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Using SysNet tools to quantify the trade-off between food production and environmental quality

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The *International Rice Research Notes* (IRRN) expedites communication among scientists concerned with the development of improved technology for rice and rice-based systems. The IRRN is a mechanism to help scientists keep each other informed of current rice research findings. The concise scientific notes are meant to encourage rice scientists to communicate with one another to obtain details on the research reported. The IRRN is published three times a year in April, August, and December by the International Rice Research Institute.

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About the cover Tools have been developed by the Systems Research Network for Ecoregional Land-Use Planning in Tropical Asia (SysNet) to explore different development options for the agricultural sector and help formulate decision support systems for integrated resource management.

Cover photos: Christian Witt, Reimund Roetter

MINI REVIEW

Using SysNet tools to quantify the trade-off between food production and environmental quality

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Rapid population growth, coupled with economic expansion, is increasing the demands on land not only for agriculture but also for housing, infrastructure, recreation, and industry. Many of the agricultural regions in South and Southeast Asia characterized by intensive rice- or rice-wheat-based agroecosystems provide striking examples of conflicts in agricultural land-use objectives. The need for crop diversification to increase labor productivity and farmers' income and prevent migration to rapidly expanding megacities often directly conflicts with the necessary increase in staple food production and maintenance or improvement of the quality of the natural resource base (soil, water, air). Identification and implementation of production systems and technologies that make optimum use of external inputs and natural resources and avoid natural resource degradation, and policy measures supporting their adoption for sustainable agricultural development, would be the keys to resolving such conflicts.

In this context, one of the research challenges is how to develop effective tools for land-use planning and resource analysis that can make the issues transparent in the search for feasible solutions.

In late 1996, the Systems Research Network for Ecoregional Land-Use Planning in Tropical Asia (SysNet) was launched as a methodology development project in support of the IRRI-coordinated Ecoregional Initiative for the Humid and Subhumid Tropics of Asia [EcoR(I)]. The project was expected to contribute to the design, exploration, and evaluation of land-use options at higher integration levels. Specifically, its objectives were to develop methodologies and tools for exploratory land-use analysis and to evaluate these for generating options for policy and technical changes. To realize these objectives, SysNet set up case studies at a subnational scale at four sites: Haryana State in India, the Kedah-Perlis Region in Malaysia, Ilocos Norte Province in the Philippines, and Can Tho Province in Vietnam. The study regions differ considerably in biophysical and socioeconomic conditions (Table 1) and represent a cross-section of intensively cultivated agricultural areas in tropical Asia (Roetter et al 1998).

SysNet operates on the premise that planners and policymakers need systems analysis methodologies and tools, since the complexity of the problems is such that it is no longer sufficient to evaluate land-use options at the field and farm levels.

In this review, some major results from the 1997-2000 project period are illustrated by summarizing the development of tools for the integration of data and information to optimize land use under multiple objectives. Moreover, the results of the most recent scenario analyses for two case study regions are presented.

Developing the tools for resolving conflicts

To demonstrate how and to what extent agroecosystems could meet current and future development objectives of rural societies, a systems approach to agricultural land-use planning has been applied. It aims at identifying conflicts in land-use objectives, exploring feasible options, and improving decisions on land and resource use at the subnational scale (Van Keulen et al 2000).

To this end, SysNet has developed and operationalized a common modeling framework, including comprehensive databases and modeling components (tools), tailored to the specific situation of the individual (four) case study areas. The tools include database management systems, crop models to estimate yields, expert systems, geographic information systems (GIS) for quantitative description of production activities and for land evaluation and assessment of resources, and linear programming models for regional optimization of land use under multiple objectives. These components plus the databases on biophysical and socioeconomic conditions and policy views were integrated to form the land-use planning and analysis system (LUPAS, Fig. 1) (Hoanh et al 1998). LUPAS is based on the interactive multiple-goal linear programming (IMGLP) technique (De Wit et al 1988), in which agricultural systems are characterized through

- databases on biophysical and socioeconomic resources and development targets,
- an input-output model for all promising production activities and technologies,
- a multiple-criteria decision method (MGLP model), and
- sets of goal variables (representing specific objectives and constraints).

In consultations with local stakeholders, agricultural development objectives and constraints related to production, income, employment, and environmental impact were identified and translated into scenarios combining multiple objectives; one objective was optimized while minimum requirements were set for others. In successive iterations, goal restrictions were tightened to quantify trade-offs between conflicting goals. The choice and degree of tightening of goal restrictions reflect the specific

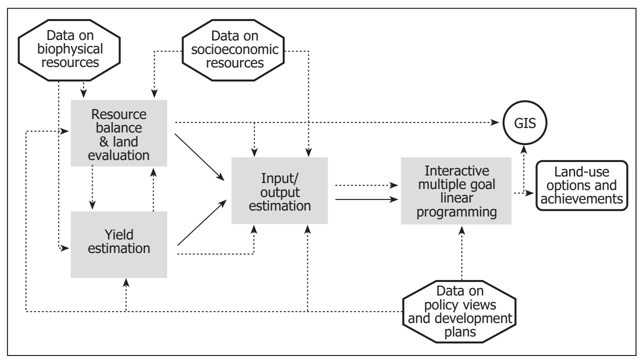

Fig. 1. Structure of the LUPAS modeling framework.

Table 1. Main characteristics of the four case study sites.

Characteristic	Haryana, India	Kedah-Perlis, Malaysia	Ilocos Norte, Philippines	Can Tho, Vietnam
Study area				
Total area (million ha)	4.42	1.01	0.34	0.30
Agricultural land area (million ha)	3.72	0.53	0.13	0.25
Population (million persons)	16.5	1.6	0.5	1.9
Agricultural labor (million persons)	2.8	0.3	0.2	0.9
MGLP model[a]				
Agroecological units	87	19	37	18
Administrative units	16	11	23	7
Land units	257	87	200	32
Land use types	14	18	23	19
Products	11	15	17	18
Crops	10	16	21	28
Technology levels	5	3	3	2
Objectives[b]	14	12	9	10

[a]As of 30 Sep 2000. [b]In MGLP (multiple-goal linear programming) models, an objective is expressed by a goal variable (e.g., rice production) and the associated optimization (e.g., maximize); objectives are translated into linear equations (or objective functions).

priorities for sustainable land use (Roetter et al 2000a). In LUPAS, technically feasible solutions generated by "hard systems" are confronted with the "value- or preference-driven" objectives and targets and acceptance of technical solutions as expressed by different interest groups. To reach a consensus on feasible options, scenario analyses need to be conducted interactively with different stakeholders. To facilitate this negotiation and learning process, SysNet developed the MGLP user interface (Laborte et al 2000; Web site: http://irriwww.irri.cgiar.org/IRRIIntra/sysnet/mglp/SysnetMGLP.htm).

This interface has been realized for two case studies and allows users to relate biophysical and technical opportunities of agricultural systems to societal objectives and priorities. The process or sequence of steps followed in SysNet for integrating data, information, and models into a common decision support system (DSS) and its applications for land-use scenario analysis in the four study regions have been described in detail by Roetter et al (2000a,b). The following examples illustrate the type of information that can be generated.

Results and discussion

Case study 1: Ilocos Norte Province

Agriculture in Ilocos Norte basically consists of rice-based production systems. Rice is cultivated in the wet season between June and October and diversified cropping is practiced during the dry season. Tobacco, garlic, onion, maize, sweet pepper, and tomato, all supported by groundwater irrigation, are cultivated intensively in lowlands. Rice is the most common crop. In 1993, the province had a surplus of 100,000 t above the demand of 113,000 t. A well-developed marketing system has facilitated the establishment of intensive rice-cash crop production systems (Lucas et al 1999). Table 1 summarizes the main characteristics of the study region and the MGLP model.

Public awareness on current and possible future negative environmental effects resulting from further intensification of agricultural systems was only created recently through research on groundwater pollution by the Rainfed Lowland Rice Research Consortium (RLRRC), coordinated by IRRI. In SysNet meetings with local stakeholders since 1997, an assessment of trade-offs among rice production, farmers' income, and, to a lesser extent, environmental objectives has been identified as the major issue to be addressed in exploratory land-use analysis for the province.

Three major production technologies were considered: (1) average farmers' practice, (2) best farmers' yield/high input, and (3) improved practice. Data for the input-output tables were derived from farm surveys in the province (consisting of 1,967 farms in the wet season and 2,523 farms in the dry season; Francisco 1999, unpubl.). The values for the input-output relations for the average farmers' practice were derived from the average values for these farms.

For the best farmers' yield/high input, data were derived by taking the mean of the yield values between the 90th and 95th percentile and associated input use of the survey data. Fertilizer and pesticide use was 100% higher, labor 70%; other inputs were the same as in the average farmers' practice. This was based on survey data indicating that one group of farmers approaching the best farmers' yield achieved this by almost doubling fertilizer and pesticide inputs, while labor input increased less.

For the improved practice, the same inputs as in the average farmers' practice were used, but fertilizer-use efficiency was improved. Average applications of N, P, and K decreased by 20% for nonrice crops. For rice, N application decreased by 40%, P application decreased by 15%, and K application increased by 20%. This was partly based on survey data suggesting that another group of farmers achieved the best farmers' yield with about the same input as in the average farmers' practice. We further assumed that, by better balancing nutrient supply with crop demand, the efficiency of fertilizer (macronutrients N, P, K) can be further improved as demonstrated elsewhere by efficiency increases in rice.

Results from regional analysis of trade-off between income generation and resource use are illustrated in Figures 2a-c, which show standardized values of farmers' income and use of agricultural land, fertilizer, water, pesticides, and labor for three different production technologies (scenarios). "Standardized" means that the highest values for income and resource use generated in the various income maximization runs were set at 100. Results show, for instance, that if all farmers in the province would apply technology 2 (Fig. 2b), this would considerably raise their income compared with technology 1 (Fig. 2a). Although water consumption would decrease by 28%, this would require 21% more fertilizer, 41% more pesticides, and 5% more labor. However, if all farmers would apply new, more resource-use-efficient practices (technology 3), the same income could be achieved with approximately 30% less fertilizer and pesticides (Fig. 2c).

Rice production under all scenarios would clearly remain above current production levels. That means that site-specific (and more balanced) nutrient and pest management practices can lead to considerably more income at reduced environmental cost while satisfying local demand for various crops in the province: a clear win-win situation. Some costs are involved, however, in terms of increasing farmers' knowledge and skills to achieve fertilizer efficiency gains represented by the improved practice. Investments in dissemination activities and appropriate policy interventions that would provide incentives to farmers to adopt new (nutrient) management practices are needed.

Case study 2: Haryana State

In 1965, food-grain imports in India reached 10 million t. But, in the last three decades, a quantum leap in production resulted in hardly any significant import of food grains. Now, the country is again at a crossroad, facing tremendous new challenges since food supply grows at a much slower pace than demand. Although the population continues to grow rapidly, farm-level productivity has

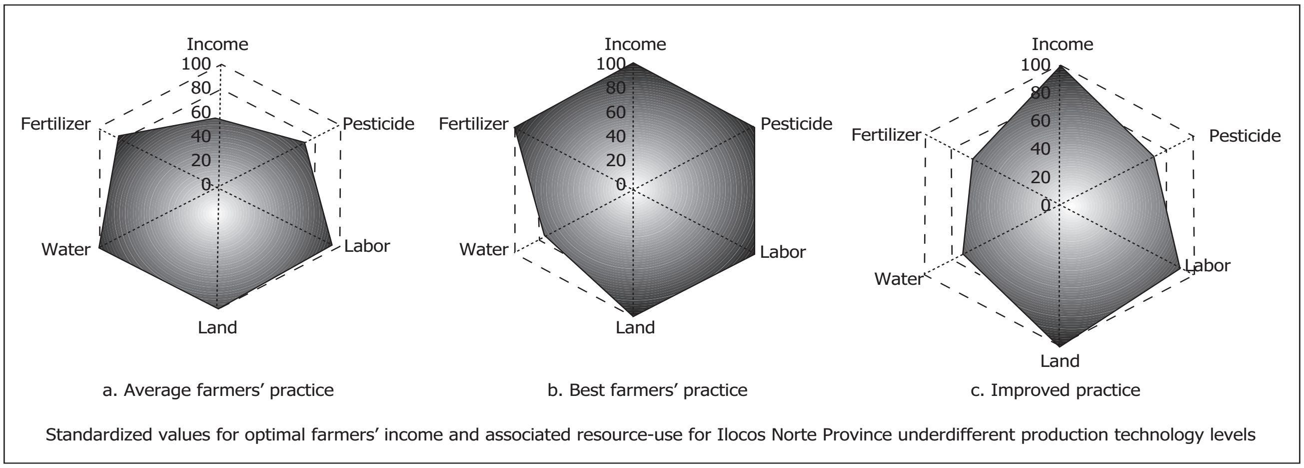

Fig. 2. Trade-off between farmers' income and resource use in Ilocos Norte Province.

stagnated, especially in intensively cultivated irrigated areas. A typical example is Haryana State in northern India, which has contributed tremendously to the success of the Green Revolution. Rice and wheat, commonly grown in a double-cropping rotation, are the major food crops of the region. During the last 35 years, the area planted to high-yielding crop varieties increased from 0.9 to 2.7 million ha and cereal production rose from 2.6 to 10.5 million t. During a 1999 stakeholder-scientist workshop at Haryana, various scenarios were formulated and analyzed. Stakeholders gave priority to the following objectives:

- Doubling of food production for Haryana (tentative goal based on a recent policy statement),
- Maximizing agricultural production while setting limits on labor migration (in the future, the supply of labor from outside Haryana may become more restricted),
- Minimizing nitrogen loss,
- Minimizing pesticide residues,
- Improving water management/intervention measures to reduce groundwater depletion,
- Maximizing income from agriculture.

A scenario giving priority to maximizing food production (Aggarwal et al 2000) showed that Haryana has a capability of producing 39.1 million t of food (rice and wheat) if there are no constraints other than available land (Table 2). This also assumed that all farmers are capable of adopting the best technologies. In this scenario, the water required was more than three times what was currently available. The scenario also indicated that this situation would need more than twice the capital currently used. Milk production, employment generation, and overall income were also considerably higher than present levels.

Since constraints to technology adoption are likely to remain for some time, this aspect was introduced as a goal restriction in the next optimization round. Results showed that, in such a case, food production dropped to 28 million t. Resource requirements were nevertheless still very high. When the water constraint was restricted to its current level of availability, results changed drastically. Food production decreased to 11.4 million t only. At the same time, income, milk production, and employment became much lower. The introduction of capital and labor as additional constraints had a relatively small effect on food production. Irrespective of scenario, the biocide index was always within permissible limits (<200), although it increased when water was imposed as an additional constraint (Table 2). In contrast, nitrogen loss was very high when land and technology were the only constraints.

General discussion

LUPAS fulfills all criteria for a decision support system for strategic land-use planning with emphasis on the agricultural sector (Walker and Zhu 2000). The recently developed user interface allows varying input-output coefficients and resource availability in combination with different assumptions on technology level, economic conditions, and policy. It also facilitates the learning processes of stakeholders on complex system behavior and establishes interaction among stakeholders. Recent data from field experiments, crop growth simulation, and farm surveys indicate a tremendous scope for improving resource-use efficiencies in intensive rice (or wheat)-based systems in South and Southeast Asia. In the regional models for Ilocos Norte and Haryana, this knowledge was translated into alternative (improved) technologies to explore future land-use options under different sets of constraints. Results from both case studies showed that it is technically feasible to maintain or increase food production with less fertilizer, pesticides, and labor. For Ilocos Norte, substantial food production and income increases would be possible, even when labor and water (under average climatic conditions) and other constraints were considered. Experience shows, however, that the scope for realizing possible resource-use efficiency gains (and associated income and production increases) at the provincial level was limited by weather-related risks. About 40% of the agricultural area depends on rainfall, and, in low-rainfall years, culti-

Table 2. Extreme values of the optimized food (rice + wheat) production (bold) in Haryana and the associated values of other variables. The values in each column are the results of separate optimizations with progressive inclusion of the constraints. In each case, the production of other crops was not allowed to be lower than the current level (Aggarwal et al 2000).

Objective variable	Unit	Constraint				
		Land	Land + technology	Land + technology + water	Land + technology + water + capital	Land + technology + water + capital + labor
Food	10^6 t	**39.1**	**28.0**	**11.4**	**11.4**	**11.1**
Milk	10^6 t	6.8	5.5	5.4	4.5	4.6
Income	10^9 rupees	109.9	77.8	54.3	56.3	54.9
Irrigation	10^9 m^3	56.4	51.2	16.3	16.2	15.5
N fertilizer	10^6 t	1.51	1.25	0.64	0.64	0.61
Employment	10^9 labor days	666	674	364	361	347
Capital	10^9 rupees	114.2	92.1	54.1	53.7	52.0
N loss	10^6 t	0.061	0.063	0.040	0.039	0.037
Biocide index	–	95	97	132	129	125

vated area and input use were reduced considerably. For Haryana, water was even a more critical resource constraint, counteracting all investments in improved knowledge- and/or capital-intensive crop management practices. In both cases, policy interventions must aim at improving water availability and use efficiency. Moreover, it needs to be stressed that sociocultural constraints to the adoption of technically promising land-use options not captured by the models have to be studied at the farm level to ensure the application of appropriate policy measures.

Conclusions and outlook

Between 1997 and 2000, SysNet developed a methodology and the tools to explore different development options for the agricultural sector, taking into account the different socioeconomic and biophysical conditions, as well as societal aspirations. The quantitative approach applied in SysNet's LUPAS clarifies the nature of different objectives and identifies optimal trade-offs among these through regional models. These are the most important lessons learned from developing LUPAS:

1. There is a need for new land-use planning methodologies and applications in Asia.
2. It is of utmost importance to involve stakeholders from the beginning in the design of the decision support system, to identify direct end users, and to have frequent interaction between research teams and local stakeholders/direct end users during the development of the decision support system.
3. Once a prototype decision support system is developed, it can serve as a vehicle to exchange information and knowledge and stimulate discussion among different stakeholder groups on land-use and related policy issues.
4. LUPAS builds systems research capacity and fosters interdisciplinarity within research institutions.
5. Initiation of a fruitful process of interactive design of future land-use options and policies requires the confidence of stakeholders in well-tested methodologies and tools.

The future incorporation of methods and tools for multidecision-level (farm, municipality, region) analysis (Zander and Kächele 1999) in LUPAS will result in a powerful and versatile decision support system for integrated resource management and policy design.

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Web notes

www.PlanetRice.net

There is a new e-mail service for rice research. Called PlanetRice.net, this service features The Research Report, which is sent free by subscription. You can sign up to have rice news delivered to you by e-mail. To subscribe to The Research Report from PlanetRice, and other information-packed newsletters, go to http://207.254.121.65//newsletter/newsubscriber.cfm. The site is available at http://www.planetrice.net/images/Research_header.gif or http://www.planetrice.net/images/zenecasponsor.gif

PlanetRice contains numerous links to companies, news stories, and special events related to rice. The site recently carried stories about flooding in Bangladesh, India's role in the rice genome project, Japanese aid to North Korea, the development of high-yielding fragrant jasmine rice in Thailand, and a discovery in Australia of the gene that controls plant flowering, among others. One could easily spend hours looking around this site, and a visit is highly recommended.

The Research Report has three main features: Hot Topics, Spotlight on ... , and Technical Advances.

To keep updated on rice research, PlanetRice recommends a visit to the following sites:

- Rice Genome Research Program (RGP) at http://rgp.dna.affrc.go.jp/rgp/rgpintro.html or http://rgp.dna.affrc.go.jp/GenomeSeq.html.
- TIGR Rice Gene Index (OsGI) at http://www.tigr.org/tdb/ogi/GenInfo.html
- Collaboration (individuals and research centers) on RGP at http://rgp.dna.affrc.go.jp/Seqcollab.html
- American Phytopathological Society at http://www.scisoc.org/
- Rice processing research, Center for Food Processing and Engineering,University of Arkansas, at http://www.riceprog.baeg.engr.uark.edu/
- Food science, Institute of Food Technologists at http://www.ift.org
- Economic research, Regional Coordination Centre for Research and Development of Coarse Grains, Pulses, Roots and Tuber Crops in the Humid Tropics of Asia and the Pacific, Bogor, Indonesia, at http://www.cgprt.org.sg

www.parc.gov.pk

The Pakistan Agricultural Research Council (PARC) recently launched its Web site. The site has facts about PARC, its functions, research activities, establishment, training facilities available, research linkages, and commercial technologies developed by PARC. Links to this user-friendly site have been provided from other well-known Web sites such those of as ISNAR and FAO.

The site has four important databases: (1) Pakistan Agriculture Database, (2) NARC Library Database, (3) National Agricultural Research Information System of Pakistan (NARISP), and (4) Union Database of Journals. In addition, it features an agro-forum, an online discussion group on agriculture, and other related sites.

Sources: PlanetRice; Pakistan Agricultural Research Council

Variability of rice koji for enzyme activities using *Basidiomycetes*

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Current mushroom research has concentrated more on nutritional and medicinal aspects. Mushrooms belong to a class of fungi called *Basidiomycetes*, which are a source of important enzymes used in making food and medicine. A liquid culture of mycelium and carpophore is commonly used to extract and refine these enzymes. This method, however, is time- and labor-consuming and costly.

