahaweli H Zone. One hundred rice farmers were included in the field investigation. A pretested questionnaire was used to gather data just after the 2001-02 maha season (Apr-May). A scoring procedure was applied to rank farmers' views on technology dissemination. Rank 1 is given seven points and rank 7 is given one point. Table 1 shows the various technologies as ranked by farmers in terms of importance. Sixty-three farmers had identified varietal recommendations as the most important technology disseminated. Sixteen farmers gave the same technology a ranking of 2. The total score for each technology is the sum of the products of the number of farmer-respondents in a rank class multiplied by the corresponding score point.

The technological innovations that have been disseminated were ranked by farmers thus: varieties (1), fertilizer (2), pest and disease control methods (3), irrigation methods (4), weed control methods (5), land preparation methods (6), and transplanting methods (7).

Similarly, farmer needs were also identified using the same ranking procedure. Table 2 shows the ranking of these needs.

The most important need identified by rice farmers is to gain knowledge on organic farming (Table 2). Market information, training, input supply, credit facilities, and business counseling, in that order, were also deemed important.

The study reveals that the technologies disseminated do not match the farmers' needs. It is crucial that extension efforts be reoriented to serve the current needs pointed out by farmers.

Table 1. Farmers' ranking of various technologies in terms of importance.

Technology	Rank[a]								
	1	2	3	4	5	6	7	Total[b] score	Final rank
Varietal recommendations	63	16	9	3	3	4	2	613	1
Fertilizer recommendations	8	44	16	11	13	4	4	495	2
Pest and disease control methods	7	9	26	32	13	7	6	420	3
Weed control methods	1	9	19	20	22	20	9	351	5
Land preparation methods	3	5	14	20	19	23	16	320	6
Irrigation methods	12	15	9	8	14	28	14	363	4
Transplanting methods	7	2	7	7	16	14	47	247	7

[a]Rank 1 is given seven points; rank 7 is given one point. [b]Sum of products of number of farmer-respondents multiplied by corresponding score point.

Table 2. Farmers' ranking of actual needs.

Need	Rank[a]							
	1	2	3	4	5	6	Total score[b]	Final rank
Loan/credit	7	8	5	14	42	24	252	5
Knowledge on organic farming	47	24	13	12	3	1	497	1
Market information	12	26	37	17	7	1	416	2
Training	9	28	32	21	8	2	403	3
Input supply	24	8	9	28	24	7	359	4
Business counseling	0	3	4	9	16	68	158	6

[a]Rank 1 is given six points; rank 6 is given one point. [b]Sum of products of number of farmer-respondents multiplied by corresponding score point.

Advance estimation of rice production in India using weather indices

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Estimation of crop production from area and yield estimates based on sample surveys and crop-cutting experiments, an approach currently being followed in India, can give final estimates only after the crops are actually harvested. However, various policy decisions related to pricing, marketing, export/import, distribution, etc., necessitate the use of advance estimates. A simple model based on weather indices can be used to obtain accurate estimates of annual rice production even before the crop is harvested.

Crop production in India largely depends on the summer monsoon (June to September), which provides about 80–90% of annual rainfall in most parts of the country. The summer monsoon rainfall is the main source of water for the kharif crop. Rainwater stored as soil moisture and other water resources (lakes, reservoirs, and rivers) are also important for the–*rabi*–and other irrigated crops. Parthasarathy et al (1988) have estimated the annual food-grain production in the country using the all-India summer monsoon rainfall data. The rainfall data, however, showed significant variations in time and space. To obtain more accurate production estimates, the temporal and spatial variations of monsoon rainfall were also included in the model through suitable weather indices.

Rice, the most important crop in India, is currently grown on 44.6 million ha, contributing about 42% of total food-grain production. The time series of annual rice production constitutes a prominently increasing trend, which is superimposed onto year-to-year fluctuations (Fig. 1a). The increasing trend—which is attributed to nonmeteorological factors such as increased gross sown area, improved technology, fertilizer application, pest and disease control, etc.—has been estimated by fitting an exponential equation (Mooley et al 1981, Parthasarathy et al 1988) of the following form into the historical annual rice production data for the period 1950-2000:

Trend = EXP (0.0272931 * YEAR) * 1.79309E-22 . . . . (1)
($R^2 = 0.96$)

As previously stated, the year-to-year fluctuations in rice production are mainly due to variations in monsoon rainfall and can be estimated from weather indices. To identify suitable weather indices, production indices (PI) of rice have been obtained (Fig. 1b) by eliminating the trend component (obtained from Eq. 1) from actual production in each year:

PI = (Production/trend)*100 . . (2)

To include intraseasonal and spatial variations of monsoon rainfall in the estimation model, monthly (June-September) rainfall indices (RI) have been constructed from the area-weighted rainfall of the subdivisions (See table), with which the annual rice PI has significant correlations—i.e., Σ Ri*Ai, where Ri is rainfall and Ai is area of the ith subdivision. Similarly, in considering year-to-year variations of monsoon rainfall, the southern oscillation index (SOI) has been included in the model. SOI—the index that measures the atmospheric pressure difference between Tahiti and Darwin—is known to have a significant relationship with interannual variability of the Indian summer monsoon. A multiple regression model has been developed to estimate the annual rice PI from the monthly RIs and SOI as follows:

PI = 58.293 + 0.0396*+ 0.088*+ 0.0381*+ 0.0253*+ 0.226*SOI . . . (3)
($R^2 = 0.70$)

This model explains nearly 70% of the variance in PI. Annual rice production is evaluated from the PI estimated above and the trend value (T) is estimated from equation 1: production = (PI*T)/100. The estimates of annual rice production, which can be obtained by October (well before the crops are harvested), are found to be in close agreement (within

Subdivisions considered for construction of monthly rainfall indices.

Month	Meteorological subdivisions[a]
June	Jharkhand, east Madhya Pradesh, Konkan and Goa, Madhya Maharashtra, Marathwada, Vidarbha, coastal Andhra Pradesh, and Telangana
July	East Uttar Pradesh, west Uttar Pradesh, Haryana, Punjab, east Madhya Pradesh, Rayalaseema, Tamil Nadu, north interior Karnataka, and south interior Karnataka
August	Jharkhand, Haryana, east Rajasthan, east Madhya Pradesh, Gujarat, Marathwada, Vidarbha, and Telangana
September	Sub-Himalayan West Bengal, Gangetic West Bengal, Orissa, west Uttar Pradesh, Haryana, east Rajasthan, west Madhya Pradesh, east Madhya Pradesh, Gujarat, Saurashtra & Kutch, coastal Andhra Pradesh, and coastal Karnataka

[a]For reference map, see Parthasarathy et al (1988).

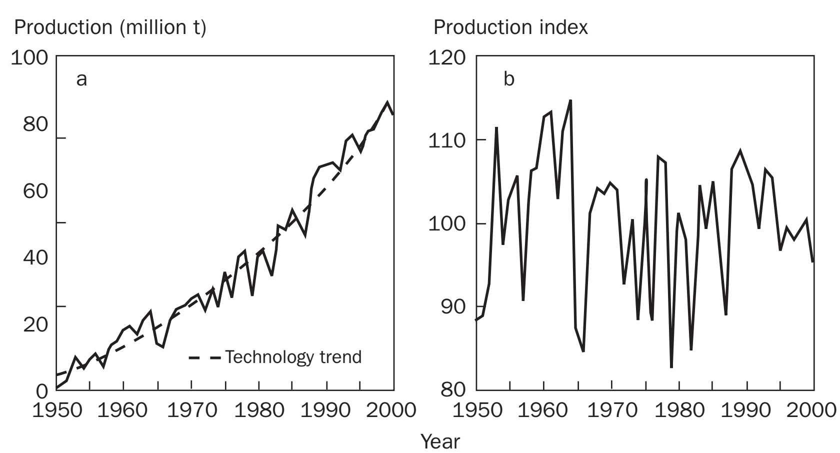

Fig. 1. All-India annual rice production (a) and production index (b), 1950-2000.

±5%, except in a few years) with actual values (Fig. 2). The all-India annual rice production for 2001-02 was predicted to be 93.1 million t (with a deviation of +2% from actual values) in October 2001, vis-à-vis the official final estimate of 91.6 million t available in June 2002, 8 mo in advance.

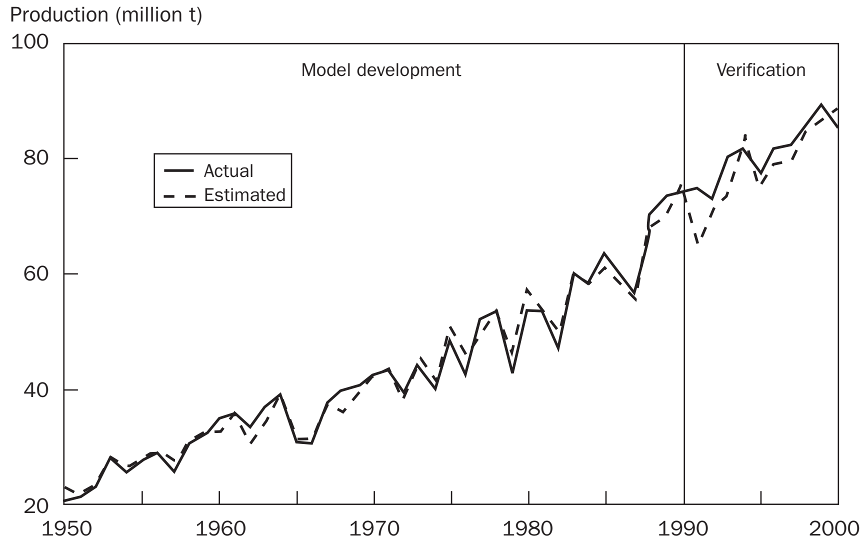

Fig. 2. Actual and estimated values of annual rice production in India during model development (1950-89) and verification (1990-2000) periods.

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Impact of soil reclamation on productivity, income, and employment of rice farmers: a case study of the Krishnagiri Reservoir Project area

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The area of salt-affected soils is increasing with time. In India, nearly 7 million ha are affected by the salt problem and, in Tamil Nadu state alone, this problem is acute on an area of 0.3 million ha (Parshad 1989). The salt problem alone accounts for a 20–80% reduction in yield. Efforts to reclaim and re-vegetate these soils require appropriate technologies. Improper diagnoses and the adoption of inappropriate technologies would result in a waste of time and scarce resources.

A case study was undertaken in the Krishnagiri Reservoir Project (KRP) area to find out the impact of soil reclamation on rice productivity, income, and employment of rice farmers. The data were collected in the KRP area in Dharmapuri District of Tamil Nadu, India. Agriculture is the major means of livelihood of the people. A variety of agricultural crops such as cereals, millet, and pulses and horticultural crops such as mango and tomato are grown in the dry farming areas of this tract. Among the food crops, rice occupies a pivotal place in the food and livelihood systems of the human and livestock population of this district. In Dharmapuri District, rice is grown on about 64,000 ha. Traditionally grown in two seasons, wet (July-November) and dry (December-March), by canal and well irrigation, respectively, rice has a productivity of 3.2 t ha^{-1} (Kannaiyan 2002). Nearly 12% of the total rice area has salinity-related problems. The KRP area, where rice alone could be cultivated, faces serious salt problems.