Cereals can also be used as a solid substrate to culture *Basidiomycetes*. Rice *koji*, a product made from rice, can be used as a culture medium to produce *Aspergillus oryzae*, a source of enzymes such as alpha-, beta-, and glucoamylase and protease. β-amylase is used to make yoghurt, vinegar, and alcohol, whereas protease can be used to produce soy sauce and other food ingredients.

We studied the possibility of using rice koji media for mushroom culture and examined the variability of enzyme activities on these media. The experiment, replicated six times, was carried out at the Laboratory of Rice Processing, NHAES, in 1998.

We used rice koji from five cultivars with different quality characteristics (Dongjinbyeo, Hyangnambyeo, Yangjobyeo, Heugnambyeo, and Sinseonchalbyeo) and four *Basidiomycetes* (*Pleurotus ostreatus*, *Lentineus edodes*, *Hericium erinaceus*, and *Ganoderma lucidum*). The degree of mycelial growth of the *Basidiomycetes* on rice koji was scored visually 20 d after culture, and enzyme activities of protease and β-amylase were measured by standard procedures. Statistical analysis was done using Duncan's multiple range test (DMRT).

Results showed that mycelial growth was better in *P. ostreatus* and *G. lucidum* than in the other two *Basidiomycetes*. Among the rice koji cultivars, poor mycelial growth was observed in Sinseonchalbyeo, whereas active growth was noted in the others (Table 1). This is because Sinseonchalbyeo is a waxy (glutinous) variety. Adding water makes its granules sticky, thus retarding mycelial growth of *Basidiomycetes*.

Among the *Basidiomycetes*, the highest β-amylase activity was observed in *G. lucidum* (450–538 units, Table 2), whereas the highest protease activity was seen in *P. ostreatus* (17.9–33.1). Among the cultivars tested as culture media, Heugnambyeo had the highest β-amylase and protease activities. These results indicate that rice *koji* of Heugnambyeo with *G. lucidum* and *P. ostreatus* can be used as a good source of β-amylase and protease, respectively. It can also be used as a substitute for liquid culture in extracting enzymes for food. Because Heugnambyeo has high micronutrients, correlation between micronutrients and enzymes could be further examined.

Table 1. Mycelial growth of *Basidiomycetes* on rice koji media, Korea, 1998.[a]

Variety	*Pleurotus ostreatus*	*Lentineus edodes*	*Hericium erinaceus*	*Ganoderma lucidum*
Dongjinbyeo	+++	++	++	+++
Hyangnambyeo	+++	++	++	+++
Yangjobyeo	+++	++	++	+++
Heugnambyeo	+++	++	++	+++
Sinseonchalbyeo	+++	+	++	+++

[a]+ = bad, +++ = good.

Table 2. β-amylase and protease activities[a] **in rice koji using *Basidiomycetes*, Korea, 1998.**

Variety	β-amylase (units)				Protease (units)			
	Pleurotus ostreatus	*Lentineus edodes*	*Hericium erinaceus*	*Ganoderma lucidum*	*Pleurotus ostreatus*	*Lentineus edodes*	*Hericium erinaceus*	*Ganoderma lucidum*
Dongjinbyeo	137.3 e	393.2 c	87.7 c	466.0 d	17.9 c	11.3 a	15.9 c	11.2 c
Hyangnambyeo	208.6 b	401.0 b	111.8 b	523.3 b	19.9 c	9.9 b	16.3 c	16.6 a
Yangjobyeo	155.7 d	309.2 d	68.5 d	450.3 e	21.9 c	7.8 c	22.1 b	16.6 a
Heugnambyeo	170.7 c	518.3 a	64.1 d	538.2 a	33.1 a	7.8 c	25.8 a	12.1 b
Sinseonchalbyeo	259.0 a	402.5 b	117.3 a	497.8 c	27.9 b	11.4 a	22.3 b	11.5 c

[a]Means followed by a common letter are not significantly different at the 5% level by DMRT.

Developing *eui*-cytoplasmic male sterile lines and applying them in hybrid rice breeding

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In hybrid rice development, a serious problem associated with cytoplasmic male sterile (CMS) lines is poor panicle exsertion, which reduces outcrossing rate and hybrid seed production. Gibberellic acid (GA_3) has been routinely used to solve this problem. Other problems arise from application of GA_3, however, including increased costs, reduced seed quality, and possible environmental hazards. Rugter and Carnahan (1981) reported a recessive mutant that can cause elongation of the uppermost internode, referred to as the *eui-1* gene. Since *eui* can play the same role as GA_3 when transferred into CMS lines, this finding has attracted much interest in the development of CMS lines. We generated *eui* mutants through irradiation on both maintainer (B) and restorer (R) lines and transferred *eui-1* into CMS lines in China to improve hybrid rice seed production efficiency (Yang 1998). We report here the discovery of a new *eui* gene, referred to as *eui-2*(t), and the development of several B and R lines with the *eui* gene (designated as eA and eR), as well as the development of several hybrids with *eui* CMS lines.

Table 1 shows the characteristics of four commercially released eA lines compared with their corresponding non-*eui* isogenic A lines. Results indicated that both *eui-1* and *eui-2* significantly affected several height-related traits (plant height, panicle length, and panicle neck exsertion) without affecting pollen sterility. In general, *eui-1* had a greater effect on these traits than *eui-2*. The expression of both genes appeared to be affected by genetic backgrounds. For example, *eui-1* had more spikelets panicle^{-1} and higher exposed stigma percentage when transferred into a II-32 genetic background than in XA or G46.

Table 2 shows the yield performance and yield-related traits of the seven hybrids developed from the *eui*-CMS lines compared with counterparts from their corresponding non-*eui* CMS lines from a complete randomized block design in the early season of 1999. In the XA background, *eui*-hybrids were ~10 cm taller than the non-*eui* hybrids; no difference was detected for the other traits. Thus, *eui-1* appeared to be completely dominant. In GA and II-32 genetic backgrounds, however, *eui* hybrids were only 4 cm taller than non-*eui* hybrids, and both were basically identical for all traits, except that the *eui* hybrid had significantly higher yield than the non-*eui* hybrid in the II-32 back-

Table 1. Comparison of seven agronomic traits between eA lines and their corresponding A lines.

CMS line	Plant height (cm)	Panicle length (cm)	Panicle neck exsertion (cm)	Spikelet panicle^{-1} (no.)	Spikelet length (cm)	Stigma exsertion (%)	Pollen abortive rate (%)
XeA[a]	91.53 a	23.25 a	1.62 a	107.8 a	0.94 a	–	–
XeA[b]	79.09 b	21.93 a	–4.55 b	126.1 a	0.95 a	29.5 a	94.1 a
XA (ck)	69.05 c	18.70 b	–7.10 c	106.8 a	0.90 a	25.6 a	91.0 a
II-32eA[a]	111.20 a	28.50 a	3.70 a	271.0 a	0.79 a	74.1 a	91.7 a
II-32A(ck)	86.00 b	25.30 b	–11.20 b	218.0 b	0.76 b	57.5 b	90.8 a
G46eA[a]	108.60 a	23.00 a	–9.73 a	241.2 a	0.74 a	24.5 a	99.5 a
G46A(ck)	91.05 b	22.65 a	–14.54 b	245.7 a	0.72 b	23.3 a	99.9 a

[a]eA lines with (*eui-1 eui-1*) gene type, [b]Lines with (*eui-2 eui-2*) gene type. Different letters indicate significant difference between eA and A lines at the 5% level.

Table 2. Comparison of yield and agronomic traits between some characters *eui* hybrids and non-*eui* hybrids.

Hybrid	Growth duration (d)	Plant height (cm)	Panicle length (cm)	Total grain number	Seed set rate (%)	Effective panicles (no.)	1,000-grain weight (g)	Yield (g m^{-2})
XA/R-127	123	101.0 b	25.8 a	106.9 a	89.9	9.1	31.8	561.7 a
XeA/eR-127[a]	120	109.4 a	26.3 a	105.5 a	93.8	9.3	32.3	626.1 a
XeA[b]/eR-127[a]	119	110.5 a	26.1 a	100.7 a	92.8	9.6	32.9	593.9 a
GA/R-127	125	117.1 b	27.9 a	141.6 a	91.1	9.3	29.4	533.4 a
GA/eR-127[a]	123	121.8 a	28.0 a	145.0 a	92.7	9.2	29.5	544.7 a
II-32A/R-127	126	104.8 b	26.2 a	144.6 a	85.7	8.1	27.6	440.6 b
II-32eA[a]/R-127	124	108.3 a	27.4 a	145.4 a	85.7	8.1	28.6	531.7 a

[a]eA lines with (*eui-1 eui-1*) gene type. [b]Lines with (*eui-2 eui-2*) gene type. Different letters indicate significant difference between eA and A lines at the 5% level.

ground. This yield advantage was observed in many other *eui* hybrids (data not shown). Of these *eui*-hybrids, G46A/eR-127 is being tested in the Fujian provincial multilocation yield trials.

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Prediction of hybrid performance in rice: comparisons among best linear unbiased prediction (BLUP) procedure, midparent value, and molecular marker distance

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Since its success in China in the 1970s, hybrid rice technology has spread to other tropical countries such as India, Vietnam, Bangladesh, and the Philippines. Compared with inbred cultivars, the development of hybrid rice is more costly because it entails identification of parental lines that produce hybrids with superior yield. To reduce the number of crosses and the time consumed in field evaluation, an efficient prediction method for hybrid performance would be useful.

Midparent value (MPV), which is the average of both parents of a hybrid, is a classical method of predicting hybrid performance. This method, however, proved to be less efficient in predicting for traits with low heritability. Genetic distances derived from molecular markers were reported to have a certain significant correlation with hybrid yield performance, but this method is expensive. Notably, the best linear unbiased prediction (BLUP) procedure has been successfully applied to predict single-cross performance of maize and soybean (Bernardo 1994, Panter and Allen 1995).

The BLUP method, which combines field testing of related hybrids and acquiring pedigree information or molecular data, holds great promise in hybrid performance prediction (Charcosset et al 1998). This study compared the efficiency of the BLUP procedure, MPV, and marker distance derived from microsatellite DNA assays in predicting F_1 hybrid performance in rice.

Rice lines used in this study were 66 F_1 hybrids derived from 10 cytoplasmic male sterile-wild abortive (CMS-WA) lines and 23 promising restorer lines. Field experiments were conducted at the UPLB farm in the 1998 dry season. Data were collected for 100-grain weight, single-plant yield, and panicle weight. DNA was extracted and purified following a modified CTAB procedure. The polymerase chain reaction (PCR) protocol and silver staining procedures were those used in the genetic laboratory of PhilRice. Thirty-seven primer pairs were used in the assay.

The MPV of a cross was defined as the mean of two parental lines. The pedigrees of parental lines of hybrid rice were traced back to ancestors that had no known pedigree information. Coefficient of parentage was estimated using the recursive method. The Nei and Li coefficient was used as a measure of genetic similarity.

The mixed linear model was assumed as $Y = X\beta + Za + Zd + e$, where Y is a vector of the observed hybrid yield, X and Z are known matrices, a is a vector of additive genetic effect, d is a vector of dominant genetic effects, and e is the vector of residual effects.

Correlation analyses were performed for MPV and the Nei and Li coefficient vs observed values. A set of 43 hybrids was used for generating additive, dominant, and residual variances, following the nest design (North Carolina design I) using SAS PROC GLM. BLUP-predicted values for the remaining 23 hybrids were obtained using a software developed by the senior author.

Results suggested a large dominant variance for plant yield. The highest heritability was noted for 100-grain weight, while single-plant yield and panicle weight had low to intermediate heritability (see table). With the BLUP procedure, predicted grain yield plant^{-1} and panicle weight were significantly correlated with observed values of F_1 hybrids. A highly significant linear relationship was found only between MPV and observations for 100-grain weight. There was no linear relationship between Nei-Li distance and any traits of F_1 hybrids (Figs. 1–3). Thus, the BLUP may be superior to MPV in predicting F_1 hybrid performance for low to intermediate heritable traits. The level of correlation can be improved if more accurate pedigree records and genetic variance estimates are acquired.

The BLUP procedure to be used in hybrid rice breeding programs has the following advantages:

- Only data of actual performance from related hybrids were required; field testing of parental lines was thus avoided.

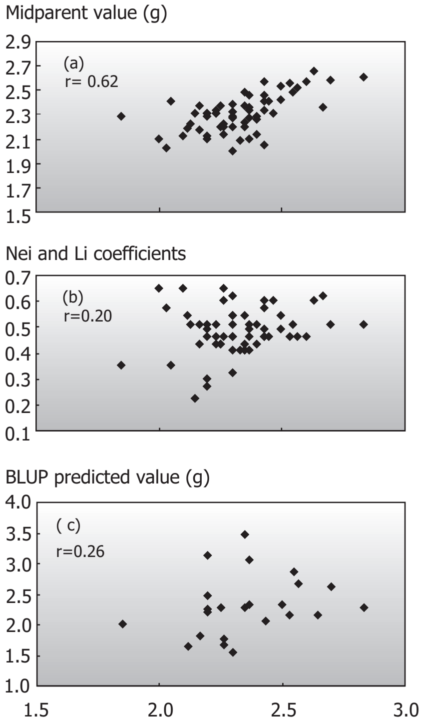

Fig. 1. Correlation between values predicted by BLUP and observed values for plant yield, plant height, and total plant weight.

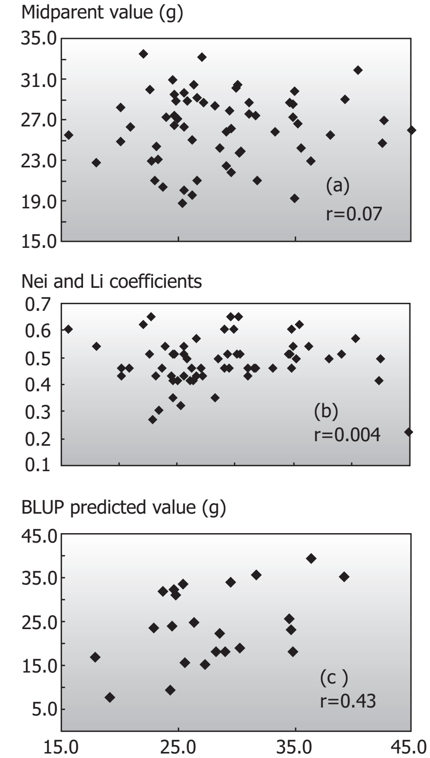

Fig. 2. Correlation between observed values and MPV for plant yield, plant height, and total plant weight.

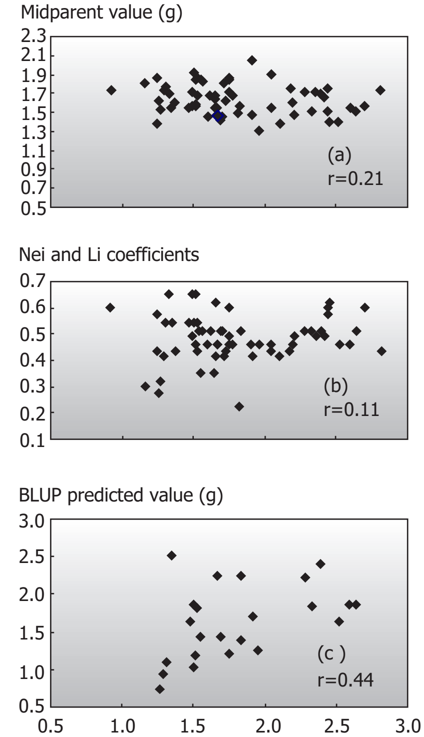

Fig. 3. Correlation between observed values and Nei-Li genetic distance for plant yield, plant height, and total plant weight.

Genetic variance and heritability for 100-grain weight, grain yield plant^{-1}, and panicle weight.

	100-grain weight	Grain yield plant^{-1}	Panicle weight
Additive variance	0.088	31.8	0.287
Dominant variance	0.008	63.7	0.153
Residual variance	0.013	0.6	0.067
Heritability (narrow)	80.9%	33.1%	56.6%

- Covariances among hybrids were estimated using the coefficient of coancestry and variances of general and specific combining ability, thus making pedigree records useful.
- Without special experiments, the BLUP procedure may provide increasing accuracy as more and more related hybrids are tested in applied breeding programs.

A computer program called "BLUP predictor," developed by the authors for this particular study, will soon be available for further testing in rice with a large number of hybrid combinations.

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Asian Agriculture Congress
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Blast analysis of the terminal sequences of cloned markers from the genetic map of rice

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Functional genomics seeks to assign a biological function to the sequences of genes and intergenic regions. This assignment may be accomplished by forward genetics, reverse genetics, or a variety of ancillary approaches. Experience shows that a large minority (25–42%) of anonymous gene sequences from a plant such as rice have sufficient sequence similarity to already characterized genes from rice or other organisms so that a reasonable inference can be made as to the class of protein encoded by the gene (Yamamoto and Sasaki 1997, Harushima et al 1998). While this sort of analysis usually falls short of establishing biological function, it can provide important clues, especially when combined with the location of the gene on a genetic or physical map of rice (Harushima et al 1998).

For this reason, we attempted to provide sequence data for 350 of the markers of the genetic map established principally by workers from Cornell University (McCouch et al 1988). These data supplement the large database assembled from sequenced markers of the genetic map developed by the Rice Genome Research Project at Tsukuba (Harushima et al 1998).

Terminal sequencing was conducted principally on both RZ clones (cDNA clones derived from RNA of etiolated leaves of IR36) and RG clones (genomic clones derived from IR36 DNA). Some barley (BCD) and oat (CDO) cDNA clones were also sequenced. The names and map locations of these clones are presented in Robeniol et al (1996), which also describes the manual sequencing procedure. Both ends of each clone were sequenced to allow polymerase chain reaction-based amplification of longer DNA segments than is possible with data derived from the single-pass sequencing conducted by Harushima et al (1998). The nucleotide sequences and the deduced amino acid sequences of each terminus were then compared with the Genebank databases using programs of the Basic Local Alignment Search Tool (BLAST) (Altschul et al 1990). The table shows hits with the BLAST-N program accessed through the Entrez Web site at www.ncbi.nlm.nih.gov.

A total of 76 clones, representing all 12 rice chromosomes, recorded hits on known sequences. The termini of each clone were designated as F or R, depending on whether they were sequenced using the universal forward (F) or reverse (R) sequencing primer. As all inserts had been ligated into the vectors in random orientation, there was no relationship between the F and R ends and the direction of transcription of the gene. Most of the hits (71%) were among the RZ clones, consistent with those clones from the cDNA library. Relatively few hits (24%) were found among the RG clones, which were random *Pst*I genomic clones. The remainder (5%) were BCD and CDO cDNA clones. In 20% of the 76 clones registering hits, both termini hit on known genes and, in all of these cases, the same class of protein was revealed, even if the name was different, as in the case of RZ244. For this clone, the F terminus hit ferric leghemoglobin reductase and the R terminus hit lipoamide dehydrogenase, but these proteins have the same function and in soybean nodules are probably the same proteins. For the remaining 80% of the clones, only the F or R terminus hit a known gene. The usual reason for the lack of homology at the other terminus was that the terminus corresponded to a poorly conserved region of the gene such as the 3'-untranslated region.

Most of the hits were to rice and other plant genes and were unequivocal, including 19 hits on genes known only from dicotyledonous plants. Three hits were to nonplant genes (maize dwarf mottle virus coat protein, *Caenorhabditis* dolichol monophosphate mannose synthase, human isovaleryl CoA dehydrogenase). Further sequencing would be required to confirm these particular hits. The hits included several cases in which more than one member of a gene family was revealed. Alpha-tubulin was found on chromosomes 1 and 3, ferredoxin III on chromosomes 2 and 3, and cytosolic glyceraldehyde 3-phosphate dehydrogenase (GAPDH) on chromosomes 4 (twice) and 8. Translational elongation factors were found on chromosomes 2, 3, and 12. As further genes of known function are isolated and deposited in public databases, the number of hits registered by the 350 clone markers listed by Robeniol et al (1996) is expected to increase from the 76 recorded here. In addition, the current hits will be examined more closely to determine their patterns of expression and their biological function in terms of specific traits.

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Rice, oat, and barley DNA sequences with significant homology to known genes.

Chr	Locus	Putative identification	Score	Organism
1	RZ566 F	Metallothionine	231	Rice
	RZ566 R	Metallothionine	565	Rice
1	RZ836 F	α-tubulin (RIP3)	194	Rice
	RZ836 R	α-tubulin (RIP3)	468	Rice
1	RZ588 R	β-ketoacyl-ACP synthase	748	Castor bean
1	RZ730 R	Ubiquitin conjugate enzyme	372	Maize
1	RZ744 R	B2 protein	236	Carrot
1	RG345 F	Peptidase of D1 protein	155	Barley
1	RZ382 R	Coat protein of dwarf mottle virus	160	Maize DM virus
1	RG233 F	Enoyl-CoA hydratase	323	*Arabidopsis*
	RG233 R	FeS cluster assembly gene	233	*Azotobacter*
1	BCD828 R	Mitochondrial ATP-2F1-ATPase	665	Wheat
2	RZ204 F	Mitochondrial ATP/ADP translocator	792	Rice
	RZ204 R	Mitochondrial ATP/ADP translocator	1,160	Rice
2	RZ643 F	Ferredoxin III	160	Maize
2	RZ643 R	Ferredoxin III	519	Maize
2	RZ962 F	Ribosomal protein L17a	223	Rice
2	RZ962 R	Ribosomal protein l17a	848	Rice
2	RZ273 R	Mitochondrial ATP/ADP translocator	539	Rice
2	RZ876 F	EF-tuf a	712	Soybean
2	RZ87 R	ATP dependent protease ClpC	173	Tomato
2	RG256 F	Plastidic aspartate amino transferase	661	*Panicum*
2	RG120 F	DNA repair protein	228	Mouse
2	RZ476 R	EF-gamma	483	*Arabidopsis*
2	RG322 R	DNA binding protein	161	Pea
3	RZ16 F	Ascorbate peroxidase	231	Rice
	RZ16 R	Ascorbate peroxidase	887	Rice
3	RZ589 F	α-tubulin (RIP3)	348	Rice
	RZ589 R	α-tubulin (RIP3)	730	Rice
3	RG754 F	Phosphoglycerate mutase	261	Maize
	RG754 R	Phosphoglycerate mutase	393	Ricinus
3	RZ142 F	Dolichol monophosphate mannose synthase	50	*Caenorhabditis*
3	RZ448 R	Phosphoglucomutase	870	Maize
3	RZ576 F	Plastidic ribosomal protein	542	*Arabidopsis*
3	RZ585 F	Histone H3	194	Rice
3	RZ614 F	Ferredoxin III	181	Maize
3	RZ574 R	Cell wall protein	216	*Arabidopsis*
3	RG179 F	UDPG dehydrogenase	484	Soybean
3	RG418X F	KAT C/KAT A kinesin	254	*Arabidopsis*
3	RZ993X F	EF-1 a	135	Rice
4	RZ740 F	S-adenosyl methionine decarboxylase	811	Rice
4	CDO1328 F	GADPH (pseudogene)	227	Maize
4	RZ86 F	Cytosolic GADPH	716	Barley
4	RZ250 R	Molybdenum co-factor biosynthetic enzyme	355	*Arabidopsis*
4	RG449 F	Serine/threonine protein kinase	190	*Arabidopsis*
5	RZ244 F	Ferric leghemoglobin reductase	48	Soybean
	RZ244 R	Lipoamide dehydrogenase	431	Soybean
5	RZ390 F	Cytochrome b5	1,035	Rice
5	RZ455 R	GTP binding protein	184	Tomato
5	CDO580 R	Isovaleryl CoA dehydrogenase	446	Human
6	RZ508 F	Catalase	1,095	Rice
	RZ508 R	Catalase	516	Rice
6	RG64 F	Blast resistance clone	1,051	Rice
	RG64 R	Blast resistance clone	891	Rice
6	RZ140 F	Homeobox protein	524	Tomato
6	RZ2X R	Human PRP8 protein	330	Human
6	RZ405 R	High-affinity K transporter	475	Wheat
6	RZ682 R	Nodulation protein nodK	296	*Escherichia coli*
7	RZ488 F	mRNA for thioredoxin h	383	Rice
	RZ488 R	mRNA for thioredoxin h	307	Rice
7	RZ509 R	bpw1 water transport protein	135	Barley
7	RG128 F	mRNA for acyl-(acyl protein) thioesterase	165	*Arabidopsis*
7	RG156 F	Rat cytomegalovirus DNA biosynthetic enzyme	164	Rat virus
8	RZ143 F	Cytosolic GADPH	655	Rice
8	RZ617 F	Poly-A binding protein	680	Wheat
8	RZ649 F	Fructose diphosphate aldolase	336	Rice
8	RZ997 F	Plastidic Cu/Zn superoxide dismutase	487	Rice
	RZ997 R	Plastidic Cu/Zn superoxide dismutase	974	Rice
8	RZ572 F	Cytosolic APX	294	Maize
8	RG20 F	Meristem L1 layer homeobox protein	265	*Arabidopsis*
8	RZ698 F	Plastidic Pi/PEP transporter	313	Maize
	RZ698 R	Plastid Pi/PEP transporter	641	Maize
9	RZ792 F	Nucleic acid binding protein	269	Maize
9	CDO590 R	Protein phosphatase	523	Tobacco
9	RZ206 F	VDAC protein/porin	325	Wheat
9	RZ228 F	HSP82	650	Rice
9	RZ337 R	Suppressor-like protein	431	*Arabidopsis*
10	RZ500	Sugar transporter	379	*Arabidopsis*
10	RZ561 F	Cell division cycle protein cDc48 mRNA	393	*Arabidopsis*
10	RZ892 R	Alanine amino transferase	787	*Panicum*
10	RZ400 F	GTP binding protein	657	Lotus
10	RZ536 R	Rubisco activase	716	Rice
11	RZ900 F	S-adenosyl homocysteine dehydratase	746	*C. roseus*
11	RG247 F	Peptide transporter	176	Barley
11	RG118 R	Exon of ACC oxidase	158	Apple
11	RZ737 F	Lipid transfer protein	1,071	Rice
12	RG218 F	β-ketoacyl CoA synthase	201	*S.chinensis*
12	RZ261 F	Dehydroquinate dehydratase	299	Tobacco
12	RZ397 F	Glutathione S-transferase	216	Wheat
12	RG396 R	Plastidic transketolase	484	Potato
12	RZ993X F	EF-1 a	125	Rice

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Molecular tools for zygotic embryo ablation in rice

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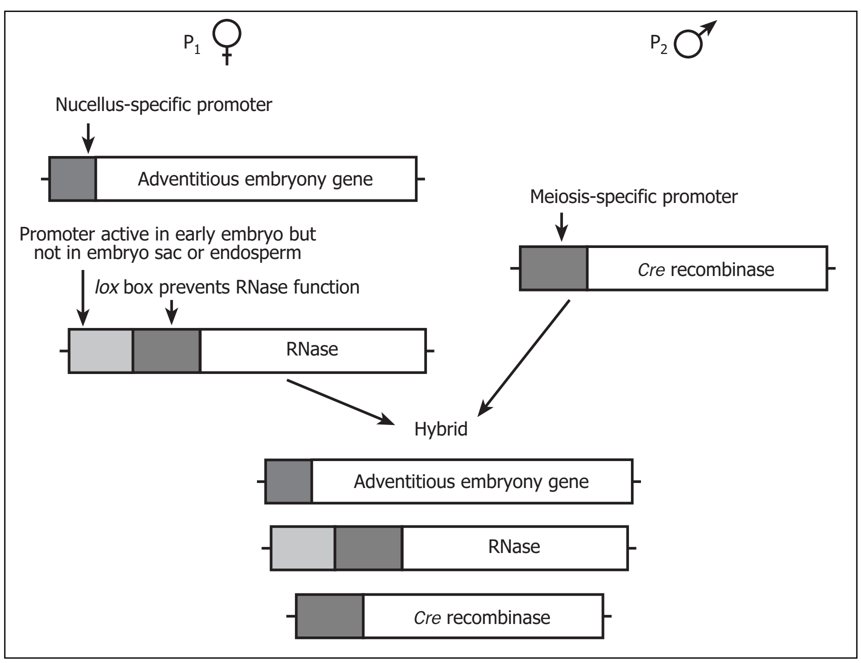
One of the serious constraints to hybrid rice technology adoption is the high cost of seed production. The dependence of hybrid seed production on parental crosses and the loss of heterotic vigor in successive generations can be eliminated if hybrid seeds can be multiplied asexually. Apomixis is an asexual means of seed production that occurs in several plant species including wild relatives of cereals such as maize, pearl millet, and wheat (Khush et al 1994). Careful searches made in rice germplasm so far have not revealed any occurrence of apomixis in rice (Rutger 1992, Brar et al 1995). Although several apomictic mechanisms exist, apomixis in principle is achieved by (1) cessation of steps leading to zygotic embryo development and (2) induction of an asexual embryo in nucellar tissue. Our goal is to develop apomictic rice through genetic engineering. In this note, we report the strategy and progress made in generating tools for arresting sexual embryo development.

The simplest way of arresting the development of the sexual embryo is to generate an inhibitory protein under the control of an egg- or zygote-specific promoter. Since such a promoter is to date not available in plants, we have taken a two-gene approach, which uses the *Cre-lox* recombination system (see figure). The *Cre* recombinase will be delivered through meiotic lineage to the zygote where it will excise the *lox* box intervening the coding region of a gene that can cause ablation (RNase, for example). Such a mechanism necessitates isolation of (1) a gene that is specifically expressed in meiotic cells and (2) a gene that is favorably expressed in the embryo but not in the embryo sac or endosperm. We have chosen *DMC1*, a meiosis-specific gene in yeast, and *REE5*, a 254-bp cDNA fragment that is accumulated in rice zygotic embryos (Kikuchi et al 1998).

Following a report that *DMC1* of *Arabidopsis* is meiosis-specific (Klimyuk and Jones 1997), we decided to isolate rice *DMC1* and test its expression pattern. We designed primers from partial rice Genebank sequence data (accession no. U85613) and amplified a 417-bp rice genomic fragment that encodes *DMC1*. Nested-polymerase chain reaction (PCR) and Southern analyses suggested the presence of two rice *DMC1* genes. We isolated the two genes (*DMC1A* and *DMC1B*) from the IR64 bacterial artificial chromosome library and designed sequence-specific primers and probes to study their expression. Reverse transcriptase (RT)-PCR and Northern analyses revealed that both *DMC1A* and *DMC1B* are expressed in panicles at meiosis and in mitotically active tissues such as root tips and calli. Therefore, we conclude that rice *DMC1* genes are not meiosis-specific. We are currently exploring the potential utility of rice homologues of other yeast meiosis-specific genes such as *SPO11*.

REE5-specific PCR and Southern analyses indicated that the rice genome contains two *REE5* genes. By screening the IR36 genomic library, we isolated clones containing the two *REE5* genes. To isolate the *REE5* gene that is expressed during early embryogenesis, we performed 3' rapid amplification of cDNA ends (3' RACE) using spikelets at 2 d after fertilization. We then screened the genomic clones containing the two *REE5* genes using 3'-untranslated regions derived from the 3' RACE clone. Sequence analyses revealed that *REE5* encodes a novel phosphoprotein. We are currently studying the expression pattern of *REE5* genes using RT-PCR, Northern, and *in situ* hybridization techniques.



A schematic diagram showing the constructs that can be used to derive an apomictic hybrid rice.

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Rayada B3—a high-yielding, ufra-resistant deepwater rice for Assam, India

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Of the 2 million ha of rice land affected by flood every year in Assam, India, 490,000 are planted to deepwater rice. During the long growing period from March to December, deepwater rice is exposed to attacks by different pests and diseases. Among them, infestation by rice stem nematode, *Ditylenchus angustus,* commonly called ufra disease, is considered a major problem, causing a 30–100% yield loss.

Several deepwater and semi-deepwater rice varieties were screened for resistance to ufra nematode during 1991-92 under field conditions at RARS. Among the entries tested, a few Rayada selections collected from Bangladesh, such as Rayada 16-06, Rayada 16-09, and Rayada B3, were resistant to ufra in Assam. These lines were further screened for ufra resistance and yielding ability in a replicated trial from 1993 to 1997 in diseased and disease-free areas. The diseased plot was selected from a naturally infested field and ufra disease pressure was further increased by adding inoculum at sowing, whereas earthen bunds around the field kept the control plot ufra-free. Table 1 presents the panicle infestation rate and grain yield per hectare of the lines over the years. Statistical analysis (3 RBD) followed after transformation of percentage infestation data.

All the lines exhibited significant variation in ufra infestation and yield. Rayada 16-06, Rayada 16-09, and Rayada B3 had good resistance to the nematode with 10.0%, 12.6%, and 18.8% mean panicle infestation rates, respectively. On the other hand, susceptible check variety Rangabao was severely affected (80.9%). Simultaneously, Rayada B3 showed a higher average mean yield (0.95 t ha^{-1}) than the other three varieties in ufra-endemic areas. Table 2 shows the mean yield of lines over years in the ufra-free area. Under ufra-free conditions also, Rayada B3 outyielded all three varieties with a mean average yield of 2.0 t ha^{-1}. Rayada B3 had a 22% yield advantage over Rangabao.

Rayada B3 is a photoperiod-sensitive and tall but nonelongating deepwater rice that can withstand up to 1.5 m water depth, with a mean height of 150 cm. Its grains are heavier (29 g 1,000 grains^{-1}) and coarse and the kernels are red. Rayada B3 yielded 0.2 -0.4 t ha^{-1} under direct-seeded conditions and 0.5 t ha^{-1} under transplanted conditions.

Acknowledgments

The authors thank the Director of Research (Agriculture), Assam Agricultural University, and the Chief Scientist, RARS, North Lakhimpur, Assam, for providing facilities for the study.

Table 1. Panicle infestation rate and yield of ufra-resistant lines in ufra-endemic hot spots of RARS, North Lakhimpur, Assam, 1993-97.

Variety	Panicle infestation rate (%) and grain yield (t ha^{-1})[a]					
	1993	1994	1995	1996	1997	Mean
Rayada B3	19.1	12.5	26.5	14.4	21.2	18.8
	(0.8)	(1.0)	(0.9)	(1.1)	(na)	(0.9)
Rayada 16-06	9.4	8.5	14.5	9.8	21.0	12.6
	(0.8)	(0.5)	(0.4)	(0.6)	(na)	(0.6)
Rayada 16-09	8.7	8.2	11.2	6.7	15.6	10.1
	(0.6)	(0.5)	(0.4)	(0.5)	(na)	(0.5)
Rangabao	60.6	80.3	95.5	72.7	95.2	80.9
(susceptible check)	(0.8)	(0.6)	(0.2)	(0.6)	(na)	(0.6)
CD (0.5%)	8.2	6.4	3.9	8.7	2.7	
	(0.9)	(1.2)	(0.9)	(0.7)	(–)	

[a]Numbers in parentheses are grain yield. na = not available.

Table 2. Yield of Rayada lines in ufra-free area of RARS, North Lakhimpur, Assam, 1993-97.

Variety	Yield (t ha^{-1})					
	1993	1994	1995	1996	1997	Mean
Rayada B3	1.0	2.2	2.2	2.0	2.4	2.0
Rayada 16-06	0.6	0.7	0.8	0.7	0.8	0.8
Rayada 16-09	0.4	0.5	0.6	0.5	0.6	0.5
Rangabao	1.3	1.7	1.8	1.4	1.9	1.6
CD (0.5%)	1.05	1.15	0.83	0.99	0.93	

Relationships among the CC, DD, and EE genomes in the *Oryza officinalis* complex detected by two-probe genomic *in situ* hybridization

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The *Oryza officinalis* complex is the largest in the genus *Oryza*, containing diploid species with BB, CC, or EE genomes and tetraploid species with BBCC or CCDD genomes. Several species in this complex such as *O. officinalis*, *O. australiensis*, and *O. minuta* have been intensively used in rice breeding programs because of their useful genes for disease and insect resistance (Brar and Khush 1997). Three closely related tetraploid species, *O. latifolia*, *O. alta,* and *O. grandiglumis,* from Central and South America were reported as allotetraploid with the CCDD genomes, even though no diploid species has been found as the D genome donor in *Oryza*.

Some researchers believe that the DD genome originated from the AA genome, whereas others think it differentiated from the CC genome. The first proposition should be ruled out because the CD-genome species has a greater genetic distance from the A-genome species than species containing other genomes (Wang et al 1992, Aggarwal et al 1999). Recent studies indicated that the DD genome and EE genome (from *O. australiensis*) are most closely related, and that the ancestor of the EE genome might have played an important role in the formation of the CD-genome species (Wang et al 1992, Ge et al 1999). The relationships between the DD and CC or DD and EE genomes, however, still need clarification.

Two-probe genomic *in situ* hybridization (GISH) technology, also called multicolor FISH or bicolor FISH, is an ideal tool for studying relationships among different genomes. This study confirmed the existence of CC and DD genomes in the tetraploid *O. alta* and investigated the relationships among the CC, DD, and EE genomes using the two-probe GISH.

The genomic DNA of three diploid wild rice species, *O. officinalis* (2n = 24, CC genome), *O. eichingeri* (2n = 24, CC), and *O. australiensis* (2n = 24, EE), was used as the probe. Plant materials used in the study are listed in Table 1 with their origins. Chromosome samples of *O. alta* were prepared using an enzymatic maceration and air-dry method. *In situ* hybridization followed that described by Leitch et al (1994). The hybridization stringency and posthybridization washing stringency are shown in Table 2. Stringency is a crucial factor in determining hybridization between homologous sequences or similar sequences. Under low stringency, GISH results reflect the similarity between probe and target sequences, whereas under high stringency, GISH results mainly indicate homologous hybridization. Thus, the identity (homology) and similarity between genomes could be estimated well.

When the chromosomes of *O. alta* were probed with the C-genome DNA from *O. officinalis*, the two genomes in *O. alta* could not be distinguished (Fig. 1a) under conditions of low stringency (50–60%). This result indicates a relatively high similarity of DNA sequences between CC and DD genomes in *O. alta*. Under 78–86% stringency, most chromosomes from the CC genome (labeled with strong green signals) and the DD genome (labeled with weak signals) could be distinguished, but some could not be accurately identified due to minor differences in their fluorescence intensity (Fig. 2a). This suggests that the differentiation between CC and DD genomes is not significant. When hybridized with the C-genome DNA from *O.*

Table 1. Wild *Oryza* species used in this study with their genomes and origins.

Species	Accession no.	2n	Genome	Source/country
O. officinalis	Zhou-198	24	CC	China
O. eichingeri	IRGC 101144	24	CC	Uganda
O. australiensis	IRGC 105263	24	EE	Australia
O. alta	IRGC 100161	48	CCDD	Brazil

Table 2. Chromosome samples, probe constitutions, and stringencies used.[a]

Chromosome sample	Probes	Hybridization stringency	Posthybridization stringency
O. alta	DIG-EE (*O. australiensis*)[b] BIO-CC (*O. officinalis*)	65–75%	50–60%
O. alta	DIG-EE (*O. australiensis*) BIO-CC (*O. officinalis*)	65–75%	78–86%
O. alta	DIG-CC (*O. eichingeri*) BIO-EE (*O. australiensis*)	65–75%	96–100%

[a]Stringency was calculated by using the equation described by Meinkoth and Wahl (1984). The GC content (50–70%) was estimated according to sequencing data of 20 genes (*O. sativa*) from the Genebank. The probe length varies from 200 bp to 500 bp as shown by running a small gel. [b]DIG-EE means the total DNA of the EE genome labeled with digoxigenin; BIO-CC means the total DNA of the CC genome labeled with biotin.

eichingeri and stained with DAPI under conditions of 96–100% stringency, most of the C-genome (violet signals) and D-genome (blue color) chromosomes could be distinguished (Fig. 3a). In most cases, hybridization signals did not homogeneously cover the entire length of the C-genome chromosomes; instead, stronger signals appeared only in certain regions of the chromosomes. Hybridization sites with visible signals were also detected on the D-genome chromosomes. It is difficult to clearly identify all chromosomes of the CC and DD genomes in *O. alta*. Based on these results, we concluded that *O. alta* (including *O. latifolia* and *O. grandiglumis*) is not a strict allotetraploid species.

When chromosomes of *O. alta* were probed by the labeled genomic DNA from *O. australiensis* (EE genome), the red hybridization signals covered all chromosomes (Fig. 1b) under conditions of low stringency (50–60%), suggesting a high similarity in DNA sequences between EE and CC and DD genomes. Under conditions of 78–86% stringency, hybridization signals are small and weak on most chromosomes; stronger signals are mainly located on C-genome chromosomes (Fig. 2b). Under 96–100% stringency, hybridization signals are so weak that further signal amplification had to be made. The amplified hybridization signals (bluish green) were mainly located on chromosomes of the CC genome. Hybridization signals on chromosomes of the DD genome were very weak or invisible (Fig. 3b).

These results together indicate considerable differentiation of the EE genome from CC and DD genomes, and higher affinity of the EE genome to the CC genome than to the DD genome. In conclusion, we believe that the EE genome is not the direct donor of the DD genome. The origin of the DD genome still remains uncertain and needs further study. This study fully demonstrated the advantages of using GISH in identifying genomic constitution and detecting relationships among genomes.