We obtained data on the cost of rice cultivation, cost of reclamation, and impact of reclamation on productivity, income, and employment of farmers in the KRP command area.

The farmers were grouped into three on the basis of the location of their farmholding along the canal area of the reservoir—

head, middle, or tail region. A sample consisting of 180 rice farmers was selected randomly in the command area. To find out the impact of soil reclamation, 60 farmers were selected from each region of the canal and they were again subdivided into two groups—adopters and nonadopters of soil reclamation technology.

Reclamation of salt-affected lands required considerable capital in the initial year of the operation. Investments were made in bunding and leveling of land, leaching the salts with irrigation water, applying gypsum and organic manure, and draining water from the salt-affected rice fields. On average, the capital requirement per hectare for adopters was Rs 3032. Average productivity and coefficients of variation (CVs) were determined for both adopters and nonadopters of the soil reclamation technology. The results are presented in Table 1.

The soil reclamation technology has influenced the productivity status of rice significantly (Table 1). Adopters had a higher rice yield than nonadopters. For adopters, the mean productivity achieved after reclamation was higher than that before reclamation. The CVs were much less in the case of adopters in the tail region because of low salt intensity. The head region was adversely affected by salinity as shown by the higher CV.

Besides increasing crop productivity and income, the salt reclamation process also created large employment opportunities. The study revealed that, on average, 1 ha of reclaimed area used 32.28 man-days of labor. After reclamation, the labor requirement increased because more people were needed for crop production and harvesting activities in the following years.

To find out the impact of salt reclamation on net income, rice productivity, and additional employment opportunities of adopters (before and after reclamation) and nonadopters, a comparative analysis of cultivation cost, net income realized, grain yield obtained, and total employment generated was made.

Table 2 showed that the reclamation technology widely influenced grain yield, net income, and labor use in the case of adopters. The increased cost of cultivation and the greater labor use after reclamation resulted in improved varieties and better plant management and protection practices. Poor crop yield, low income, and less labor use characterized the nonadopter group.

Variation within adopters and nonadopters existed because of the proximity and soil features of the head, middle, and tail re-

Table 1. Variations in yield and productivity status of rice grown by adopters and nonadopters under different locations in the Krishnagiri Reservoir Project area.

KRP region	Adopters				Nonadopters	
	Before reclamation		After reclamation			
	Productivity (kg ha^{-1})	CV (%)	Productivity (kg ha^{-1})	CV (%)	Productivity (kg ha^{-1})	CV (%)
Tail	2,750	29.9	4,202	22.1	2,109	32.2
Middle	2,530	30.8	3,800	26.9	1,972	35.9
Head	2,141	34.6	3,463	27.2	1,635	40.8

Table 2. Comparison of net income (in Rs ha^{-1}), rice productivity (t ha^{-1}), and labor use (man-days) between adopters and nonadopters of soil reclamation technology in the KRP area.

Canal region	Adopters								Nonadopters			
	Before reclamation				After reclamation							
	Cultivation cost[a] (Rs ha^{-1})	Grain yield (t ha^{-1})	Net income (Rs ha^{-1})	Labor use (man-days)	Cultivation cost (Rs ha^{-1})	Grain yield (t ha^{-1})	Net income (Rs ha^{-1})	Labor use (man-days)	Cultivation cost (Rs ha^{-1})	Grain yield (t ha^{-1})	Net income (Rs ha^{-1})	Labor use (mad-days)
Head	15,321	2.14	912	96.15	18,224	3.46	3,455	114.38	11,234	1.63	201	65.24
Middle	19,146	2.53	1,866	104.11	20,544	3.80	4,643	120.63	13,457	1.97	488	72.39
Tail	20,517	2.75	2,433	120.63	22,726	4.20	5,211	132.91	15,696	2.10	735	88.34

[a]US$1 = Rs 47.23.

gions of the reservoir area. The salt reclamation process indeed had a direct impact on rice productivity, net farm income, and employment generation. The indirect benefits were an increase in land value and conservation of the soil-crop environment.

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Exposure of Bangladeshi rice farmers to early flood risk

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Floodplain agriculture in Bangladesh is characterized by smallholders operating marginal parcels of land, with heavy reliance on the winter rice crop. When the annual floods, which normally begin in early or mid-June, arrive even a week or two early, they may submerge the standing rice crop prior to harvest, often causing considerable damage. Where overbank flooding from main river channels is the principal source of early flood risk, as in the case with flash floods in the northeast, structural means of flood control such as submersible embankments may be effectively employed. In north-central Bangladesh, however, much of the early flooding is from local rainfall impoundment, and therefore structural methods are less helpful. Using biophysical and socioeconomic data collected in north-central Bangladesh, we investigated (1) the extent and patterns of damage caused by 1- and 2-wk early floods and (2) what readily available (nonstructural) opportunities existed to reduce such risk.

A previous floodplain livelihood project (Barr 2000) in the Charan *beel* (floodplain water body) and floodplain area in Tangail District had collected a set of biophysical and socioeconomic data over the 1997-98 hydrological year. These included flood depth and spread measurements, plot-level cropping pattern, monthly crop growth stage, and socioeconomic information. These data were stored in a project geographic information system (GIS). The start of the flood in 1997-98 was perceived in the study area as normal. On that basis, we took these data as the baseline, simulated the arrival of 1- and 2-wk early flood events using GIS methods, computed damage estimates using simple water depth and yield damage parameters to answer question 1, and queried the plot-specific cropping pattern information to answer question 2 above.