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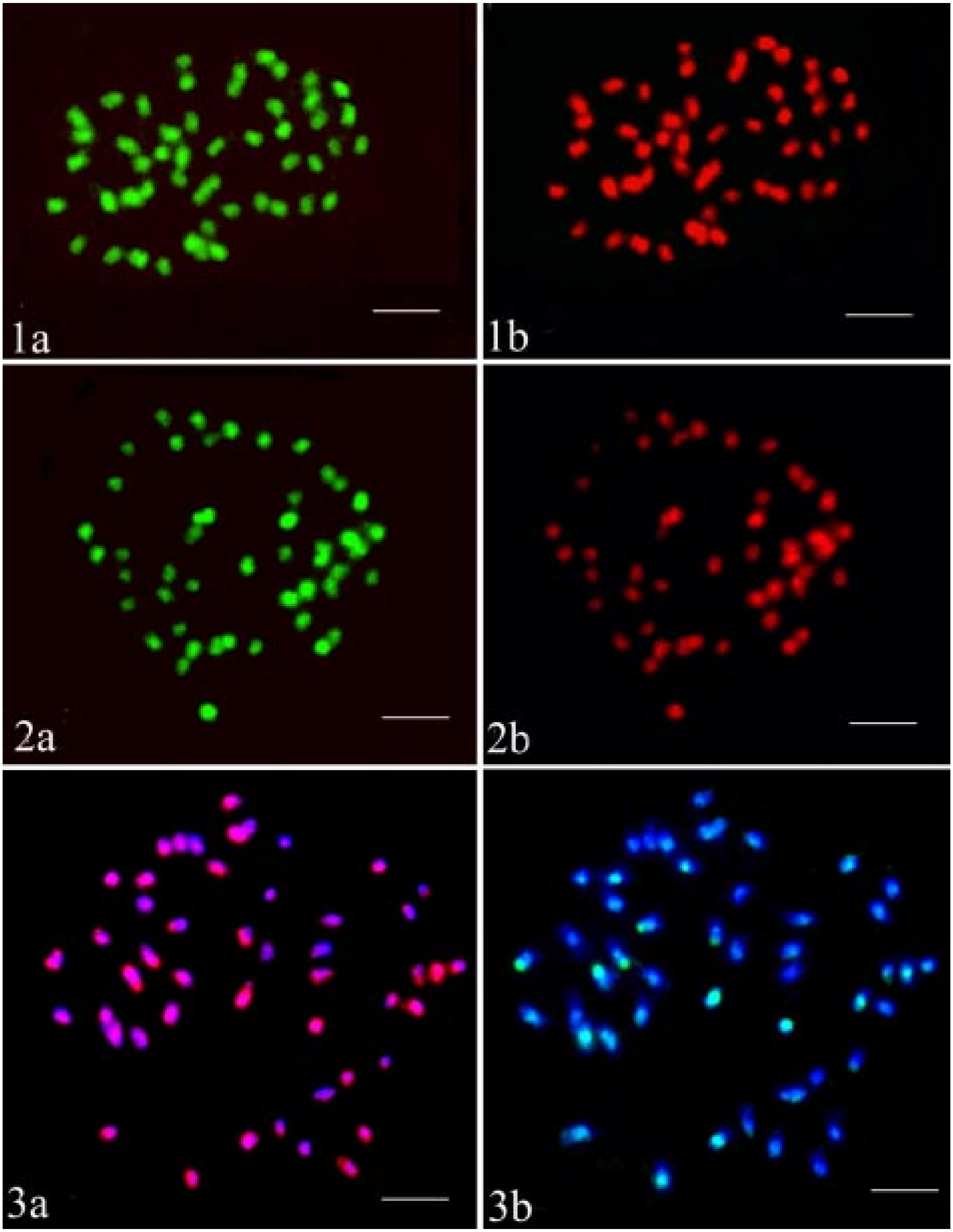

Figs. 1-3. Metaphase chromosomes of *O. alta* after genomic *in situ* hybridization with the C and E-genome species in different posthybridization washing stringencies. Chromosomes hybridized with the C-genome DNA from *O. officinalis* (Fig. 1a) and E-genome DNA from *O. australiensis* (Fig. 1b) under conditions of 50–60% stringency. Chromosomes hybridized with the same probes as in Figures 1a and 1b, but under 78–86% stringency (Fig. 2). Chromosomes probed with C-genome DNA from *O. eichingeri* (Fig. 3a) and E-genome DNA from *O. australiensis* (Fig. 3b) and counterstained with DAPI. The posthybridization washing stringency was 96–100%. The hybridization signals of the E-genome probe were amplified. Scale bar = 5 µm.

Impact of *Aspergillus niger* AN27 on growth promotion and sheath blight disease reduction in rice

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Sheath blight caused by *Rhizoctonia solani* Kuhn is a threat to rice cultivation in different agroclimatic conditions. Many bacteria and fungi from rice field soils are antagonistic to *R. solani* (Gogoi and Roy 1993, Roy 1984, 1993, Sen et al 1993).

We tested the ability of *Aspergillus niger* AN27 and its bioformulation to suppress sheath blight. Seeds of Pusa Basmati 1 were planted in four nursery trays (650 seeds tray^{-1}). Seeds of one tray were treated with the bioformulation *Kalisena* SD at 4 g kg^{-1} before planting. Untreated seeds were sown in the other three trays. At transplanting, root and shoot length of plants and biomass were measured for each treatment. Twenty-five-day-old seedlings were transplanted at 15 × 15-cm spacing in a randomized block design with four treatments. Three replications of two 3-m rows were maintained. Standard agronomic practices were followed. The experiment was conducted for two continuous crop years (1997 and 1998). Plants were inoculated with a virulent isolate of *R. solani* by placing two colonized typha bits (Bhaktavatsalam et al 1978) in the center tillers of each hill at 40 d after transplanting (maximum tillering). At 45 d after inoculation, number of total tillers, infected tillers, effective tillers, lesion height, and disease reduction were measured.

The 1997 and 1998 results were similar and were thus averaged. Plants raised from treated seeds (PTS) were significantly more vigorous, showing an increase of 6.5 and 10.0 cm in root and shoot length, respectively, and 100% heavier biomass than the untreated seedlings at transplanting (Table 1). In the field, PTS had significantly more tillers per plant and a higher percentage of effective tillers (Table 1). There was a 32.9% disease reduction in PTS; in the spray treatment of *A. niger* AN27, reduction was only 12.2%. Average lesion height was also reduced up to 14.5% in PTS (Table 2).

These results indicate that resistance to sheath blight is induced in rice by the biocontrol agent *A. niger* AN27 and its bioformulation *Kalisena* SD. Roy (1993) reported that infection of sheath blight could be reduced by adding *A. terreus* in potted plants. The cellulolytic activity of *R. solani,* however, could not be reduced. Reduction of *R. solani* by *A. terreus*, particularly when plants are treated before inoculation with sclerotia of the pathogen, was reported by Gogoi and Roy (1993). Sen et al (1993) found that *A. niger*, isolated from the rhizosphere of a healthy muskmelon plant adjacent to wilted areas, proved to be an effective biocontrol agent against *R. solani* by way of antibiosis, overgrowth, and hyperparasitism. *Kalisena* SD, developed by IARI, has been launched in the market to control soil-borne plant pathogens and to promote plant growth.

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Table 1. Impact of *Aspergillus niger* AN27 and its bioformulation *Kalisena* SD on growth of rice cv Pusa Basmati 1 inoculated with *Rhizoctonia solani*.

Treatment	Transplant			Tillers	
	Root length (cm) Av of 20	Shoot length (cm) Av of 20	Biomass (g) Av of 100	Total no. plant^{-1}	Percent effective
Seed dressing *Kalisena* SD	13.4	40.0	60.0	11.4	93.7 (75.75)[a]
Sheath spray *A. niger* AN27	6.9	29.9	30.3	9.5	83.2 (65.80)
Untreated, inoculated	6.9	29.9	30.0	8.8	76.6 (61.09)
Untreated, uninoculated	6.9	30.0	30.0	8.8	76.1 (60.46)
CD at $P = 0.05$				1.17	3.46

[a]Numbers in parentheses are arcsine-transformed values.

Table 2. Effect of *A. niger* AN27 and its bioformulation *Kalisena* SD on sheath blight of rice.

Treatment	Infected tillers (%)	Disease reduction over control (%)	Lesion height (%)
Seed dressing	63.7	32.9	66.7
Kalisena SD	(52.95)[a]	(34.87)	(54.76)
Sheath spray	83.8	12.2	72.3
A. niger AN27	(66.28)	(20.32)	(58.24)
Untreated, inoculated	98.0	0.0	81.2
	(78.62)	(4.05)	(64.32)
Untreated, uninoculated	0.0	0.0	–
	(4.05)	(4.05)	(4.05)
CD at $P = 0.05$	3.14	3.30	2.09

[a]Numbers in parentheses are arcsine-transformed values.

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Influence of rice varieties on parasitism of the African rice gall midge (AfRGM)

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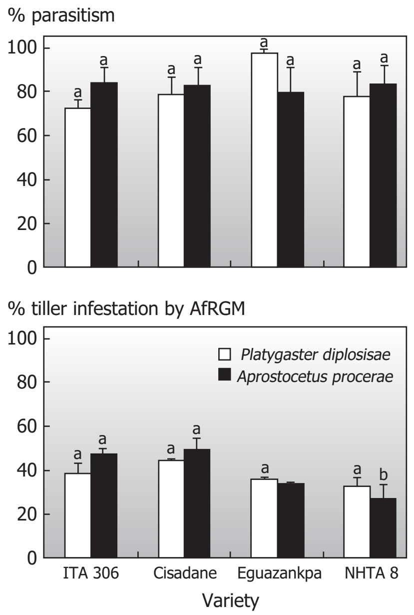
The African rice gall midge (AfRGM), *Orseolia oryzivora* Harris & Gagné (Diptera: Cecidomyiidae), is a major constraint to rainfed and irrigated lowland rice production in Africa. The most common natural enemies associated with AfRGM are the polyembryonic endoparasitoid *Platygaster diplosisae* Risbec (Hymenoptera: Platygasteridae) and the solitary ectoparasitoid *Aprostocetus procerae* Risbec (Hymenoptera: Eulophidae). These species have potential as biological control agents against AfRGM (Williams et al 1997). The extent to which the activity of these parasitoids may be influenced by rice genotype is not well known. This is a crucial issue because the effects of resistance factor(s) in the rice genotype on the developing midge larvae are likely to be exhibited on the next trophic level of association, i.e., on the AfRGM parasitoids. Such interactions are known to exist in maize, sorghum, and other crops (Potting et al 1995, Nwanze and Nwilene 1998).

Some natural enemies are known to base their foraging strategies on plant volatiles that mediate searching behavior, especially at longer distances. Plant resistance to insects can result from antagonism due to the presence of chemicals in various plant tissues. To optimize the benefits from integrating the breeding for resistance to AfRGM and biological control, it is desirable that these management options be either complementary or synergistic and not antagonistic.

A trial was carried out in 1998 at the Ebonyi State College of Agriculture greenhouse in the Ikwo local government area, near Abakaliki, Ebonyi State, southeast Nigeria. Ikwo is in the forest/savanna transition zone. The AfRGM and its parasitoids *P. diplosisae* and *A. procerae* were reared in seedboxes in the greenhouse (25–30 °C temperature and 50–90% relative humidity). The cultures had been maintained for 4 wk prior to the experiments. Four rice varieties showing different levels of resistance—ITA306 (susceptible), Cisadane (tolerant), NHTA8 (partially resistant), and Eguazankpa (widely grown traditional variety in the middle belt of Nigeria) (Williams et al 1997)—were used to determine whether these differences in resistance affected parasitism of *P. diplosisae* and *A. procerae*.

The experiment was laid out in a randomized complete block design with three replications. About 80 seedlings in each seedbox were exposed to 10 gravid female and 5 male AfRGM at 12 d after seeding. Two days after AfRGM infestation, twenty 1-d-old gravid females of *P. diplosisae* were released in each box. Two weeks after AfRGM infestation, when pupation commenced, twenty 1-d-old gravid females of *A. procerae* were released in each box. (Separate boxes were infested with *P. diplosisae* and *A. procerae*.) Four weeks after parasitoid introduction, 40 plants per box were dissected and data on the following were recorded: tillers with galls, total tillers, number of larvae/pupae collected from galls, number of larvae/pupae parasitized, and percent parasitism. Data were subjected to analysis of variance.

Under no-choice conditions, in the experiment with *A. procerae,* AfRGM infestation of partially resistant variety NHTA8 was significantly lower than that of ITA306 and Cisadane at 50 d after crop emergence (Fig. 1). In the experiment with *P. diplosisae,* however, the four varieties did not differ in levels of AfRGM infestation. There was no significant difference in the number of larvae/pupae parasitized, and percent parasitism by both parasitoids was also consistently high in the four varieties (see figure). Both parasitoids attacked almost every gall that was infested. The



Effect of rice varieties on the parasitism of AfRGM by *Platygaster diplosisae* and *Aprostocetus procerae* and the percentage of tillers with galls. Means (± S.E.) within a row for each parasitoid followed by the same letter are not significantly different at *P*>0.05; least significant difference.

high level of parasitism in the four varieties suggests that host plants offer no antagonistic effects to AfRGM parasitoids. The plant resistance factors in NHTA8 and Eguazankpa did not influence parasitoid activity or level of parasitism under no-choice conditions, indicating that the interaction between host-plant resistance and AfRGM parasitoids would thus be synergistic or additive and could result in successful integration of these two important pest management options. This is particularly important in the integrated pest management of AfRGM for which desirable levels of resistance have not yet been achieved.

Results, however, might differ under free-choice conditions. Tritrophic interactions should be explored by plant breeders and insect ecologists who aim to produce resistant varieties which, when infested, still produce volatiles in sufficient amounts to attract parasitoids or predators. With recent advances in hybridization and molecular markers at WARDA, efforts are under way to increase rice resistance and understanding of such tritrophic interactions in cereal-based ecosystems.

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Ecological characterization of biotic constraints to rice in Cambodia

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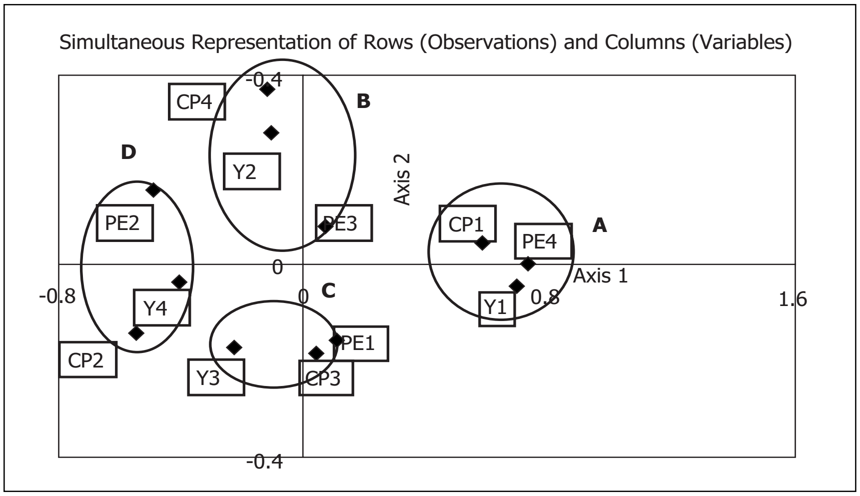
From 1994 to 1998, a total of 73 rainfed lowland rice fields (RLR) (>0.3 ha each) in Cambodia were studied to determine which pests affect yields and how cropping practices affect pest levels. From 1997 to 2000, this information was used to generate testable hypotheses for crop protection research and to help prioritize the integrated pest management (IPM) research program of CIAP. The data collection methods of Savary et al (1996) were adapted to Cambodian conditions. "Pests" included insects, weeds, and diseases. Farmer interviews (Jahn et al 1997b), pest collections, and practical considerations (e.g., ease of recognizing the pest or its damage) were used to determine which pests to include in the study. Pesticides were not used in any of the fields in this study.

Data were gathered at four crop development stages: tillering, booting, milk, and maturity. The yield of each field was estimated by averaging the weights of three randomly selected 2 × 5-m^2 harvested areas, converted to t ha^{-1} and adjusted to 14% moisture. Pest incidence was recorded from 10 hills chosen haphazardly from each field. Weed infestation was measured as the percentage weed cover in three 1-m^2 areas that included sampling hill number 3, 6, and 9. The analysis proceeded in five steps: (1) determination of average injury levels of each pest for each crop stage, (2) categorization of variables (i.e., pest, cropping practices, and yield) into classes, (3) testing for independence of paired variables (i.e., pest levels, cropping practices, and yields) in contingency tables, (4) clustering of cropping practices, yields, and pest profiles, and (5) development of contingency tables and correspondence analysis. Data were analyzed with Excel® and STAT-ITCF®.

Correspondence analysis between combined variables (i.e., cropping practices and pest profiles) and yields resulted in the formation of four domains (see figure). Low levels of gall midge damage (i.e., 0–0.2% tiller damage) were recorded in the highest yielding fields (domain D, table). The lowest yielding fields had high



Graphical display of correspondence analysis of the biotic constraint data matrix. The cropping practice (CP), yield (Y), and pest (PE) clusters can be grouped into four domains described in the table.

Characteristics of the domains derived from Figure 1.

Domain	Clusters	Cropping practices and yields	Pest constraints
A	Y1, CP1 PE4	Late-duration rice varieties and some medium varieties Low application of mineral fertilizer Very diverse water management Very low yield	Weeds, gall midge, cut worm, and brown spot
B	Y2, CP4 PE3	Early rice varieties Low application of mineral fertilizer Water depths very diverse Low yield	Brown spot, gall midge, sucking insects
C	Y3, CP3 PE1	Medium rice varieties High application of minerals Too much water Medium yield	Weeds, whorl maggot, hispa, sucking insects, and gall midge
D	Y4, CP2	Medium cultivars and some early varieties High application of mineral fertilizer and manure Little standing water High yield	Narrow brown spot

levels of gall midge (1–59% tiller damage), cutworm (15–51% leaf damage), brown spot (32–94% leaf damage), and weeds (10–30% weed cover) (domain A, table).

Study results led the CIAP IPM Program to assess the importance of gall midge in different parts of Cambodia and to conduct field trials to evaluate varietal resistance to gall midge (Jahn et al 1997a, Jahn and Khiev 1998). From 1998 to 2000, CIAP conducted experiments to test hypotheses generated by the characterization study, including whether the levels of pest damage recorded in the characterization study could actually reduce yields (see Khiev, "Effects of simulated pest damage on rice yields," p 27–28); how well early and medium-duration varieties compete against weeds; and investigations on the interactions of fertilizer, variety, pests, and yield.

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Field screening of stem borer resistance in new plant type lines

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IRRI is developing rice varieties with higher yield potential by changing rice architecture to match an ideotype known as the new plant type (NPT) (Peng et al 1994). The features of the NPT include fewer and larger tillers, all of which are productive; sturdy stems; and erect, deep green leaves. At the IRRI Experiment Station, some plots of NPT lines have been highly damaged by stem borers, particularly by striped stem borer (SSB) *Chilo suppressalis* (Walker). We conducted a field screening of NPT lines and existing IRRI varieties to compare levels of stem borer damage. We also examined the relation of tiller number and silica content to stem borer damage.

Screening was conducted at IRRI (Los Baños, Laguna, Philippines) and PhilRice (Maligaya) during the 1998 dry season (DS, February to May). Thirty NPT lines and three IRRI varieties (IR62, which is relatively susceptible to SSB; and IR64 and IR72, which are moderately resistant to stem borers) were transplanted in plots of 100 plants (5 rows of 20 plants) in a randomized complete block design with four replications. Numbers of tillers and deadhearts (DH) were scored at 39 d after transplanting (DAT) at IRRI and 60 DAT at PhilRice. Numbers of panicles and whiteheads (WH) were scored at 85 DAT, at which time the shorter duration lines were close to harvest and the longest duration lines were at hard dough stage. At WH sampling, 20 plants from each replicate plot were removed and dissected to count the number of larvae and pupae of SSB, yellow stem borer (YSB, *Scirpophaga incertulas* [Walker]), gold fringed stem borer (GFSB, *Chilo auricilias* Dudgeon), and pink stem borer (PSB, *Sesamia inferens* [Walker]). An additional five plants from each replicate plot at the IRRI site were removed and analyzed for silica content (Yoshida et al 1976).

There was substantial variation in levels of DH and WH among NPT lines (see table). Many lines did not differ significantly from IR64 or IR72 in %DH or %WH, while other lines had much higher damage. This result suggests that there may be potential for improving stem borer resistance in the NPT by further selection or breeding with NPT lines that show lower damage in screening trials.

The values of %WH were negatively correlated with the number of productive tillers per hill for both IRRI ($r = -0.38$, df = 31, $0.05>P>0.01$) and PhilRice sites ($r = -0.64$, df = 31, $P<0.01$). When only NPT lines were included in the analysis, the correlation between number of productive tillers and %WH was not significant for the IRRI site ($r = -0.11$, df = 28, $P>0.05$) but was highly significant for PhilRice ($r = -0.78$, df = 28, $P<0.01$). The fact that the number of productive tillers accounted for such a high proportion of the variation in %WH indicates that the results should be interpreted with caution. The most resistant entries may be those with a low %WH despite having less productive tillers per hill, such as IR66738-118-1-2 and IR65600-27-1-2-2.

The negative correlation between tiller number and %WH may be partly because varieties with fewer tillers tend to have larger tiller diameter (Peng et al 1994). Some studies have found a positive correlation between stem diameter and stem borer susceptibility (Chaudhary et al 1984, Ntamos and Koutroubas 2000).

SSB accounted for >90% of larvae and pupae recovered from dissected plants of 11 entries at IRRI, with the exception of IR62 (79%) and IR64 (76%) (see table). YSB and PSB were of approximately equal abundance in plants dissected at IRRI, while GFSB was not common (data not shown). At PhilRice, SSB was also the most common species recovered (see table), followed by PSB. IR62, IR64, and IR72 were among the entries with the lowest proportion of SSB recovered at PhilRice. These results are surprising because YSB is usually the most abundant stem borer in tropical wetland rice (Shepard et al 1995). Our results are consistent with earlier observations at the IRRI Experiment Station that NPT lines may be more attractive or suitable hosts to SSB than existing IRRI varieties.

A positive correlation between stem borer resistance and silica content has been reported in some studies (Chaudhary et al 1984). In our study, the silica content of entries fell within a narrow range (5.44–6.78%) and did not differ significantly among entries (see table). There was no correlation between silica content and %DH ($r = -0.19$, df = 31, $P>0.05$) or %WH ($r = -0.03$, df = 31, $P>0.05$).

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Evaluation of new plant type lines and IRRI varieties for stem borer resistance at two Philippine sites, 1998 DS.[a]

Entry	IRRI						PhilRice				
	Vegetative stage		Reproductive stage				Vegetative stage		Reproductive stage		
	Tillers (no.)	% DH[b]	Productive tillers (no.)	% WH[b]	% SSB[c,d]	Silica content (%)	Tillers (no.)	% DH[b]	Productive tillers (no.)	% WH[b]	% SSB[b,d]
IR65564-22-2-3	11.9	12.9	9.8	34.0	94.5	5.6	13.0	19.6	10.4	38.0	60.5
		(20.7)		(35.6)	(9.7)			(26.2)		(38.0)	(52.2)
IR65564-44-2-3	10.3	5.2	8.9	15.9	97.0	6.3	15.7	19.9	9.3	35.3	70.7
		(12.8)		(23.2)	(9.8)			(26.5)		(36.3)	(58.3)
IR65564-44-5-1	10.4	7.5	10.0	31.4	97.0	5.5	14.6	16.4	11.8	29.4	74.4
		(15.7)		(34.0)	(9.8)			(23.6)		(32.7)	(60.8)
IR65597-29-3-2-3	10.3	10.3	6.5	37.6	96.2	6.2	11.3	18.8	9.4	36.8	88.4
		(18.2)		(37.8)	(9.8)			(25.2)		(37.3)	(70.9)
IR65598-112-2	9.8	11.2	5.0	31.3	99.2	6.4	13.7	24.4	7.0	41.5	79.0
		(19.0)		(33.7)	(10.0)			(29.5)		(40.0)	(63.0)
IR65600-1-2-3	8.6	9.2	5.8	60.0	97.0	5.8	11.7	23.7	7.6	40.6	77.2
		(17.3)		(50.9)	(9.8)			(29.0)		(39.3)	(62.0)
IR65911-127-6-2-3	10.6	12.3	6.3	36.1	97.6	5.7	13.1	29.5	7.6	35.1	79.7
		(20.5		(36.8)	(9.9)			(32.8)		(36.1)	(63.4)
IR65600-27-1-2-2	9.2	14.9	7.3	29.1	96.2	6.5	12.0	13.4	8.7	20.3	72.5
		(22.6)		(32.6)	(9.8)			(21.3)		(26.4)	58.6)
IR65600-32-4-6-1	10.6	10.2	7.3	27.1	97.2	6.2	14.5	25.6	8.1	32.0	71.0
		(18.4		(31.3)	(9.9)			(30.1)		(34.3)	(57.5)
IR65600-38-1-2-1	10.8	7.2	6.2	28.7	98.3	6.4	12.8	21.0	8.6	33.4	68.8
		(15.4)		(32.4)	(9.9)			(27.0)		(35.2)	(56.6)
IR65600-42-5-2	10.2	8.0	9.9	35.8	97.6	6.2	14.5	18.9	11.4	27.9	81.6
		(16.1)		(36.7)	(9.9)			(2.7)		(31.7)	(64.8)
IR65600-54-6-3	9.9	6.2	9.5	36.1	96.8	6.8	14.2	19.8	11.1	29.5	78.0
		(14.1)		(36.9)	(9.8)			(26.3)		(32.9)	(62.2)
IR65600-77-4-2-1	9.0	13.1	7.0	30.7	98.5	6.1	12.9	21.9	9.8	29.6	80.5
		(20.7)		(33.6)	(9.9)			(27.9)		(32.9)	(64.2)
IR65600-85-1-1	11.5	11.4	7.9	27.1	92.7	6.3	15.8	26.5	9.1	49.0	72.7
		(19.5)		(31.2)	(9.6)			(30.9)		(44.4)	(58.7)
IR65600-87-2-2-3	11.1	9.0	8.5	36.0	97.1	6.3	15.1	23.7	9.1	44.4	63.3
		(17.4)		(36.8)	(9.9)			(29.1)		(41.7)	(53.2)
IR65600-95-4-5	11.7	14.3	7.1	19.5	97.8	5.8	17.4	23.1	10.1	28.5	58.6
		(21.6)		(25.6)	(9.9)			(28.7)		(32.1)	(50.1)
IR65600-96-1-2-2	11.3	10.3	7.1	21.8	98.4	5.4	17.8	20.4	12.5	23.7	62.1
		(18.0)		(27.6)	(9.9)			(26.6)		(29.1)	(52.4)
IR65601-35-6-2-3	9.0	9.1	7.8	43.7	98.1	6.5	13.5	19.8	8.2	37.2	62.7
		(17.0)		(41.3)	(9.9)			(26.2)		(37.5)	(52.9)
IR65601-52-2-3	10.2	11.8	8.9	33.1	98.2	6.3	15.5	20.0	8.4	40.8	78.0
		(19.2)		(34.9)	(9.9)			(26.5)		(39.6)	(63.8)
IR66-158-38-3-2-1	11.8	9.9	9.2	40.6	96.6	6.2	14.9	20.2	10.1	44.2	78.0
		(18.3)		(39.6)	(9.8)			(26.6)		(41.6)	(62.4)
IR66159-164-5-3-5	10.6	10.7	10.5	35.7	96.8	5.4	14.5	18.6	12.5	30.2	82.0
		(18.2)		(36.3)	(9.8)			(25.5)		(33.1)	(65.2)
IR66159-189-5-5-3	10.1	7.7	9.6	35.8	98.8	6.2	17.0	19.9	14.3	24.1	68.7
		(15.6)		(36.7)	(9.9)			(26.3)		(29.2)	(56.2)
IR66160-121-4-1-1	11.6	6.8	12.4	17.8	90.4	6.8	15.7	18.2	15.7	15.0	51.4
		(15.0)		(24.8)	(9.5)			(25.1)		(22.4)	(45.5)
IR66160-121-4-4-2	11.1	11.3	10.9	15.5	97.4	6.2	14.7	19.2	13.0	16.9	53.3
		(19.5)		(23.0)	(9.9)			(25.7)		(24.2)	(47.0)
IR66160-5-2-3-2	11.2	6.7	11.5	34.1	99.3	6.2	15.8	18.9	14.6	20.2	74.6
		(14.5)		(35.7)	(10.0)			(25.6)		(26.6)	(59.9)
IR66165-24-6-3-2	12.8	12.1	7.5	36.8	96.6	6.0	15.4	26.3	8.4	46.0	54.0
		(20.2)		(37.3)	(9.8)			(30.7)		(42.7)	47.4)
IR66738-118-1-2	12.9	7.3	7.3	15.1	95.4	6.2	15.7	23.2	8.6	33.7	72.6
		(15.5)		(22.8)	(9.8)			(28.7)		(35.4)	(59.1)
IR66750-6-2-1	9.7	7.4	6.0	32.1	97.5	5.9	15.1	26.1	8.3	42.7	68.0
		(15.4)		(34.1)	(9.9)			(30.7)		(40.7)	(56.2)
IR67396-16-3-3-1	12.6	6.1	6.7	6.6	97.1	5.5	16.9	17.0	13.6	23.6	48.8
		(14.2)		(14.3)	(9.8)			(24.1)		(29.0)	(44.3)

continued...

Entry	IRRI						PhilRice				
	Vegetative stage		Reproductive stage				Vegetative stage		Reproductive stage		
	Tillers (no.)	% DH[b]	Productive tillers (no.)	% WH[b]	% SSB[c,d]	Silica content (%)	Tillers (no.)	% DH[b]	Productive tillers (no.)	% WH[b]	% SSB [b,d]
IR67962-84-2-2	10.6	11.2 (19.5)	5.9	28.4 (32.1)	99.0 (10.0)	5.9	15.2	27.7 (31.6)	7.4	35.9 (36.8)	69.9 (57.0)
IR62	15.0	5.7 (13.6)	20.6	17.7 (24.8)	79.2 (8.9)	6.3	27.2	19.7 (26.0)	26.9	27.8 (31.7)	42.5 (40.4)
IR64	17.6	10.8 (18.9)	20.6	107 (19.0)	76.3 (8.7)	6.4	21.9	17.8 (24.6)	21.8	13.5 (21.5)	36.4 (36.7)
IR72	13.9	7.0 (15.2)	11.7	16.1 (23.6)	92.1 (9.6)	6.2	29.2	10.1 (17.8	25.7	17.1 (24.3)	53.5 (46.5)
LSD (0.05)	2.3	5.7	2.3	6.3	0.4	n.s	3.3	5.1	2.3	7.2	14.1
LSD (0.01)	3.0	7.5	3.0	8.3	0.5		4.3	6.8	3.1	9.5	18.7

[a]DH = deadhearts, WH = whiteheads. [b]Numbers in parentheses are arcsine-square root-transformed means. [c]Numbers in parentheses are square root-transformed means. [d]% of larvae and pupae in dissected plants infested with SSB.

Effects of simulated pest damage on rice yields

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The types and levels of damage affecting rice yields at different crop stages were evaluated by simulating pest damage. Many plant species have the ability to decrease the negative effects of injury on yield, a process known as compensation (Pedigo 1991). Rice can compensate for stem borer damage at the tillering stage (Rubia 1994). Rice plants, however, do not compensate for cut tillers to the same degree that they compensate for stem borer damage (Rubia 1996).

Four damage simulation trials were conducted from February 1998 to January 1999 in Phnom Penh, Cambodia, using a randomized complete block design with four replications and four treatments per replicate. Each replicate consisted of a concrete basin (2.8 m × 2.4 m surface, 0.6 m deep), filled with soil to a depth of 0.4 m. The NPK rate was the same in all experiments—60-60-30 kg ha^{-1}, applied as 30-30-30 NPK basally and 30-30 NP at panicle initiation (PI). There were 30 seedlings treatment^{-1} (1 seedling hill^{-1}) at 20-cm spacing. IR66 seedlings (25 d old) and medium-duration CAR11 seedlings (33 d old) were transplanted. In these experiments, "50% damage" refers to complete removal of half of the leaves or stems, not cutting the leaves or stems in half. The weight and moisture content of each plot's yield were recorded. Weights were adjusted to 14% moisture and converted to t ha^{-1}. Significant differences in mean treatment yields were detected by ANOVA and LSD with IRRISTAT 4.0.

Removing all of the leaves from seedlings and cutting off 50% of the leaves at tillering did not significantly reduce yields of IR66. Cutting off 50% of the leaves at booting significantly reduced yields. Cutting off 50% of tillers at booting significantly reduced yields of IR66. Cutting off 50% of tillers at stem elongation, however, did not significantly reduce yields. LSD analysis produced an inconclusive result for treatments with all seedlings cut off at water level. Cutting off 100% of stems at the seedling, tillering, or booting stage of IR66 resulted in yields significantly lower than those of undamaged controls. No IR66 seedlings recovered from cutting at ground level in standing water (Table 1). Cutting off all seedlings at ground level, cutting off all tillers 30 d after transplanting (DAT) at the water surface, and cutting off all tillers at booting at water level significantly reduced yields of CAR11, although some plants showed vegetative recovery (Table 2). Unlike IR66, CAR11 seedlings exhibited some recovery from cutting at ground level in standing water.

The yields in these experiments are typically achieved by Cambodian rice farmers. These results suggest that rice has a considerable capacity to compensate for or recover from drastic damage. Removing all leaves during the seedling stage and 50% of leaves during stem elongation did not reduce yields, while removing 50% of leaves at booting did. A leaf damage of more than 50% by pests is quite rare. This suggests that, before PI, it may not be necessary to manage pests of rainfed rice, which restrict their damage to leaves, except to lower pest density and reduce damage at PI. Likewise, pests that cut tillers such as rats (Jahn et al 1999) are more likely to reduce yields after PI.

Table 1. Yield response of IR66 to simulated pest damage at different crop stages.

Treatment	Mean yield (t ha^{-1})	F	PROB	5% LSD
Cut off all seedling leaves	3.1	3.91*	0.04	0.467
Cut off 50% of leaves at tillering	3.2			
Cut off 50% of leaves at booting	2.6			
Control for trial no. 1	3.3			
Cut off all seedlings at water level	2.8	5.19*	0.02	0.518
Cut off 50% of tillers at stem elongation	3.1			
Cut off 50% of tillers at booting	2.5			
Control for trial no. 2	3.3			
Cut off all seedlings at ground level	0	78.43**	0.001	0.485
Cut off all tillers 30 DAT at water level	1.5			
Cut off all tillers at booting at water level	0.5			
Control for trial no. 3	3.0			

* = significantly different at 0.05% level, ** = significantly different at 0.01% level, PROB = probability.

Table 2. Yield response of CAR11 to complete stem-cutting at different crop stages.

Treatment	Mean yield (t ha^{-1})	F	PROB	5% LSD
Cut off all seedlings at ground level	1.2	38.47**	0.001	0.786
Cut off all tillers 30 DAT at water level	2.8			
Cut off all tillers at booting at water level	0.4			
Control	3.8			

** = significantly different at 0.01% level, PROB = probability.

Even before PI, extensive rat damage could reduce yields, as indicated by the observation that cutting 50% of tillers at stem elongation did not reduce yields, but cutting all tillers at 30 DAT reduced yields. Crabs and snails (Jahn et al 1998), which cut off seedlings at ground level, are expected to reduce yields of early or medium-maturing varieties. Armyworms, cutworms, and some grasshopper species destroy rice plants down to the water level, which could suppress yields if damage were done at booting, though not necessarily at the seedling stage. Cutting off 50% of tillers at stem elongation did not reduce yields of IR66, suggesting that it could tolerate rat damage up to at least 50% tiller cut (per plant, not per field) before PI.

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Genotypic variation in rice susceptibility to boron deficiency

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Rice, despite being relatively insensitive to boron (B) deficiency (Rerkasem et al 1988, Rerkasem and Jamod 1997), suffers from this disorder in Pakistan (Chaudhary et al 1977) and elsewhere (Shorrocks 1997). For example, about 0.6 million ha of rice in Pakistan suffer from B deficiency (NFDC 1998). Although B fertilization is the simplest and most cost-effective solution to the problem, various practical constraints prohibit its adoption by farmers cultivating low-B soils. Genetic variation in B acquisition and efficiency in biomass production is manipulated in many crop species for managing B deficiency (Rerkasem and Jamod 1997). Therefore, we studied some major rice cultivars in Pakistan for their comparative B efficiency.

A greenhouse study was conducted using a B-deficient (hot water extractable B 0.08 mg kg^{-1}) silty clay loam surface soil (0–20 cm) of the Rajar series (Typic Ustortents) with pH (1:1) 8.0, EC 0.27 dS m^{-1}, $CaCO_3$ equivalent to 3.2%, organic matter 0.38%, and AB-DTPA extractable nutrient contents (mg kg^{-1}): NO_3-N, 1.2; phosphorus (P), 0.07; potassium (K), 68; zinc (Zn), 0.56; and copper (Cu), 2.3. Four cultivars each of basmati types (fine aromatic—e.g., Super Basmati, Basmati 6129, Basmati 385, and Basmati 370) and IRRI types (medium-long grain/coarse grain, e.g., DR83, KS282, Pakhal, and IR6) were used. Four rice seedlings transplanted in 5-kg soil portions, placed in polyethylene-lined plastic pots, were supplied with two rates of B, 0 (control) or 1.5 mg B kg^{-1} soil as H_3BO_3. Basal fertilization included 800 mg N kg^{-1}, 100 mg P kg^{-1}, 600 mg K kg^{-1}, 10 mg Zn kg^{-1}, and 5 mg Cu kg^{-1} soil. One-fourth of the dose of N and K and the full dose of the other nutrients were applied before transplanting. The other three-fourths of N and K were applied in three equal splits—30, 45, and 60 d after transplanting, respectively. Soil in all pots was kept continuously flooded by irrigating with deionized water. Pots were arranged in a split-plot design, assigning cultivars to main plots and B to subplots, with three replications. Young whole shoots (<30 cm tall) of two plants in each pot were sampled for B analysis. Grain and straw yield of the remaining two plants were recorded at maturity. Plant tissues were dry-ashed and B concentration in the digests was determined colorimetrically using azomethine-H.

Boron deficiency delayed inflorescence by 4 d in all cultivars. Rice cultivars grown without B exhibited differential sensitivity to B deficiency, with susceptibility of Super Basmati > Basmati 6129 > DR83 > KS282 > Basmati 385 > Pakhal > Basmati 370 > IR6 ($P < 0.05$; see table). With B application, a maximum yield increase of 46% over the control was observed in Super Basmati and a minimum of 10% was seen in IR6. Straw yield increase with B fertilization was maximum in Super Basmati (77%) and minimum in Basmati 370 (2%). There was hardly any relationship between magnitude of reduction in grain and straw yields of various cultivars and B deficiency (see table). Half of the basmati (fine aromatic) and IRRI varieties (coarse grain) yielded >20% more with B application. The cultivars' sensitivity to B

Mean grain and straw yield, B concentration in young whole shoots, and B uptake by rice cultivars as affected by B application to a B-deficient soil.

Cultivar	Grain yield[a] (g $plant^{-1}$)		Straw yield[a] (g $plant^{-1}$)		B concentration in whole shoots[a] (mg kg^{-1})		B uptake[a] (mg $plant^{-1}$)		Fertilizer B recovery (% of applied B)	Agronomic efficiency (g grain g^{-1} applied B)
	Control	+B	Control	+B	Control	+B	Control	+B		
Super Basmati	22	31	95 fg	168 d	4.50 fg	7.00 de	549 g	1420 d	0.12	1320
Basmati 6129	17	23	239 b	268 a	4.60 fg	5.60 ef	1339 de	2338 b	0.13	746
DR83	38	46	74 gh	107 f	5.50 efg	10.00 ab	591 g	1182 a	0.08	1120
KS282	39	47	78 gh	86 fg	5.30 fg	10.70 a	553 g	960 f	0.05	886
Basmati 385	35	41	202 c	277 a	4.26 fg	7.71 cd	1256 de	2698 a	0.19	1054
Pakhal	36	42	59 h	79 gh	4.30 fg	8.00 cd	517 g	954 f	0.06	894
Basmati 370	30	34	167 d	171 d	3.94 g	8.60 bc	894 f	1635 c	0.10	614
IR6	40	44	135 e	156 de	5.50 efg	8.91 bc	696 g	1330 de	0.08	534
LSD (0.05)	3.6	3.6	21	21	1.47	1.47	177	177		

[a]Values within a parameter followed by different letters are significantly different at $P < 0.05$.

deficiency was not related to grain length/fineness or biomass produced per plant (see table). Contrary to the belief that B deficiency hampers grain setting more than vegetative growth (Rerkasem and Jamod 1997), the magnitude of straw biomass reduction was greater than grain yield reduction in Super Basmati, DR83, Basmati 385, and Pakhal.

Rice cultivars differed significantly in B uptake when grown under identical environmental conditions. For example, Basmati 6129 was 2.6 times more efficient in using B from B-deficient soil than Pakhal ($P < 0.05$; see table). Despite its higher B use efficiency, however, Basmati 6129 was more susceptible to B deficiency than Pakhal (see table). Fertilizer B recovery is the fraction of applied B taken up in aboveground plant parts, while agronomic efficiency refers to extra grain yield over the control yield per unit of applied B. Boron-efficient and -inefficient rice genotypes were distinguishable by B concentration in their B-deficient plant tissues, B uptake, fertilizer B recovery, and agronomic efficiency (see table).

Basmati is famous for its aroma and long, fine grains. As Super Basmati, a premier basmati cultivar in Pakistan, was more sensitive to B deficiency than other basmati varieties, the situation is rather alarming because of widespread low soil B in Pakistan (NFDC 1998) and elsewhere (Shorrocks 1997). Boron efficiency is believed to be a single gene-controlled trait. Therefore, tailoring or selecting plant genotypes for B-deficient soils might be more practical than changing the soil to fit the plant. Genetic manipulation, through an efficient molecular approach, could help transfer the B-efficient trait of Basmati 370 or IR6 into currently popular fine aromatic varieties such as Super Basmati.

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Effect of mixing black clay soil and organic amendment on properties of coarse-textured soil and rice yield

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In Tamil Nadu, rice is grown on coarse-textured soils across a significant area with marginal yields. To improve soil, water, and nutrient retention and to enhance rice yields, a field experiment was conducted during the wet seasons of 1996-97 and 1997-98 (October-January), with each season trial done in one of two adjacent fields. Treatments used were different incorporation levels of black clay soil (0, 20, 40, 60, 80, and 100 t ha^{-1}), with or without 25 t raw coir pith ha^{-1}, replicated thrice in a randomized block design. The black clay soil and coir pith were mixed with the puddled soil up to 20 cm depth by trampling and leveling before transplanting. At the beginning of the experiment, soil in control plots had comparable properties such as contents of clay, silt, organic carbon, total N, P, K, Ca, and Mg, available N, P, K, and exchangeable Ca and Mg, electrical conductivity (EC), pH, and cation exchange capacity (CEC) as the soil in the rest of the field. Rice varieties IR60 and ADT36 (parentage: local variety, Triveni/IR20) were grown in the first and second croppings, respectively. Grain and straw yield were recorded. Neither field supported any crop other than the wet-season rice crop under study. The soil was coarse-textured throughout the solum of 2 m and was classified as a coarse loamy, kaolinitic, nonacid, isomegathermic Typic Ustipsamment.