Results revealed that, as expected, plot-level damage due to early floods was strongly dictated by elevation of the land. Following the standard definition of land elevation in Bangladesh, 45% of the very low (VL) plots were seen from the simulations to suffer some damage even from a 1-wk early flood. Significantly, when the damage does occur, it is likely to be substantial. Most of the affected VL plots are almost completely damaged by a 1-wk early flood. Two-week early flood damaged about half the VL plots. For the low (L) plots, 1-wk early floods damaged only 8% of the plots, while 2-wk early floods damaged about 40% of the plots. Higher land elevations were not seen to suffer any damage from these simulated flood events.

It is not surprising that VL plots suffer most from early flood events. But what factors explain the damage to some VL plots, while others remain undamaged? Analysis of plot-level cropping patterns provided an interesting clue in this regard. Every single undamaged VL plot was found to be devoted to a single crop of winter rice, whereas 90% of the damaged VL plots were found to include a mustard crop just prior to the winter rice. Mustard is a cash crop, and the farmers in the area use proceeds from its sale to finance expensive inputs for the high-yielding rice crop (HYV) immediately following. The necessity for some farmers to do this appears to be delaying the planting of rice, resulting in correspondingly later harvests and increased exposure to early floods. Another interesting pattern found in the data was that the damaged VL plots were mostly planted to the older generation of relatively long-duration HYVs such as IR8, while shorter duration varieties with comparable yield, such as BR26 and BR28, have been available for some time now.

In summary, our results show that even the slightly early flood events (1 to 2 wk) that occur with reasonable frequency in north-central Bangladesh are prone to cause significant damage to very low elevation winter rice plots. Yet, our evidence shows that this is not a problem requiring new investments in technology. Rather, credit provision for input financing and extension help with existent shorter duration varieties can go a long way in ameliorating this situation.

Reference

Barr JJF. 2000. Investigation of livelihood strategies and resource use patterns in floodplain production systems in Bangladesh. Project final technical report to Department for International Development-Natural Resource Systems Programme, UK.

Acknowledgments

This document is an output from a project funded by the UK Department for International Development (DFID) for the benefit of developing countries. The project was funded under DFID's Renewable Natural Resources Research Strategy (RNRRS) through the Natural Resource Systems Programme (NRSP).

Low-input management of swarming caterpillar outbreak in central India

M. Thomas, Krishi Vigyan Kendra, Shahdol 484001, India

Shahdol is predominantly a tribal district in the central Indian state of Madhya Pradesh. Tribals are indigenous forest-dependent communities. Constituting 46% of the district population, the tribe members have low income and low literacy rates.

Agriculture is one of the main sources of livelihood in Shahdol. The district receives a mean annual rainfall of 1,072 mm, usually, from July to September. The number of rainy days during the period may reach 48. Rainfall is erratic and its distribution uneven. The undulating terrain and sandy soil fail to retain the rainwater that flows rapidly, carrying with it the topsoil. The soil is predominantly sandy, though black soil is also found in small mosaic patterns in the district.

A majority of the farmers belong to the complex diverse risk-prone (CDR) group. Only 7% of the total cultivated area (343,900 ha) in the district is irrigated from various sources. Thus, the wet season is the main cultivation period and rice is the main crop, occupying 204,234 ha or 60% of the total cultivated area. Lowland rice occupies 40%; the rest is upland rice. The erratic rainfall, the poor moisture-holding capacity and fertility of the soil, as well as the socioeconomic conditions of the CDR farmers compel them to practice low-input rainfed rice farming. The resulting yields are usually poor (0.05 and 0.13 t ha^{-1}, respectively, from upland and lowland under normal conditions).

In July 1999, there was an outbreak of swarming caterpillar *Spodoptera mauritia* in the Kotma block, one of nine development blocks in Shahdol, where rice is cultivated on 15,346 ha. It occurred in two villages, Changari and Gohendra, covering an area of around 250 ha. During the survey, *S. mauritia* was found to cause severe damage to the rice crop, more in late-sown rice and in low-lying rice fields. Direct-sown rice, mostly in the upland, escaped the attack. However, crops raised by broadcasting of pregerminated seeds and through a nursery were not spared. The larval population density (LPD) was greater in the lowland than in the upland areas. The LPD varied from 10 to 12 m^{-2} in rice fields where pregerminated seeds were broadcast. Such fields were usually located in the lower portions of the uplands and from where the lowlands begin. In the lowland, the LPD was 1–2 per plant. In nursery beds, the LPD was 138–142 m^{-2}, with a population density of almost 7–9 per plant. The transplanted fields had a comparatively lower LPD (76–79 m^{-2}), with 3–5 per plant).

The *S. mauritia* larvae were found devouring rice foliage even during daylight hours. In the bunds of low-lying fields, larvae were found in clusters, one over the other. In the beginning, farmers thought that stray cattle caused the damage when they grazed at night. But there were no hoof marks. A closer look revealed larvae in large numbers devouring the rice plants. A few farmers tried resowing but results were discouraging.

Because farmers in the area cannot afford pesticides, they tried to pour kerosene into the stagnant water in the bunded fields (2 L of kerosene or burned engine oil per half hectare). With the use of a long rope stretched across the bunds, two persons walked through the field, shaking the plants rigorously. The larvae that fell into the water with kerosene died. Methyl parathion (2% dust applied at 25 kg ha^{-1}) along the bunds of the field killed the pest, preventing migration to other rice fields. The technique was widely adopted because it proved to be a cheap and effective method for managing the *S. mauritia* epidemic within a short time.