Postharvest soil samples (0–20 cm) were analyzed for particle size (International Pipette), organic carbon (chromic acid), EC and pH (saturation paste extract), NH_4OAc-CEC, Kjeldahl-total N, Pemberton-total P, total K (Stanford and English), total Ca and Mg (Versonate), available N ($KMnO_4$), Olsen P, and NH_4OAc-extractable K, Ca, and Mg.

All soil properties were influenced by treatments (see table). For incremental amendments of 20 t black clay soil ha^{-1}, there was progressive improvement in most of the parameters, which might have enhanced crop yield. Addition of coir pith alone or in combination with black clay soil helped boost levels of available N, K, and organic carbon. Reduction in total soil K, Ca, and Mg due to coir pith addition suggested soil dissolution by organic acids produced during decomposition of coir pith, which might have promoted increased nutrient availability to the crop. The significant increase in CEC of sandy soil due to the addition of black clay soil may have enhanced nutrient retention and minimized leaching of nutrients, as low CEC can constrain crop performance in coarse-textured soils.

Addition of coir pith alone to sandy soil markedly decreased soil pH, indicating the acidifying effect of organic acid pro-

Effect of mixing black clay soil and organic amendment on sandy soil properties[a] at postharvest and yields of rice crop.

Treatment	Clay (%)	Silt (%)	Organic carbon (%)	EC (dS m^{-1})	pH	Available (%)			Exch. cations (c mole $[p^+]$ kg^{-1})		CEC (c mole $[p^+]$ kg^{-1})	Total (%)					Yield (t ha^{-1})			
																	1996-97 IR60		1997-98 ADT36	
						N	P	K	Ca^{++}	Mg^{++}		N	P	K	Ca	Mg	Grain	Straw	Grain	Straw
Control	14.4	12.3	0.15	0.10	7.4	0.009	0.0003	0.011	1.4	0.8	2.2	0.02	0.003	0.10	0.46	0.27	2.3	4.2	2.6	4.1
20 t black clay soil ha^{-1}	15.5	13.1	0.26	0.25	7.9	0.011	0.0004	0.013	2.2	1.3	3.3	0.02	0.006	0.13	0.57	0.36	2.4	4.6	3.0	4.4
20 t black clay soil + 25 t coir pith ha^{-1}	15.7	13.1	0.48	0.12	7.6	0.011	0.0004	0.013	2.1	1.2	4.3	0.02	0.005	0.12	0.50	0.34	2.5	4.7	3.1	4.4
40 t black clay soil ha^{-1}	16.8	13.9	0.37	0.19	8.2	0.012	0.0005	0.014	3.7	2.1	5.3	0.02	0.008	0.16	0.68	0.49	2.6	5.1	3.5	4.7
40 t black clay soil ha^{-1} + 25 t coir pith ha^{-1}	17.0	13.7	0.53	0.16	7.9	0.013	0.0005	0.015	3.1	1.9	6.3	0.02	0.007	0.15	0.62	0.44	2.7	5.2	3.7	4.8
60 t black clay soil ha^{-1}	18.0	14.5	0.46	0.20	8.3	0.014	0.0005	0.016	4.5	3.1	7.5	0.02	0.009	0.18	0.79	0.59	2.8	5.5	4.0	5.1
60 t black clay soil + 25 t coir pith ha^{-1}	18.2	14.3	0.60	0.16	8.1	0.015	0.0006	0.017	4.2	2.9	8.2	0.02	0.008	0.17	0.70	0.52	2.9	5.7	4.1	5.1
80 t black clay soil ha^{-1}	19.2	15.7	0.54	0.23	8.5	0.015	0.0006	0.017	6.7	3.7	9.4	0.02	0.012	0.22	0.88	0.73	3.0	5.8	4.4	5.4
80 t black clay soil + 25 t coir pith ha^{-1}	19.4	15.4	0.72	0.19	8.2	0.016	0.0006	0.018	6.4	3.6	10.2	0.02	0.010	0.20	0.81	0.70	3.2	6.0	4.6	5.4
100 t black clay soil ha^{-1}	20.5	16.5	0.65	0.26	8.6	0.017	0.0007	0.018	7.5	4.4	11.4	0.02	0.014	0.23	0.95	0.82	3.3	6.2	5.0	5.6
100 t black clay soil + 25 t coir pith ha^{-1}	20.8	16.4	0.73	0.21	8.4	0.017	0.0007	0.019	7.4	4.2	12.1	0.02	0.013	0.21	0.89	0.78	3.8	6.8	5.3	6.0
25 t coir pith ha^{-1}	14.3	11.6	0.36	0.07	6.7	0.009	0.0004	0.013	1.2	0.6	2.9	0.02	0.002	0.10	0.38	0.19	2.4	4.3	2.9	4.2
SED	0.1	0.1	0.01	0.00	0.1	1.3×10^{-4}	1.3×10^{-6}	1.3×10^{-4}	0.1	0.0	0.1	0.01	0.001	0.00	0.01	0.03	0.027	0.036	0.033	0.068
LSD (0.01)	0.2	0.4	0.01	0.02	0.1	3.1×10^{-4}	9.3×10^{-6}	4.4×10^{-4}	0.2	0.1	0.2	0.23	0.004	0.00	0.02	0.07	0.076	0.10	0.099	0.193

[a]Because soil properties of the experimental fields were similar in both seasons, only data pertaining to 1997-98 are presented along with yields of both seasons' experiments. EC = electrical conductivity, SED = standard error of difference, LSD = least significant difference.

duced upon decomposition. Therefore, it is advisable to add coir pith with a pH-buffering material such as black clay soil to slow down acidification.

The treatments significantly influenced yields of grain and straw in both cropping periods. Treatments with black clay soil had the greater benefit, probably due to the integrated effect of all improved soil properties discussed earlier. Grain and straw yields of ADT36 were higher during the 1997-98 wet season than those of IR60 in the previous wet season. The harvest index of ADT36 increased incrementally with the addition of black clay soil from 0.39 to 0.47, but it scarcely responded to the addition of coir pith (data not shown). The harvest index of IR60 did not respond to either treatment.

In summary, adding 100 t of black clay ha^{-1} alone during the first year and 25 t of raw coir pith ha^{-1} once every year may enhance the productivity of rice grown on sandy soil. An economic analysis showed that if black clay soil and coir pith are available within 10 km of the experimental field, their application would be profitable proportionate to the level of black clay soil added (data not shown). The highest net profit was US$297.53 ha^{-1} (US$1 = Indian Rs 43) under the treatment of 100 t black clay soil and 25 t coir pith ha^{-1}, and the lowest was under the control plot with US$57.02 ha^{-1}. These research results would be applicable wherever black clay soil and coir pith treatments are possible.

Response of salt-tolerant rice somaclones to different levels of nitrogen

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Breeding for and subsequent cultivation of tolerant varieties have proved effective in harnessing limiting ecosystems worldwide, which otherwise remain idle. In the humid tropics of Bay islands, about 4,000 ha in valleys remain fallow due to frequent inundation with tidal sea water. Our earlier attempts to cultivate conventionally bred salt-tolerant rice varieties in those areas were only partially successful due to the inherent low yield of available varieties. The potential of in vitro culture-induced variation (somaclonal variation) was explored in developing salt-tolerant rice varieties suitable for such areas. Nine promising somaclones derived from a tall traditional salt-tolerant cultivar Pokkali (Mandal et al 1999) were assessed for their response to different N doses in the wet tropics of Andaman islands. The major objective was to select the most suitable among the somaclones and to determine the optimum level of N requirement to attain maximum yield.

The experiment was conducted under rainfed conditions at the Field Crops Research Station of CARI, Port Blair (lat 11° 41' 13.04" N; long 92° 43' 30.16" E), in a split-plot design with three replications during the wet seasons of 1997 and 1998. Nine semidwarf somaclones, with parents Pokkali and a modern high-yielding variety (HYV)—Taichung Sen Yu—as check, formed the main plot (Table 1). Four levels of N (0, 40, 80, 120 kg ha^{-1}) were used in the subplot (plot size 4 m × 3 m). Selected somaclones were originally developed from 1,190 primary regenerants by recurrent selection for seven generations under saline and normal soils. The soil of the experimental plot—a typical salt soil of the area—was clay loam in texture, with a pH of 6.8 containing 142 kg ha^{-1} alkaline permanganate extractable available N (low level), 16 kg Olsen P ha^{-1} (medium level), and 182 kg NH_4OAc-extractable K ha^{-1} (medium level). Based on the yield of each entry at different N levels pooled over years, quadratic response functions were fitted. Using these functions, the optimum N levels as well as the agronomic N use efficiency at optimum N levels were determined for each of the somaclones.

The somaclones displayed significant variation in yield and yield-attributing characters. Five out of nine somaclones were significantly taller, whereas others were on a par with the check variety. Taichung Sen Yu produced the most tillers per plant and was on a par with BTS16. Tiller number per plant of all other somaclones varied between 10 and 12. BTS24 showed the highest number of panicles per plant. Panicle length did not vary much among the somaclones. All somaclones except BTS2 outyielded the check (Table 1). BTS24 had the highest yield, which was on a par with BTS18, BTS13, and BTS17. The average yield of all somaclones pooled over years was significantly higher than that of Taichung Sen Yu, except for BTS11-11, BTS11-3-1, and BTS2. On average, the somaclones produced 18.5% higher yield than the check, with a maximum of 30% for BTS24. The harvest index (HI) of the somaclones, ranging from 33.0% to 37.5%, was also better than the check's (30.8%), except for BTS11-3-1, BTS11-16, and BTS11-11.

Table 1. Grain yield (t ha^{-1}) of salt-tolerant Pokkali somaclones at different N levels.

Somaclone	N level (kg ha^{-1})				
	0	40	80	120	Mean[a]
			1996-97		
BTS17	3.1	4.0	4.4	4.3	4.0 a
BTS18	3.2	3.9	4.4	4.3	4.0 a
BTS2	2.6	3.2	3.4	3.3	3.1
BTS24	3.5	4.3	4.5	4.3	4.2 a
BTS11-3-1	2.4	3.2	3.8	3.6	3.3
BTS11-16	2.3	3.3	3.9	3.5	3.2
BTS13	3.3	4.0	4.3	4.2	3.9 a
BTS11-11	2.6	3.2	3.4	3.3	3.1
BTS16	2.6	3.6	4.2	4.0	3.6
Pokkali (parent)	1.9	2.4	2.6	2.3	2.3
Taichung Sen Yu (HYV check)	2.6	3.2	3.4	3.2	3.1
Mean	2.7	3.5	4.2 a	4.0 a	
CD (*P* = 0.05)	Variety = 0.26, Nitrogen = 0.32, V x N = not significant				
			1997-98		
BTS17	3.4	4.2	4.6	4.6	4.2 a
BTS18	3.4	4.2	4.7	4.6	4.2 a
BTS2	2.6	3.4	3.6	3.4	3.2
BTS24	3.4	4.3	4.8	4.7	4.3 a
BTS11-3-1	2.6	3.4	3.9	3.6	3.4
BTS11-16	2.8	3.6	4.0	4.0	3.6
BTS13	3.4	4.2	4.5	4.4	4.1 a
BTS11-11	2.8	3.6	4.0	3.7	3.5
BTS16	3.0	3.6	4.2	4.2	3.7
Pokkali (parent)	1.8	2.3	2.6	2.3	2.3
Taichung Sen Yu (HYV check)	3.0	3.6	4.0	3.9	3.6
Mean	2.9	3.7	4.1 a	4.0 a	
CD (*P* = 0.05)	Variety = 0.20, Nitrogen = 0.25, V x N = not significant				

[a]a = denotes statistical parity among treatments.

The yield of somaclones peaked at 80 kg N ha^{-1} but declined beyond 80 kg ha^{-1}. The calculated optimum level of N for the somaclones varied between 63 and 75 kg ha^{-1} (Table 2). The calculated maximum agronomic N-use efficiency was for BTS24 (10.6 kg ha^{-1} kg^{-1} N), followed by BTS18, BTS13, and BTS11-16. Vigorous crop growth seemed to be governed by a large number of tillers and higher yield-attributing characters. The highest yield of BTS24 at all N levels probably resulted in higher agronomic N-use efficiency compared with other somaclones (Table 1). This line also showed a more distinct quadratic response function compared with other lines (Table 2).

In summary, 63–70 kg N ha^{-1} seems to be the optimum range to obtain maximum yields of Pokkali somaclones in the wet tropics of the Andamans. BTS24 was the most promising somaclone, outyielding the check Taichung Sen Yu. BTS24 may be cultivated on a large scale in the Andamans and tested elsewhere under similar agronomic environments.

Reference

Mandal AB, Pramanik SC, Choudhury B, Bandyopadhyay AK. 1999. Salt-tolerant somaclones: performance under normal saline soils in Bay Islands. Field Crops Res. 61:13–21.

Table 2. Response function of Pokkali somaclones at different N levels.

Somaclone	Response function[a]	R^2[b]	Optimum N level (kg ha^{-1})	Grain yield at optimum N level (t ha^{-1})	Agronomic N-use efficiency
BTS17	$Y = 3,284 + 10.45\ X - 0.024\ x^2$	0.778*	66.4	3.9	8.86
BTS18	$Y = 3,145 + 11.34\ X - 0.027\ x^2$	0.885*	69.7	3.8	9.45
BTS2	$Y = 2,463 + 9.14\ X - 0.019\ x^2$	0.739*	63.7	3.0	7.90
BTS24	$Y = 3,326 + 11.74\ X - 0.015\ x^2$	0.757*	75.4	4.1	10.60
BTS11-3-1	$Y = 2,346 + 9.75\ X - 0.021\ x^2$	0.802*	64.0	2.9	8.40
BTS11-16	$Y = 2,472 + 10.42\ X - 0.015\ x^2$	0.833*	62.7	3.1	9.48
BTS13	$Y = 3,147 + 10.57\ X - 0.014\ x^2$	0.752*	71.6	3.8	9.57
BTS11-11	$Y = 2,446 + 9.65\ X - 0.018\ x^2$	0.789*	65.7	3.0	8.47
BTS16	$Y = 2,437 + 10.15\ X - 0.021\ x^2$	0.872*	70.0	3.0	8.68
Pokkali (parent)	$Y = 2,026 + 1.77\ X - 0.018\ x^2$	0.778*	52.4	2.1	9.54
Taichung Sen Yu (HYV check)	$Y = 2,365 + 9.72\ X - 0.024\ x^2$	0.801*	63.6	2.9	8.19

[a]Y = yield in kg ha^{-1}, X = N level in kg ha^{-1}. [b]* = significant at $P = 0.05$.

Information support system for rice crop management

TropRice is an information support system of best-bet practices designed to provide practical field-level guides for rice crop management in the tropics. It aims to help users make informed decisions related to rice production.

It is not a single system for the world. It contains some generic information, but some are site- or region-specific. TropRice is intended to be a template that could be modified for different environments. As improved systems on component technologies become available, they will replace or be linked to the system. The present system is aimed at irrigated rice in a Los Baños, Philippines-type of environment.

TropRice is an ongoing project developed by IRRI scientists and specialists who have contributed to the technical content. It is intended for intermediary technology transfer agents as a response to the recognition that many farmers do not have access to information on how to grow rice. Current information technology offers new ways of packaging and presenting information. The system is being evaluated among three separate groups: nongovernment organizations, farmers, and the private and public sector.

Web site: http://www.cgiar.org/irri/TropRice

Source: *Training Center, IRRI*

TropRice

Effect of late planting and lopping on productivity of traditional tall basmati rice

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Among several high-quality aromatic/scented rice varieties grown in India, traditional tall basmati varieties are continuously being threatened by high-yielding cultivars. They are now considered endangered cultivars. The main reason for the genetic erosion is their low productivity, which is mainly attributed to severe lodging and poor response to nitrogen. If efforts are not made to improve their productivity and to preserve them, they may become extinct very soon.

In improving their productivity, their genetic makeup must not be altered. Agrophysiological manipulation is thus indispensable and is perhaps the only viable biological approach to conserve these precious genetic resources. Using two traditional tall basmati rice cultivars, Basmati 370 and Karnal Local, a field experiment was carried out to improve grain yield without genetic manipulation.

The trial was conducted at the IARI research farm during the 1998 and 1999 wet seasons. The field was divided into three blocks, each divided further into six plots to accommodate three treatments: normal planting (T1), late planting (T2), and lopping (cutting of foliage) (T3). The field was fertilized with a full dose of P and K at 40 and 30 kg ha^{-1}, respectively, before planting. Under normal-planting and lopping treatments, 30-d-old seedlings were transplanted in mid-July, whereas under the late-planting treatment, transplanting was delayed by a month (i.e., in mid-August) with seedlings used for normal planting (60 d old). All plots received a full dose of 50 kg N ha^{-1} 1 wk after transplanting. Lopping was done from 40–50 cm above the ground at panicle initiation stage to reduce the luxurious vegetative growth of shoots, which is responsible for lodging.

Results show that both lopping and late planting improved the productivity of both cultivars, but the extent of improvement was significantly higher in Basmati 370 than in Karnal Local (see table). Agrophysiological manipulation, such as lopping and late planting, caused a marked reduction in height and vegetative shoot growth, which in turn reduced the extent of lodging and eventually resulted in higher productivity. The number of tillers m^{-2}, grains panicle^{-1}, and harvest index were increased. Lodging is considered the main biological constraint to sink potential realization in traditional tall rice cultivars. Despite the significant reduction in biological yield by nongenetic manipulation, the marked increase in grain yield was mainly attributed to a significant improvement in harvest index. Irrespective of treatments, Basmati 370 had better yield and yield-attributing characters than Karnal Local. Thus, agrophysiological manipulation improved the productivity of these basmati rice varieties without any effect on grain and cooking quality characteristics.

Growth, yield, and yield components of basmati rice cultivars as influenced by late planting and lopping.

Variety/ treatment	Plant height (cm)	Panicles m^{-2} (no.)	Grains panicle^{-1} (no.)	1,000-grain wt (g)	Economic yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
				1998 wet season				
Basmati 370								
Normal	170	405	35	24.0	3.2	11.8	15.0	21
Late planting	152	412	45	24.5	4.1	8.4	12.5	33
Lopping	155	410	50	23.8	3.9	8.1	12.0	32
Karnal Local								
Normal	175	390	30	23.5	2.5	12.0	14.5	17
Late planting	156	415	40	23.2	3.2	9.8	13.0	24
Lopping	165	406	35	23.3	2.8	8.7	11.5	24
LSD (5%)								
Variety (V)	ns	ns	3	ns[a]	0.5	ns	1.3	4
Treatment (T)	12	15	5	ns	0.8	3.1	3.0	7
V × T	16	17	9	ns	1.1	3.8	3.5	10
				1999 wet season				
Basmati 370								
Normal	165	400	40	24.0	3.8	13.2	17.0	22
Late planting	145	410	50	24.2	4.8	8.8	13.6	35
Lopping	150	405	58	24.5	4.5	8.5	13.0	35
Karnal Local								
Normal	170	385	35	23.0	2.8	13.2	16.0	18
Late planting	150	415	52	23.5	3.5	10.5	14.0	25
Lopping	160	400	50	23.5	3.0	7.0	10.0	30
LSD (5%)								
Variety (V)	ns	ns	4	ns	0.5	ns	1.1	5
Treatment (T)	10	12	6	ns	0.7	2.5	2.8	8
V × T	15	16	10	ns	1.0	3.2	3.5	10

[a]ns = nonsignificant.

Effect of buckwheat rotation with rice on total productivity in southern Ukraine

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Results from several experiment stations in Poltava, Sumy, and other areas in the Ukraine have shown that buckwheat is a good rotation crop. Productivity of winter wheat and rye after buckwheat is higher than after stubble crops (wheat, barley, oats) and silage corn. In some years, buckwheat, as a fertility-building crop, does not have the same effect as pea (Yefimenko and Barabash 1986). Its high efficiency as a rotation crop is confirmed by farmers working under different soil and climatic regions of the Ukraine.

Studies done by the Ukrainian Institute of Microbiology revealed the presence of nitrogen-fixing *Azospirillum brasilense* 18-2 in buckwheat root rhizosphere (Lokhova 1997). This is probably how the buckwheat root system improves soil fertility for the succeeding crops.

Buckwheat adds much fresh organic matter to the soil: the amount of stubble after buckwheat in the soil of the Ukrainian Experimental Station rice field was 26.4 t ha^{-1} vs 24.3 t ha^{-1} for alfalfa-grass sod. Repnikov (1991) found that grain yield of rice increased after buckwheat (4.7 t ha^{-1}) in contrast with rice after rice (2.2 t ha^{-1}).

Populidi (1976) reported that rice after buckwheat on a 60-ha rice farm in Romanovsky of the Rostov region (Russia) yielded 3.3 t ha^{-1} and a 29-ha area 2.5 t ha^{-1} under black fallow (unsown during vegetative period, weed-free) conditions.