. . . .

Knowledge, attitudes, and practices on rat management of Ifugao rice farmers, Philippines

B.M. Catudan, R.C. Joshi, E.B. Gergon, N.V. Desamero, L.S. Sebastian, Philippine Rice Research Institute (PhilRice), Maligaya, Muñoz Science City, 3119 Nueva Ecija: J.C. Cabigat, Local Government Unit (LGU), Banaue, Ifugao; and A. Cayong, LGU, Hungduan, Ifugao, Philippines

In the Ifugao rice terraces (IRT), farmers consistently rank rats as their most important biotic constraint to rice crop production (Joshi et al 2000). However, these farmers' sociodemographic characteristics and existing knowledge, attitudes, and practices on rat management are undocumented. Hence, prior to introducing the community-trap barrier system (C-TBS) in two Ifugao municipalities, Banaue and Hungduan, PhilRice and the towns' local government units (LGUs) initiated a baseline survey in November 2002.

Thirty randomly selected respondents from the master lists of farmers in each of the two towns were surveyed using a structured questionnaire. Data were analyzed descriptively using frequencies, percentages, averages, and ranges. Multivariate and correlation analyses were also used to identify indicators associated with rat management.

The farmers' average ages were 49 and 45 for Banaue and Hungduan, respectively. The majority were married and had an average of 24 years of rice farming experience.

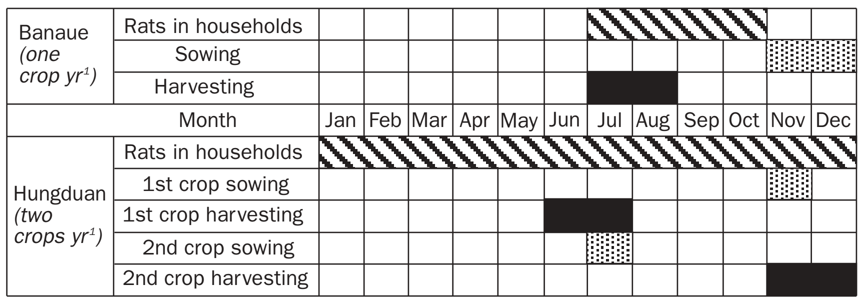
All respondents regarded rat damage as their first or second most serious problem in rice production (Table 1), and they had the least control over it compared with other production problems. They claimed that rats are destructive year-round and that all of their neighboring farmers also complained of rat damage. All respondents in Banaue and 43% in Hungduan had no idea about what gives rise to the seasonal abundance of rats in their fields (see figure). In Banaue, rats move from fields to farmers' households during harvest and stay on until rice is sown again. In Hungduan, rats are found in households year-round.

Rice yield losses from rat damage reached 50% in Banaue and 38% for the first crop and 75% for the second crop in Hungduan (Table 2). Rat management strategies employed by farmers were sanitation and rodenticide baiting, but these did not reduce rat damage because the frequency and timing of interventions coincided with peaks in the rat population. Sanitation of terrace walls was done 1 mo after of sowing in both Banaue and Hungduan. On the other hand, 53% (Banaue) and 47% (Hungduan) of the farmers applied rodenticides about 2 mo before harvest. Both interventions were done individually by farmers.

Table 1. Farmers' ranking of various rice pest problems in Banaue and Hungduan, Ifugao rice terraces, Philippines.

Location/pest	Rank 1		Rank 2		Rank 3		Rank 4		Rank 5		Total, by response	
	n[a]	%	n	%	n	%	n	%	n	%	N	%
Banaue												
Rodents	19	63	10	33							29	97
Insect pests			4	13	10	33	1	3			15	50
Blast/other diseases									1	3	1	3
Snails	10	33	14	47	4	13					28	93
Weeds					1	3					1	3
Total, by rank, Banaue	29		28		15		1		1		74	
Hungduan												
Rodents	26	87	4	13							30	100
Insect pests			5	17	15	50	2	7	1	3	23	77
Blast/other diseases	4	13	20	67	4	13					28	93
Snails					2	7	1	3			3	10
Weeds					4	13	8	27	4	13	16	53
Total, by rank, Hungduan	30		29		25		11		5		100	

[a]n = number of farmers.



Seasonal dynamics of rats in relation to sowing and harvesting of rice.

Table 2. Crop loss due to rats, Banaue and Hungduan, Ifugao rice terraces, Philippines.

Item	Banaue				Hungduan			
	n[a]	Mean ± SE	Min	Max	n	Mean ± SE	Min	Max
Damaged tillers								
1st cropping	27	10 ± 12.2	2	50	29	22 ± 10.9	2	60
2nd cropping					14	37 ± 26.7	16	95
Yield loss								
1st cropping	29	18 ± 12.3	2	50	30	9 ± 6.8	1	38
2nd cropping					8	30 ± 22.5	14	75

[a]n = number of farmers.

Most Banaue farmers who used rodenticides were from 41 to 60 years old; their Hungduan counterparts were 21 to 40 years old. More educated farmers and those who had alternative sources of income were more likely to use rodenticides. Unlike in the lowlands, IRT farmers did not eat field rats.

Most LGU technicians advised farmers to apply rodenticides after planting, while only a few advised farmers to clean the areas surrounding their fields.

We are currently identifying the rat species present in the IRT and studying their ecology and management in the IRT, in partnership with scientists from the Community Ecology Group of the Commonwealth Scientific and Industrial Research Organisation (CSIRO), Australia.

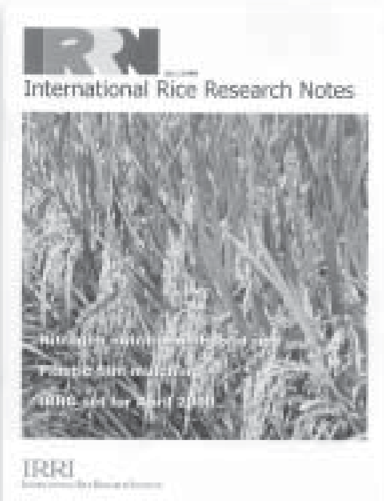
Reference

Joshi RC, Matchoc ORO, Bahatan RG, Dela Peña FA. 2000. Farmers' knowledge, attitudes and practices of rice crop and pest management at Ifugao Rice Terraces, Philippines. Int. J. Pest Manage. 46(1):43-48.

2004 IRRI group training courses (tentative listing)

Course	Duration (wk)	Target date	Coordinator(s)/ course facilitator
*English for Conversation	2	9-20 Feb	A Arboleda/D Gavino
Rice Breeding (with IRIS component)	3	9-27 Feb	G Atlin/E Castro
ARBN Genomics Workshop	1	23-26 Feb	H Leong/A Arboleda
Developing Integrated Nutrient Management Options for Delivery	2	1-12 Mar	R Buresh/D Gavino
Rice Production I	2	15-26 Mar	V Bala/E Castro
Basic Experimental Designs and Data Analysis Using IRRISTAT for Windows	1	19-23 Apr	G McLaren/ V Bartolome/S Magadia
Scientific Writing and Presentation	2	May	D Shires/A Arboleda
Introduction to the SAS System	1	21-25 Jun	G McLaren/V Bartolome/ S Magadia
*Intensive English 1	12	Jul-Sep	A Arboleda/D Gavino
Genetic Engineering, Food Safety & Awareness	1	Sep	S Datta/D Gavino
Rice Production II	2	6-17 Sep	V Bala/E Castro
Water Management	1	Oct	B Bouman
Leadership Course for Asian Women in Ag R & D	2	Oct-Nov	T Paris/G Zarsadias
*Intensive English 2	3	Nov	A Arboleda/D Gavino
Analysis of Unbalanced Data	1	15-19 Nov	G McLaren/V Bartolome/ S Magadia
Grain Quality Management	1	TBA	J Rickman/D Gavino
Intellectual Property Rights	1	TBA	TBA
IN-COUNTRY COURSES			
ORYZA2000, China	1	Apr	B Bouman
Rice Technology Transfer Systems in Asia (RDA)	2	27 Sep-8 Oct	J Lapitan/G Zarsadias
Grain Quality Management, Cambodia	1	TBA	J Rickman
Grain Quality Management, Bangladesh	1	TBA	J Rickman
Water Management, Myanmar	1	TBA	J Rickman
Tractor Training, India	1	TBA	J Rickman
Integrated Pest Management, Malaysia	2	TBA	KL Heong
Integrated Pest Management, Vietnam	2	TBA	KL Heong
Integrated Pest Management, Thailand	2	TBA	KL Heong
Integrated Pest Management, Iran	2	TBA	KL Heong

TBA = to be arranged. * = after 5 pm classes only. For details, email IRRI-Training@cgiar.org.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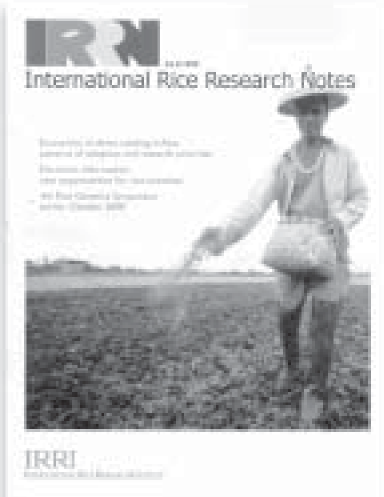
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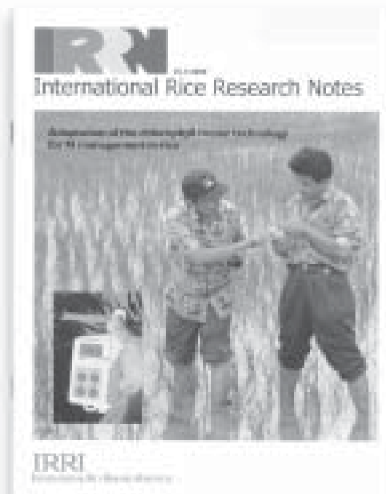
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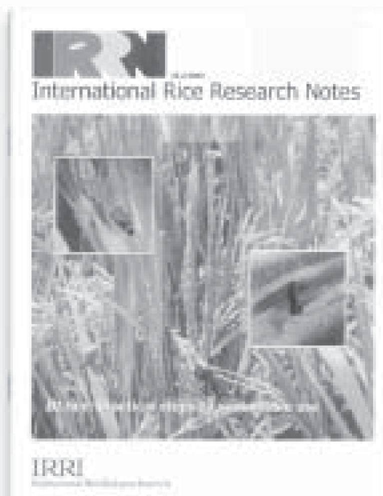
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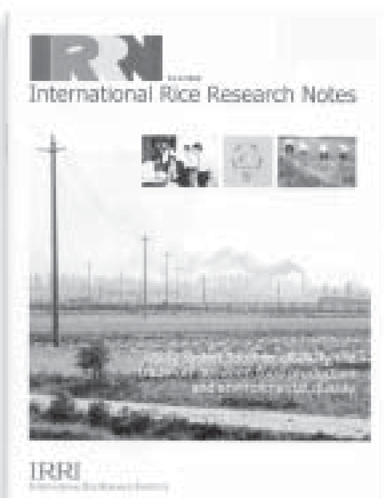
International Rice Research Notes
IRRI

IRRN welcomes three types of submitted manuscripts: research notes, mini reviews, and "notes from the field." All manuscripts must have international or pan-national relevance to rice science or production, be written in English, and be an original work of the author(s), and must not have been previously published elsewhere.