The buckwheat trials were carried out under rice crop rotation conditions in Kherson District. The area is in the south steppe zone and is characterized by arid conditions with high temperature averaging 33.5 °C and scanty and unsteady air moisture. Mean daily air temperature during July-August is 23–24 °C; maximum air temperature reaches 38–40 °C, while soil surface temperature is 60–61 °C. Average annual rainfall is 360 mm. The average windspeed is about 4 m s^{-1}, whereas maximum windspeed is 20 m s^{-1}. Annual evaporation for the region is about 900–1,000 mm. The longest of sunshine recorded is 15 h and 50 min. Climatic conditions in southern Ukraine allow two crops per year during the warm period.

The topsoil of the experimental site is meadow-chestnut (a semihydromorphic soil with glay feature), compressed, with a pH of 7.6, and a humus content of 2.1 in a surface soil of 20-cm depth. Sowing time for dry-seeded rice is early May; sowing time for the intercrop buckwheat is the first half of July. The rice cultivar used was Krasnodarsky 424, an Italian variety with 130-d duration, whereas the buckwheat cultivar used was Kosmeya with a 74-d duration. Rice was sown where buckwheat had been previously grown. The site under black fallow was used as a control in the same field.

Buckwheat was found to be better for rice than black fallow (Table 1). The average yield of intercropped buckwheat in 8-y field experiments under various production situations was 1.6 t ha^{-1}. Buckwheat intercropped with rice can increase the harvest of both buckwheat and rice from irrigated lands.

We estimated the economic efficiency of intercropped buckwheat in a rice system. Table 2 gives comparative data for buckwheat and various crops.

The grain production cost of intercropped buckwheat was US$199 ha^{-1}, with a net income of $237 (based on an exchange rate of US$1= 5.2109 *gryvnya* in Jan 2000). Thus, production cost was $133 t^{-1} and profitability was 119%. As a whole, total net incomes from double cropping are as follows: annual grass for green fodder + buckwheat = $318; spring barley + buckwheat = $394; and winter wheat + buckwheat = $538.

Productivity of rice can be greatly improved by intercropping buckwheat with rice. This will allow more grain production from irrigated areas and increase the profitability of rice-based cropping systems.

Table 1. Effect of buckwheat as a prerice crop on rice productivity.

Background	Rice yield (t ha^{-1})			Mean	Yield increment	
	1988	1989	1990		t ha^{-1}	%
Fallow land (control)	7.9	5.7	7.1	6.9	–	–
Buckwheat	9.2	6.6	8.9	8.2	1.3	19
LSD (5%)				0.98		

Table 2. Economic performance of some crops in rice fields.

Item	Spring barley	Winter wheat	Annual grass green fodder	Buckwheat
Yield (t ha^{-1})	3.4	4.5	13.4	1.5
Value of gross product (US$)	377	605	270	436
Production cost for 1 ha^{-1} (US$)	220	308	189	199
Net income from 1 ha^{-1} (US$)	157	301	81	237
Grain cost t^{-1} (US$)	65	68	14	133
Profitability (%)	71.4	97.7	42.7	119.1

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Effects of salt and osmotic stress on free polyamine accumulation in moderately salt-resistant rice cultivar Aiwu

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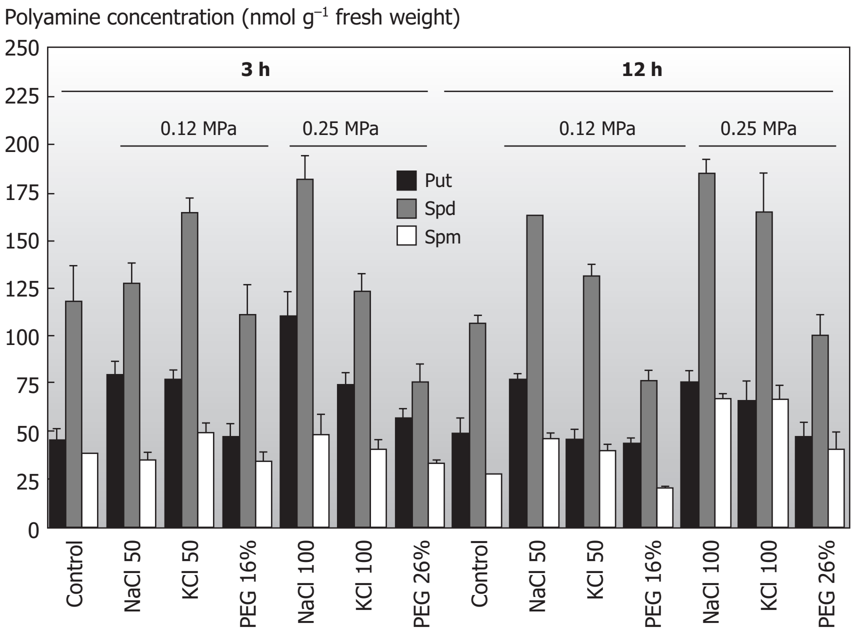
Polyamines (putrescine, sermidine, and spermine) are ubiquitous and positively charged compounds involved in the control of plant growth and development and in the response to several biotic and abiotic stresses. Data on polyamine accumulation in salt-stressed rice are contradictory and generally deal with exposure of several days to NaCl only. Our aim was to determine whether the ionic or osmotic component of salt stress is involved in the initial steps of polyamine accumulation in rice.

Twenty-five-day-old plants of cultivar Aiwu maintained on nutrient solution (Yoshida et al 1976) in a phytotron (light intensity: 300 μmol m^{-2} s^{-1}, 12 h d^{-1}, 70% relative humidity, and 30/25 °C day/night temperatures) were exposed to isoosmotic concentrations of NaCl or KCl (50 and 100 mM) or PEG (polyethylene glycol 6000; 16% and 26%). These stressing agents induced a decrease in osmotic potential of nutrient solution corresponding to –0.12 and –0.25 MPa for the two stress intensities, respectively. Stress imposition corresponded to the beginning of the light period and plants were collected after 3 and 12 h of exposure. Osmotic potential (ys) and ion content were quantified separately on roots and shoots using a vapor pressure osmometer (Wescor) and an inductively coupled argon plasma emission spectrophotometer according to Lutts et al (1999). Endogenous free polyamine was quantified by a Shimadzu RF-10Axl fluorimeter after separation by high-performance liquid chromatography (HPLC) according to Aziz et al (1999).

Dry weight percentages (DW; in %), osmotic potential ys (in MPa), Na^+ and K^+ concentrations (in mmol g^{-1} DW) in roots and shoots of plants exposed for 3 or 12 h to isoosmotic concentrations of NaCl or KCl (50 or 100 mM) or PEG (16% or 26%). The two stress intensities correspond to an induced decrease in osmotic potential of nutrient solution of –0.12 and –0.25 MPa, respectively. Values are means of eight replicates per treatment: for a given parameter, means of the same line followed by the same letter are not significantly different at *P* = 0.05, according to the method of Duncan using the MSTAT-C system (Michigan State University).

		–0.12 MPa				–0.25 MPa		
		Control	50 mM NaCl	50 mM KCl	16% PEG	100 mM NaCl	100 mM KCl	26% PEG
Roots	*3 h*							
	DW	14.80 a	19.30 b	16.60 a	21.80 b	29.60 c	14.50 a	23.50 b
	ys	–0.32 a	–0.57 b	–0.58 b	–0.32 a	–0.62 b	–0.73 c	–0.35 a
	Na^+	0.07 a	0.37 b	0.12 a	0.06 a	0.63 c	0.07 a	0.08 a
	K^+	0.84 a	0.93 a	1.31 b	0.76 a	0.86 a	1.85 c	0.69 a
	12 h							
	DW	13.90 a	18.10 b	11.40 a	20.50 b	22.10 b	11.70 a	22.80 b
	ys	–0.31 a	–0.53 b	–0.37 a	–0.25 a	–0.45 b	–0.35 a	–0.37 a
	Na^+	0.08 a	0.82 b	0.08 a	0.11 a	0.75 b	0.13 a	0.09 a
	K^+	0.62 a	0.96 b	1.67 c	0.57 a	1.09 b	3.02 c	0.67 b
Shoots	*3 h*							
	DW	17.30 a	18.00 a	17.40 a	19.80 a	19.20 a	19.50 a	21.80 b
	ys	–1.02 a	–1.16 a	–1.12 a	–1.34 b	–1.05 a	–1.17 a	–1.31 b
	Na^+	0.03 a	0.13 b	0.05 a	0.03 a	0.17 c	0.02 a	0.03 a
	K^+	1.24 a	1.32 a	1.46 b	1.09 a	1.15 a	1.43 b	0.98 a
	12 h							
	DW	16.30 a	16.60 a	18.30 a	24.20 b	20.10 a	20.40 a	25.30 b
	ys	–1.64 a	–1.66 a	–1.63 a	–2.08 b	–1.57 a	–1.50 a	–2.46 c
	Na^+	0.05 a	0.16 b	0.03 a	0.04 a	0.19 b	0.04 a	0.03 a
	K^+	1.13 a	1.15 a	1.29 b	0.91 a	1.19 a	1.61 c	0.97 a



Putrescine (Put), spermidine (Spd), and spermine (Spm) concentrations in shoots of plants exposed for 3 or 12 h to isoosmotic concentrations of NaCl, KCl, or PEG. Two concentrations of stressing agent were used: 50 mM NaCl or KCl and 16% PEG induced a decrease in the osmotic potential of –0.12 MPa in nutrient solution, whereas 100 mM NaCl or KCl and 26% PEG induced a decrease of –0.25 MPa. Each value is the mean of eight replicates and vertical bars are S.E.

Dry weight percentages increased at the root level after 3 h of exposure to NaCl or PEG but these were not affected by KCl. A slight increase in dry weight percentages at the shoot level was observed in all treatments but was statistically significant for PEG only (see table). Similarly, the shoot ys strongly decreased after 12 h of exposure to 26% PEG, while the root ys decreased in response to ionic stresses; such a decrease was more marked during the first few hours of exposure (3 h) than at the end of the treatment (12 h). Endogenous concentrations of Na^+ and K^+ increased in both roots and shoots after 3 h of exposure to NaCl and KCl, respectively, while PEG had no effect on mineral nutrition. Root (data not shown) and shoot (see figure) putrescine concentration increased after 3 h of exposure to ionic stresses but remained unaffected in the presence of PEG. At the shoot level, spermidine concentration was also lower, in most cases, in response to PEG compared with ionic stresses. Spermidine significantly increased after 12 h of exposure to the highest dose of NaCl or KCl only. In both roots and shoots, putrescine accumulation was associated with a slight increase in agmatine content, suggesting a stress-induced stimulation of arginine decarboxylase (data not shown). We conclude that polyamine accumulation in rice may occur rapidly after the beginning of salt stress exposure and does not require any osmotic signal, at least at the shoot level.

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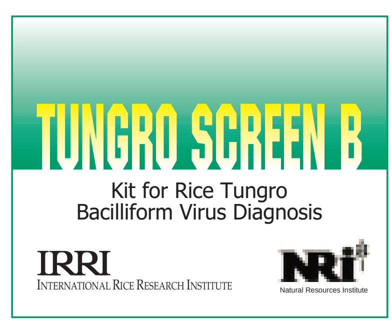
Tungro screen kits for national programs

The diagnosis of two viruses associated with the highly damaging tungro disease—rice tungro bacilliform virus (RTBV) and rice tungro spherical virus (RTSV)—is based mainly on the orange-yellow leaf discoloration symptoms exhibited on susceptible cultivars. Some of these cultivars, however, do not produce these symptoms in the field under experimental conditions.

A simple, cheap, rapid, and reliable method for detecting tungro viruses such as RTBV in rice was developed at IRRI in cooperation with the Natural Resources Institute (UK) for national programs. RTBV antisera was successfully used following a double cross-adsorption process that overcomes the problem of cross-reaction to healthy plant components. The prototype diagnostic kit was tested in the field in Bangladesh, India, Indonesia, and the Philippines. Results have shown that the kit was effective in confirming the presence of RTBV in rice samples collected from the field. The kit also had a good degree of accuracy.



This robust tool is expected to greatly facilitate tungro resistance breeding programs and has further applications for epidemiological studies and for field monitoring. Further refinement should make the kit an invaluable tool for use by rice breeders, plant pathologists, and crop protection specialists in many countries in South and Southeast Asia where tungro remains a persistent and major problem. The kit provides researchers and farmers with a quick decision-making tool to take appropriate control measures in response to emerging pest outbreaks.

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Hybrid rice—a biovillage experience

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Rice cultivation today faces the tough challenge of feeding an ever-increasing world population using shrinking resources. The scenario in a group of 19 villages in Pondicherry (south India), where the biovillage model is implemented by the M.S. Swaminathan Research Foundation, looks all the more grim with stagnating rice yields (5 t ha^{-1}) at very high input use (200 kg N ha^{-1}) in the irrigated transplanted system. The biovillage model seeks ways of addressing concurrently problems on natural resource conservation, household food security, and rural development. The model ensures sustainable productivity of the physical resource base as indicated by a baseline survey. To overcome these constraints, a participatory evaluation of the potential of hybrid rice in the biovillages was undertaken.

The methodology adopted included yield testing of rice hybrids released by research institutions through the farmers' participatory approach and demonstrations and field days to popularize test hybrids. Participatory evaluation of hybrids was done during seasonal evaluation meetings for trial farmers and during demonstrations. A survey of 100 farmers was also conducted to confirm evaluation results.

Around 60 trials were conducted to yield-test 12 hybrids over a 3-y period during dry seasons (*Naravai* [Jan-Apr] and *Sornavari* [May-Aug]) and the wet season (*Samba* [Sep-Jan]). Survey results show what farmers perceive to be the advantages and disadvantages of hybrids.

The advantages of hybrid rice include

- Higher yield (6–20% increase over local check variety)
- Farmers are motivated to adopt other management practices. (A marked reduction in the number of seedlings $hill^{-1}$ from 8–10 to 3–4 and line planting were the significant changes in cultivation practices observed.)

The disadvantages cited were

- The harvest could not be used as seeds for the next season
- Poor cooking quality of hybrids
- Higher seed cost of hybrids (by 60%) over inbred varieties and problems of seed availability
- Traders prefer inbred varieties (10–13%) over hybrids
- Less head rice recovery of hybrids (10–13% less than that of inbred varieties)
- 10–15% higher cost due to higher priced seed, weeding in nursery plot (due to lesser seed rate), and additional labor required for transplanting 1–2 seedlings $hill^{-1}$.
- Narrow yield advantage of some hybrids over inbred varieties (at least 20% yield advantage needed)
- Lesser grain weight (1,000-grain weight of 19.0 g for hybrids vs 20.8 g for inbred varieties)

About 40% of the farmers preferred hybrid rice, but the rest said they would choose hybrids if the disadvantages were overcome. An analysis of these two categories of farmers indicates that

1. Hybrid rice was preferred by farmers who
   - belong to the marginal and small farmer category and generally have low harvests (3.5–4 t ha^{-1}),
   - involve family labor in crop management and thus have a lower cultivation cost,
   - generally use inferior-quality seeds and therefore use a high seed rate (185 kg ha^{-1}) with inbred varieties,
   - sell their harvest without processing, and
   - rank grain yield more important than quality.
2. Hybrid rice was not preferred by
   - varietal seed producers who realize high income from seed production activities, and
   - large farmers who find it difficult to transplant 1–2 seedlings $hill^{-1}$ due to labor scarcity.

Based on these results, we conclude that marginal and small farmers are the potential target groups for hybrid rice, whereas women's groups could be trained to engage in hybrid rice seed production as a source of livelihood.

Farmers emphasized the need for participatory breeding of hybrids with a yield advantage of at least 20% over inbreds, better cooking quality, and lower seed cost. They also stressed the importance of ecofriendly management practices (e.g., blending organic with inorganic components in nutrient management) and standardizing drum seeder techniques to reduce labor demand to stimulate the use of hybrid rice in the biovillages.

IRRI scholarships

IRRI announces the availability of scholarships to be awarded during 2001 to support highly qualified scientists from rice-growing developing countries interested in pursuing a graduate degree in areas related to rice science. These scholarships include those provided by IRRI (PhD scholarships only) and scholarship funds which IRRI administers for other agencies, primarily the Asian Development Bank (ADB)-Japan (MS and PhD scholarships).

Scholarship slots are based on the capability of the applicants to work on areas highly relevant to the six major programs of IRRI (Irrigated, Rainfed, Upland, Cross-ecosystems, Genetic Resources, and Accelerating Impact of Rice Research).

Two kinds of scholarships are granted — full and thesis-only. Selection for all grants is highly competitive and applications must be endorsed by the applicant's institution. IRRI encourages the applications of women candidates. Scholarships may be awarded to individuals working in government organizations, universities, and nongovernment organizations.

For more information, contact: The Head, Training Center, IRRI, MCPO Box 3127, Makati City 1271, Philippines or e-mail: p.marcotte@cgiar.org

Rice market integration in Bangladesh

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Rice is the main source of protein and calorie intake in Bangladesh, contributing 93% of the total food-grain supply. The government liberalized the food grain sector in 1992 to ensure food and nutritional security. Policy instruments included removing controls, eliminating food subsidies, allowing private traders to import/export grains, and withdrawing restrictions on both domestic and international trade. The extent to which the rice market is integrated is fundamental to achieving policy objectives.

This study examines rice market integration in Bangladesh from 1992 to 1997. Following Baffes (1991), the law of one price (LOP) was used to test spatial market integration using cointegration analysis. Our testing procedure is as follows. For the LOP to hold between prices in any two markets, prices must be cointegrated. This means that their difference must be stationary, with a constant mean, a constant variance, and a constant covariance between any two observations. A necessary, but not sufficient, condition for cointegration is that each series must be integrated of the same order. First order integration I (1) is called a unit root and implies that the series is stationary in first differences.

Bangladesh has four main city markets for rice—Dhaka, Chittagong, Rajshahi, and Khulna—and we divided the country into four regions centered on each. The table shows associated markets. Nominal monthly average wholesale coarse rice prices from January 1992 to December 1997 for these 19 markets were examined. We tested for market integration by testing for the LOP first between each market in each region and second between the main city markets.

Rice markets in Bangladesh

Dhaka	**Chittagong**
Mymensingh	Noakhali
Jamalpur	Comilla
Tangail	Sylhet
Faridpur	Chittagong Hill Tracts
Rajshahi	**Khulna**
Rangpur	Jessor
Dinajpur	Kustia
Bogra	Barisal
Pabna	

In the first stage, we tested for unit roots in each series using the Dickey-Fuller test (Dickey and Fuller 1981). All were I (1) except for that in Barisal, which was excluded from further analysis. In the second stage, we tested for stationarity in the difference between each pairwise price again using the Dickey-Fuller test and all were stationary. Thus, pairwise prices were cointegrated and the LOP held universally.

We have three main results. First, the rice price in each city market was cointegrated with prices in other city markets. Second, the price in each city market was cointegrated with prices in associated markets. Third, each market in each region was cointegrated with all other markets in the same region, except for Barisal in the Khulna region. Thus, with the exception of Barisal, all markets in all regions were cointegrated by extension, and the LOP held. In contrast, the Barisal market appeared segmented, possibly because of geographical isolation.

In conclusion, following the liberalization and privatization of the food-grain sector in Bangladesh in 1992, rice markets were integrated. The government can therefore rely on market forces to supply food to deficit regions from regions producing a surplus. Moreover, its food policy, which aims to achieve the goals of food and nutritional security, appears efficient.

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The International Rice Functional Genomics Working Group

To facilitate collaboration and transfer of new findings from genomic research to applications, IRRI organized the International Rice Functional Genomics Working Group. The Working Group has the following objectives:

- Build a research community with a shared vision on rice functional genomics
- Create a common resource platform to broaden access to new knowledge and tools in functional genomics
- Accelerate application of functional genomics to rice improvement

The Working Group is intended to be a broad-based collaborative network that will benefit participants by pooling expertise and resources. To date, several institutions have expressed interest to participate in this working group.

Through a series of meetings and consultations, three activities that are considered high priority by the rice research community were identified:

1. Create an information node to communicate information related to functional genomics
2. Promote the sharing of genetic stocks
3. Facilitate sharing of resources for microarray analysis

A Web-based information node was established as an entry point for finding and sharing information and providing links to individual laboratories or organizations with interest in rice functional genomics. For more information about the site and the Working Group, go to: http://www.cgiar.org/irri/

To send comments, inputs, and suggestions, write or e-mail: genomics@irri.exch.cgiar.org

Spikelet sterility/grain discoloration in rice in Andhra Pradesh, India

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Spikelet sterility or grain discoloration was observed in all 24 villages that were surveyed in the West and East Godavari districts of Andhra Pradesh in the 1999 wet season. Affected varieties included MTU1001, MTU2067, MTU2077, MTU7029, BPT5204, and PLA1100. The pest problem had a patchy distribution in 23 villages and 1–21% of the rice area was affected. In one village, J.R. Gudem, 50% of the rice area was affected. The condition is referred to in the local language as "nallakanki tegulu."

Four types of visual symptoms were observed on affected plants: mite damage alone; mite + saprophytic fungus; mite + saprophytic fungus + sheath rot fungus; and mite + white-tip nematode + other saprophytic fungal damage. After a careful examination of many samples, we concluded that the mite is the dominant organism in all cases. The mite was identified at the Central Rice Research Institute (CRRI) as *Steneotarsonemus spinki* Smiley (Tarsonemidae). *Aphelenchoides besseyi*, the white-tip nematode, was identified at the Directorate of Rice Research, Hyderabad.