Research notes

Research notes submitted to IRRN should

- report on work conducted during the immediate past 3 yr or work in progress
- advance rice knowledge
- use appropriate research design and data collection methodology
- report pertinent, adequate data
- apply appropriate statistical analysis, and
- reach supportable conclusions.

Routine research. Reports of screening trials of varieties, fertilizer, cropping methods, and other routine observations using standard methodologies to establish local recommendations are not ordinarily accepted.

Preliminary research findings. To reach well-supported conclusions, field trials should be repeated across more than one season, in multiple seasons, or in more than one location as appropriate. Preliminary research findings from a single season or location may be accepted for publication in IRRN if the findings are of exceptional interest.

Preliminary data published in IRRN may later be published as part of a more extensive study in another peer-reviewed publication, if the original IRRN article is cited. However, a note submitted to IRRN should not consist solely of data that have been extracted from a larger publication that has already been or will soon be published elsewhere.

Multiple submissions. Normally, only one report for a single experiment will be accepted. Two or more items about the same work submitted at the same time will be returned for merging. Submitting at different times multiple notes from the same experiment is highly inappropriate. Detection will result in the rejection of all submissions on that research.

Manuscript preparation. Arrange the note as a brief statement of research objectives, a short description of project design, and a succinct discussion of results. Relate results to the objectives. Do not include abstracts. Up to five references may be cited. Restrain acknowledgments. Limit each note to no more than two pages of double-spaced typewritten text (approximately 500 words).

Each note may include up to two tables and/or figures (graphs, illustrations, or photos). Refer to all tables and figures in the text. Group tables and figures at the end of the note, each on a separate page. Tables and figures must have clear titles that adequately explain contents.

Apply these rules, as appropriate, to all research notes:

Methodology

- Include an internationally known check or control treatment in all experiments.
- Report grain yield at 14% moisture content.
- Quantify survey data, such as infection percentage, degree of severity, and sampling base.
- When evaluating susceptibility, resistance, and tolerance, report the actual quantification of damage due to stress, which was used to assess level or incidence. Specify the measurements used.
- Provide the genetic background for new varieties or breeding lines.
- Specify the rice production systems as irrigated, rainfed lowland, upland, and flood-prone (deepwater and tidal wetlands).
- Indicate the type of rice culture (transplanted, wet seeded, dry seeded).

Terminology

- If local terms for seasons are used, define them by characteristic weather (dry season, wet season, monsoon) and by months.
- Use standard, internationally recognized terms to describe rice plant parts, growth stages, and management practices. Do not use local names.
- Provide scientific names for diseases, insects, weeds, and crop plants. Do not use local names alone.
- Do not use local monetary units. Express all economic data in terms of the US$, and include the exchange rate used.
- Use generic names, not trade names, for all chemicals.
- Use the International System of Units for all measurements. For example, express yield data in metric tons per hectare (t ha^{-1}) for field studies. Do not use local units of measure.
- When using acronyms or abbreviations, write the name in full on first mention, followed by the acronym or abbreviation in parentheses. Use the abbreviation thereafter.
- Define any nonstandard abbreviation or symbol used in tables or figures in a footnote, caption, or legend.

Mini reviews

Mini reviews should address topics of current interest to a broad selection of rice researchers, and highlight new developments that are shaping current work in the field. Authors should contact the appropriate editorial board member before submitting a mini review to verify that the subject is appropriate and that no similar reviews are already in preparation. (A list of the editors and their areas of responsibility appears on the inside front cover of each IRRN issue.) Because only 1-2 mini reviews can be published per issue, IRRN will require high quality standards for manuscripts accepted for publication. The reviews should be 2000-3000 words long, including references. Refer to the guidelines for research notes for other aspects of writing and content.

Notes from the field

Notes from the field should address important new observations or trends in rice-growing areas, such as pest outbreaks or new pest introductions, or the adoption or spread of new crop management practices. These observations, while not the result of experiments, must be carefully described and documented. Notes should be approximately 250 words in length. Refer to the guidelines for research notes for other aspects of writing and content.

Review of manuscripts

The IRRN managing editor will send an acknowledgment card or an email message when a note is received. An IRRI scientist, selected by the editorial board, reviews each note. Depending on the reviewer's report, a note will be accepted for publication, rejected, or returned to the author(s) for revision.

Submission of manuscripts

Submit the original manuscript and a duplicate, each with a clear copy of all tables and figures, to IRRN. Retain a copy of the note and of all tables and figures.

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International Year of Rice

Last year, the United Nations General Assembly declared 2004 as the International Year of Rice. The International Year of Rice aims to "promote the ecological, social, and cultural diversity of rice-based production systems as a prism through which key global concerns can be addressed, such as poverty and hunger alleviation, undernourishment, food safety, environmental protection, and other important issues."

The Food and Agriculture Organization (FAO) of the UN will facilitate the implementation of activities related to the celebration through a network of stakeholders that include donors, a global working group, regional working groups, national working groups, and community working groups including farmers' groups, nongovernment organizations, and the private sector.

The initiative for the celebration was spearheaded by a Philippine-led resolution cosponsored by 43 member countries to promote awareness on sustainable development of this staple food for more than half of the world's population. Through increased awareness of the rice system, food and agricultural policy and technical, economic, social, and development goals will be better focused by all stakeholders involved in the sustainability of food systems.

The International Year of Rice logo—Rice is life—aptly captures the essence of this important staple food. The official launching of the event will be held on October 31 in New York.

As a member of the International Year of Rice Committee, IRRI is already initiating several projects that involve all rice sectors in the celebration, starting with the *IRRN* Best Article Awards and the publication of *Graindell*, a children's storybook.

IRRN Best Article Awards

What better way to celebrate the International Year of Rice (IYR) than to honor the people who work in rice research. Rice researchers work quietly in the fields and laboratories, conducting studies that they hope will make a difference in the lives of millions of rice producers and rice consumers all over the world. In its 28-year existence, the *International Rice Research Notes* (*IRRN*) has been an active partner in bringing the fruits of their labor to the scientific community. To commemorate 2004 as IYR, the Best Article Award is being established to recognize the contributions of rice researchers from national agricultural research and extension systems (NARES) in developing countries toward the advancement of rice-related knowledge and technology.

Beginning in August 2003, papers submitted for publication in the *IRRN* will be evaluated on the basis of scientific content, originality, relevance, and organization. There will be up to six winning papers from the six sections of *IRRN*—plant breeding (includes papers on molecular biology and biotechnology); genetic resources; pest science and management; soil, nutrient, and water management; crop management and physiology; and socioeconomics. The winners will be chosen by the *IRRN* Editorial Board and invited reviewers. The winning entries will be announced in the October 2004 issue of *Rice Today* and will be published in the December 2004 issue of *IRRN*.

The competition is open to all NARES rice researchers. The Award will be given to the first author of each paper. Additional authors may come from any organization. Research for all categories must have been conducted in a developing country. Each winner will receive a $500 cash prize.

The deadline for submission is 31 July 2004.

For details, contact the
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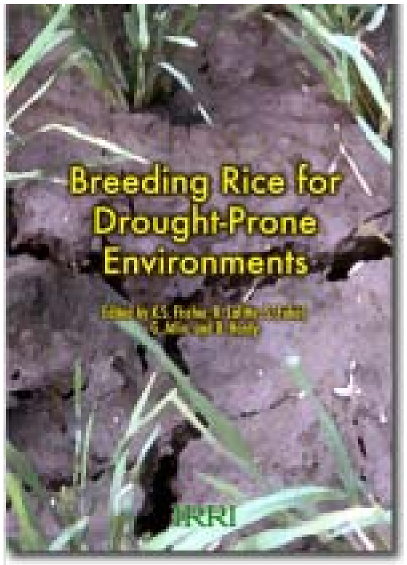


Breeding Rice for Drought-Prone Environments

K.S. Fischer, R. Lafitte, S. Fukai, G. Atlin, and B. Hardy

Many of the world's poorest farmers work in rainfed areas where water supplies are unpredictable and droughts are common. In Asia, about half of all the rice land is rainfed. While rice yields in irrigated systems have doubled and tripled over the past 30 years, only modest gains have occurred in rainfed rice because of the complexity of improving rice varieties for changeable environments and the small investment made so far in breeding rice for drought tolerance.

Drought tolerance must be integrated with mainstream breeding programs addressing agronomic adaptation, grain quality, and pest and disease resistance. This manual, prepared in collaboration with the University of Queensland, and fully funded by the Rockefeller Foundation, amplifies and updates the section on drought tolerance in the IRRI book *Rainfed Lowland Rice Improvement* (Mackill et al 1996).

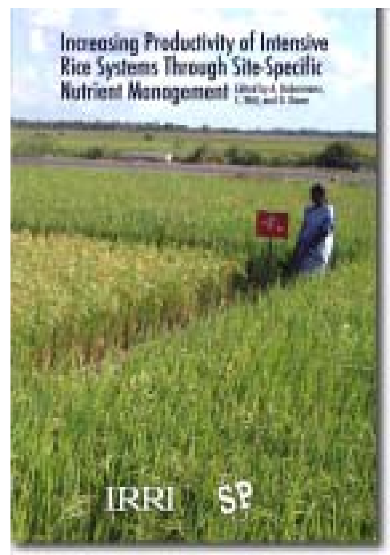
To order online, go to IRRI's publication catalog at
http://www.irri.org/publications/catalog/index.asp

Increasing Productivity of Intensive Rice Systems through Site-Specific Nutrient Management

A. Dobermann, C. Witt, and D. Dawe (co-published with Science Publishers Inc. (SPI))

Yield gains have slowed in recent years, particularly among early adopters of Green Revolution technologies. Although scientists are developing new germplasm to raise existing yield ceilings, future yield increases are likely to be smaller than in the past and will require more knowledge-intensive forms of soil and crop management that improve input efficiency and, at the same time, protect the environment. The integrated and efficient use of nutrients is one of the key issues for sustainable resource management in intensive rice systems.

After reviewing the economics of rice production and productivity trends in Asia, most of the book presents the principles of site-specific nutrient management SNM and the results of the first phase of field-testing at numerous sites in Asia. This book demonstrates how long-term commitment to interdisciplinary on-farm research forges promising generic solutions for resource management. As new tools such as a nutrient decision support system and a *Practical Guide for Nutrient Management* (Fairhurst and Witt 2002) have been developed, the theoretical development of new nutrient management concepts continues.



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