Visual symptoms such as black lesions in the leaf sheath, discolored grains, complete/partial chaffy grains, and various deformities were observed (Reissig et al 1986, Chein 1980, Rao and Prakash 1992, Rao et al 1993).

Clear mite symptoms were observed on leaves of young plants that were raised from the infested seed material, indicating that the transmission of tarsonemid mite from seed to plant is possible.

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Traditional medicinal knowledge about green leafhopper, *Nephotettix* spp., in Chhattisgarh (India)

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Green leafhoppers (GLH), principally *Nephotettix nigropictus* (Stål.) and *N. virescens* (Distant), are found in all rice-growing regions of India. These species are also known pests of rice in Japan, the Philippines, Taiwan (China), and Sri Lanka. In Chhattisgarh, *Nephotettix* sp., commonly known as Hara Maho or Saunt Keda, is one of the problematic pests of rice. To farmers and agricultural scientists, GLH is a serious pest, but to folk doctors, it is a source of additional income. Native peoples of Chhattisgarh use many problematic weeds (Oudhia 1999a), insects, spiders, and mites (Oudhia 1998, 1999b) as a source of medicine.

An ethnozoological survey was conducted in Raipur, Bastar, Bilaspur, Durg, Sarguja, Mahasamund, and Rajnandgaon districts of Chhattisgarh during 1998-99 to list the medicinal uses of common and problematic pests of different agricultural crops including rice. The study focused on folk doctors older than 60 y. In all, 20 folk doctors were interviewed and some common medicinal uses of GLH were compiled.

The survey revealed that folk doctors in the region use GLH as an additive to make traditional herbal drugs more effective. Van Bhengra (*Tridax procumbens*), a common rice weed, is used to stop any type of bleeding, and folk doctors mix fresh GLH with *Tridax* to increase its efficacy. Similarly, dried leaves of the upland weed Kukronda (*Blumea lacera*) are used to reduce the intensity of asthma attack. Dried leaves of *Blumea* with GLH are burned and the patient is advised to inhale the fumes of the mixture.

GLH was also a common major ingredient in many popular herbal combinations to treat fever and diseases such as gonorrhea. GLH that have fed on medicinal rice var. Kalimoonch were reported to be useful for treating skin problems. Freshly crushed GLH is prepared as a paste and applied on the affected area. GLH is also popularly used as a poultry feed in the region. A folk doctor from Sarguja said that GLH and brown planthopper *Nilaparvata lugens* (Stål.) combined can cure more than 40 diseases. The medicinal uses of GLH have not been previously reported.

This survey covered only a small number of the more than 2,000 folk doctors in Chhattisgarh practicing and using traditional systems of healing and medicine. A detailed survey is in progress and is expected to provide information on the medicinal uses of GLH and other rice pests. In this survey, folk doctors said that useful insects with high medicinal value can be easily identified through their specific behavior and feeding habits.

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CARDI is inaugurated

The Cambodian Agricultural Research and Development Institute (CARDI) in Phnom Penh was inaugurated on 21 November. CARDI is a multidisciplinary research institute that manages and leads all research activities to enhance agricultural development. It is the fruit of many years of work involving the Cambodia-IRRI-Australia Project (CIAP) in collaboration with Cambodia's Ministry of Agriculture, Forestry and Fisheries and Department of Agronomy and Land Improvement. Technical and financial support came from the Australian Government via AusAID.

During the ceremony, Prime Minister Hun Sen presented six awards to IRRI and ex-IRRI personnel. Drs. Glenn Denning (former head of IRRI's International Programs Management Office or IPMO) and Harry Nesbitt (CIAP team leader) received the Distinguished Collaboration Award and Drs. Ram C. Chaudhary (former coordinator of the International Network for the Genetic Evaluation of Rice or INGER), Edwin Javier, and Peter White, and Joe Rickman received the Officer Award for Collaboration. After the inauguration, the "Exchange of Letters" revising the CIAP memorandum of understanding (MOU), was signed.

MOU signatories were H.E. Chea Song, minister of agriculture, and Ambassador Louise Hand, Australian ambassador to Cambodia. Also present during the signing were Mr. Blair Exell, AusAID country representative; Dr. Ron Cantrell, IRRI director general; H.E. Teng Lao, under secretary of state responsible for CARDI; and Dr. Men Sarom, director of CARDI.

Memo of understanding signatories His Excellency Chea Song, Minister of Agriculture (seated, right) and Ambassador Louise Hand, Australian Ambassador to Cambodia (seated, left). Behind Ms. Hand is Mr. Blair Exell, AusAID country representative, and at the rear are IRRI Director General Dr. Ronald Cantrell, H.E. Teng Lao, Undersecretary of State responsible for CARDI, CIAP team leader Dr. Harry Nesbitt, and Dr. Men Sarom, Director of CARDI.

IRRI reaches out to regional media

IRRI recently signed an MOU with the Confederation of ASEAN Journalists (CAJ) that calls for strengthening CAJ-IRRI collaboration through training, better access to information, and the building of greater public awareness on the importance of rice research and production. The MOU was signed at CAJ's 13th General Assembly and Press Convention in Singapore on 23–25 October.

Dr. William Padolina, IRRI's deputy director general for partnerships, and Ivan Lim, CAJ president, signed for their respective organizations. The other CAJ cosignatories were Secretary General Norman Suratman, Permanent Secretary Adbul Razak, the Indonesian Chairman Tarman Azzam, the National Union of Journalists-Malaysia President Norila Mohd Daud, National Press Club of the Philippines President Antonio Antonio, Vietnam Journalists Association President Hong Vinh, and Lao Journalists Association President Bouaban Vorakhoun.

The MOU aims to ensure greater rice-related training opportunities for all CAJ members as well as special status as attendees at IRRI-sponsored international or regional events and conferences. IRRI is committed to helping media organizations across Asia provide the most up-to-date and accurate information available on the rice industry. In return, CAJ will encourage greater reporting of rice-related issues and assist IRRI in getting its message out to its many different stakeholders, such as farmers, other researchers, government officials, and the general public. The MOU will be implemented through work plans to be developed jointly by IRRI and CAJ.

IRRI has also been working closely with a relatively new organization called the Asia Rice Media Advocacy Network (ARMAN). Composed of journalists and media professionals with a strong interest in promoting rice, ARMAN has already established national chapters in the Philippines (IRRI-Thailand 40 yrs Rice Media Advocacy Network), India (India Media Agriculture Network), Bangladesh (Forum for Information Dissemination on Rice), and Indonesia (Dewi Seri). Thailand and Vietnam are currently organizing their own national ARMAN chapters.

ARMAN was organized as an offshoot of the Asian Media and Rice Conference held in December 1998 by the Asia Rice Foundation in Bangkok where 45 media representatives from 11 Asian countries signed a declaration recognizing the need to enhance rice reporting and urging the establishment of a rice media network to boost interest in rice advocacy among media practitioners and professionals in the region.

IRRI Filipino scientist wins CGIAR Award

Dr. Alberto Barrion, senior associate scientist of the Entomology and Plant Pathology Division (EPPD) of IRRI, was named Outstanding Local Scientist for 2000 by the Consultative Group on International Agricultural Research (CGIAR). Dr. Barrion received the award consisting of a plaque and a cash prize at the CGIAR, during International Centers' Week in Washington, D.C., in October.

The Outstanding Local Scientist Award is given to a locally recruited professional of any nationality who has made an outstanding scientific contribution in any research field. Dr. Barrion is recognized as one of the top entomologists in Asia. He is also an acclaimed araneologist, taxonomist, research scientist, and teacher/trainer.

At IRRI, he led the development of illustrated, easy-to-use insect identification kits for rice pests and their natural enemies, which have now become an important tool for rice scientists, technicians, crop protection specialists, biodiversity researchers, ecologists, and integrated pest management (IPM) experts, as well as biology and zoology students. He has also made outstanding scientific and technological contributions to the fields of systematics and the biology of rice and rice-based arthropods, especially insect pests and their natural enemies.

Through his efforts, farmers, scientists, and the public now recognize the importance and benefits of friendly insects in rice fields. He is the head of the IRRI Taxonomy Laboratory, curator of the Arthropod Reference Collection at IRRI, and is an adjunct curator of the University of the Philippines Los Baños (UPLB) Museum of Natural History.

Dr. Barrion's impressive contributions have benefited both national and international programs in areas such as IPM, biodiversity, and pest modeling. More importantly, his work provided crucial and accessible information to small and resource-poor farmers. His work on friendly insects has significantly contributed to the scientific framework for ecorational pest management with naturally occurring and diverse communities of biocontrol agents that maintain and regulate rice insect pests and increase farm profits without the use of ecologically disruptive insecticides. His work is well documented in more than 150 publications.

Dr. Barrion holds a BS in agriculture (entomology), MS in systematic entomology, and PhD in entomology from UPLB. This multiawarded entomologist was the recipient of the Philippines' Ten Outstanding Young Men Award in 1990, Outstanding Young Scientist Award from the National Academy of Sciences and Technology (NAST) in 1991, Pest Management Award from the Pest Management Council of the Philippines, and the President Estrada Special Citation Gawad Saka Award from the Department of Agriculture in 2000, among others.

He is also a member/officer of many professional organizations, such as the International Organization of Biological Control (Southeast Asia Group), American Arachnological Society, National Research Council of the Philippines, Weed Science Society of the Philippines, Philippine Association of Systematic Biologists, Biological Control Specialist Association of the Philippines, Philippine Association of Entomologists, Inc., Pest Control Council of the Philippines, UP Gamma Sigma Red Scorpions, Gamma Sigma Delta Honor Society, IRRI Filipino Scientists Association, and the UP Entomological Society.

The CGIAR Chairman's Science Awards were established in 1996 to honor scientific excellence and achievements in several categories. Other awards given by the CGIAR are in the following categories: Outstanding Local Scientific Support Staff, Promising Young Scientist, Outstanding Scientific Partnership, and Outstanding Scientific Article.

In 1996, two IRRI staff received the CGIAR Science Awards: Dr. Shaobing Peng, crop physiologist, for the Promising Young Scientist Award, and Dr. Thelma Paris, affiliate scientist/gender specialist, for the Outstanding Local Professional Award.

IRRI and Thailand celebrate 40 years of rice research collaboration

Dr. William Padolina, IRRI deputy director general for partnerships, presents a medallion replica of the International Rice Award given to King Bhumibol Adulyadej to a Thai scientist. At left is liaison scientist Dr. Boriboon Somrith.

IRRI and Thailand marked 40 years of collaboration in rice research and development this year. In pursuing its mission of undertaking rice research that benefits poor farmers and consumers worldwide, IRRI has had the full cooperation of the government and the national agricultural research system (NARS) of Thailand.

IRRI has about 40 collaborative projects with Thailand. The intensive research activities at the Ubon and Samoeng rice research centers in Thailand and the respective key sites of the Rainfed Lowland Rice and Upland Rice Research Consortia will be extended to other national rice research systems. The other projects involve INGER being coordinated by IRRI, hybrid rice, integrated pest management, and biotechnology.

To mark the 40 years of strong partnership between the Institute and Thailand, the IRRI Liaison Office in Bangkok sponsored three major events on 17–18 November. An IRRI-Thailand Rice Research Seminar was held at Kasetsart University on 17 November with the theme *40 years of Thai-IRRI collaboration and partnership in the new millennium*. About 60 scientists, agricultural researchers, representatives of academe, and Department of Agriculture (DOA) officials attended.

Dr. William Padolina, IRRI deputy director general for partnerships, visited the Rice Exhibition at the Pathum Thani Rice Research Center in Pathum Thani, near Kasetsart University. The exhibition highlighted the collaboration between IRRI and Thailand and other research agencies in germplasm collection and use, varietal improvement, rice biotechnology, production technology and farming systems, crop protection, farm machinery, and training and technology transfer. Dr. Padolina also visited Thailand's rice genebank (with 22,664 accessions) at the National Rice Seed Storage Laboratory for Genetic Resources, also in Pathum Thani.

An IRRI alumni meeting at the Rice Research Institute highlighted the events. Dr. Padolina, assisted by Dr. Boriboon Somrith, IRRI liaison scientist, presented replicas of the IRRI International Rice Award given to King Bhumibol Adulyadej to the heads of delegations from various research institutions.

Rice productivity conference held in Hangzhou, China

An international conference on *Increasing Rice Productivity* was held 27 November–1 December in Hangzhou, People's Republic of China. The meeting focused on implications for pest management. Also during the week, a satellite consultative workshop was conducted on *Effective and sustainable use of agricultural biotechnology in integrated pest management in developing countries*.

The conference provided a forum for scientists of diverse disciplines to address issues such as trends in production and management for sustaining growth, emerging pest problems, farmers' constraints, and the roles of modern technologies, such as transgenic crops, information technology, and communication science. The conference was organized by Zhejiang University, the Integrated Pest Management (IPM) Network coordinated by IRRI, and the International Organization of Biological Control (IOBC). Funding was provided by the Swiss Agency for Development and Cooperation (SDC).

Some 85 scientists from Australia, Bangladesh, Belgium, Canada, China, France, Germany, India, Indonesia, Japan, Kenya, Korea, Malaysia, Pakistan, Philippines, Switzerland, Thailand, United Kingdom, United States of America, and Vietnam attended the conference.

CGIAR centers bring "seeds of life" to East Timor

IRRI, Centro Internacional de Mejoramiento de Maiz y Trigo (CIMMYT), Centro Internacional de Agricultura Tropical (CIAT), Centro Internacional de la Papa (CIP), and International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) (all belonging to the CGIAR system) are collaborating in the Seeds of Life-East Timor project. The project also involves non-CGIAR centers including nongovernment organizations such as World Vision International (WVI) and Catholic Relief Services (CRS). The Australian Centre for International Agricultural Research (ACIAR) is funding the 3-y project that is now being implemented by a project management committee comprising representatives from ACIAR, WVI, CRS, and the Division of Agricultural Affairs of the East Timor Transitional Administration (ETTA)/United Nations Transitional Administration in East Timor (UNTAET).

The crop lines brought by CGIAR centers on 15 November are now being evaluated at experimental sites in the districts of Ainaro, Bobanaro, Baucau, Ailieu, Los Palos, and Viqueque. These sites cover the main soils and climatic zones common to East Timor and reflect operational suitability in terms of availability of staff and facilities. The 15 varieties of irrigated rice, 11 varieties of rainfed lowland rice, and 13 varieties of upland rice that IRRI contributed through INGER are planted at the sites.

These represented the first planting activities in East Timor for the 2000-01 wet seasons under the project. Where possible, trials will be established near each other to simplify security/fencing, travel, and management. A simple weather station will also be established at each site in association with the ETTA/UNTAET's program of developing the meteorology network in the country.

Germplasm adaptation trials will be undertaken for 3 y, with seed multiplication of better adapted lines for distribution to farmers in the second and third years of the project. Adapted seed may be multiplied in other countries during the East Timor dry season from April to November. East Timorese technicians will also be trained in evaluation, multiplication, and distribution of improved planting material in association with relevant CGIAR centers. The project respects international conventions such as the Convention on Biodiversity and will not test genetically modified organisms.

IRRI launches media information site

IRRI has launched a new Internet media and information tool for journalists and members of the general public interested in rice research and related issues. The address of the new Media Hotline Internet site is *www.cgiar.org/IRRI/pa/*. It can also be reached by clicking on the Media Hotline logo on the IRRI home page at www.cgiar.org/irri.

This new service offers a wide range of features not previously available on IRRI's three main Web sites, IRRI Home, Riceweb (www.riceweb.org), and Riceworld (www.riceworld.org). The main aim of the Media Hotline is to provide the latest and most up-to-date information on IRRI and its research. The new site also aims to enable the media to have access to information about the Institute and its work more easily. Journalists accessing the site can expect to find the hottest news and latest information released by the Institute.

In addition, the site offers a range of other interesting services including a comprehensive library of all press and photo releases issued by the Institute since 1999. It also contains a selection of speeches by the Institute's senior management and scientists as well as answers to frequently asked questions about IRRI, its research, and the rice industry in general.

The Media Hotline site also features links to a comprehensive list of all IRRI scientists with brief biographical details and areas of particular expertise. Thus, journalists can now select the scientist they may want to interview based on their own criteria.

Other features of the site are detailed information on all of IRRI's key donors, the research projects they support, and the history of their relationship with the Institute. In the same section, titled "Facts About Cooperation," comprehensive information is available on IRRI's relationships with its important research partners in the NARS of the world's rice-producing nations. A "Letters" section provides a library of all letters published by IRRI in an effort to correct any misinformation and clarify the Institute's position in key public debates, especially in relation to biotechnology. Certain sections of the site remain under construction and several areas are still to be fully updated, but a wide range of information is already available. Materials obtained from the Media Hotline, including all photos, may be freely used and quoted provided due credit is given to IRRI.

Cuba will host the Second International Rice Meeting and Second National Rice Congress in June 2001

The Rice Research Institute, All Union of Rice Production, and the Latin American Fund of Irrigated Rice are organizing the Second International Rice Meeting that will be held on 25–29 June 2001 at the Havana International Conference Center, Cuba.

The meeting will take place simultaneously with the Second National Rice Congress. Researchers, extension workers, production specialists, students, and other specialists from different countries are invited to discuss recent research results, problems, and perspectives of rice production.

The meetings aim to promote technology transfer, stimulate the enrichment of rice genetic diversity, discuss and exchange experiences on sustainable rice production, and update knowledge about rice production, especially that of researchers from Latin America and the Caribbean. General topics for discussion include plant breeding and phytogenetic resources, technologies for rice production, use and preservation of water resources, cropping systems, vegetable production, physiology and nutrition in rice, postharvest technologies and grain quality, rice and the environment, rice mechanization, statistical methods applied in rice research, and the world and regional rice economy.

Sponsors include IRRI, the Latin American Fund of Irrigated Rice, the Caribbean Rice Association, FAO, Brazilian Agricultural Research Enterprise (EMBRAPA), and CIAT, in collaboration with the Cuban Ministry of Science, Technology, and the Environment, Agricultural Ministry, Higher Education Ministry, and Cuba's Science Academy.

The convention will be conducted in English and Spanish.

ARRO JUNIO 25 al 29 HABANA 2001

For more information, contact Mr. Luis Alem'an Manzfarroll, Director, Instituto de Investigaciones del Arroz, Apartado 1, Bauta, La Habana, Cuba; telephone/fax: 53-7-335 993; or Ms. Mireya Mesa Tamargo, Organizadora Profesional de Congresos, Palacio de Convenciones, Apartado 16046, La Habana, Cuba; fax: 53-7-228 382, 287 996, 283 470; e-mail: mireya@palco.get.cma.net.

Sources: Palacio de Convenciones de la Habana (PALCO), Media Hotline, PA site (IRRI): *www.cgiar.org/IRRI/pa/*, IRRI electronic bulletin

IRRI training courses, 2001

Course title	Duration (in weeks)	Target date	Coordinator(s)
2-wk rice production 1 (IRRI)	2	29 January–9 February	R. Rosales/O. Garcia
2-wk rice production 2 (IRRI)	2	12–23 February	R. Rosales/O. Garcia
International Rice Information System (IRRI)	1	5–9 February	G. McLaren/I. Ferino
Basic EDDA (online)	4	19 February–16 March	G. McLaren/I. Ferino
Integrated nutrient management (IRRI)	4	5–30 March	P. Sta Cruz/R. Rosales
Scientific writing and presentation skills (IRRI)	2	2–13 April	S. Avance/M. Quiamco
Management of herbicide-resistant weeds (IRRI)		April	M. Mortimer
Digital literacy (online)	8	2 April–25 May	B. Nuñez/T. Clabita
Introduction to SAS for Windows (IRRI)	1	7–11 May	G. McLaren/I. Ferino
Research station management (IRRI)	2–4		J. Rickmann/ R. Cuyno/E. Castro
Upland rice (Thailand)	2	28 May–8 June	O. Garcia
Weed science and weed management (Africa)	2	June	M. Mortimer
Analysis of categorical data (IRRI)	1	4–8 June	G. McLaren/I. Ferino
English for agriculture (online)	12	4 June–25 August	S. Avance/B. Nuñez
Instructional video production (IRRI)	4	25 June–20 July	T. Clabita/G. Zarsadias
Introduction to IRRIStat, (IRRI)	1	2–6 July	G. McLaren/I. Ferino
Rice seed health (IRRI)	8	9 July–31Aug	T. Mew/S. Merca
G × E analysis and interpretation of results (IRRI)	2	6–17 August	G. McLaren/I. Ferino
Hybrid rice seed production (China)	4	20 August–14 September	S.S.Virmani/O. Garcia
Training of trainers (IRRI)	4	3–28 September	G. Zarsadias/ M. Quiamco/T. Clabita
Analysis of unbalanced data	1	11–15 September	G. McLaren/I. Ferino
Rice production research (Thailand)	8	8 October–30 November	S. Phumiphon/O. Garcia
Genetic engineering and rice nutrition		October/November	S.K. Datta
IT for farmers	2	5–16 November	B. Nuñez/S. Magadia
Multiagent systems for natural resources management	2	19–30 November	F. Bousquet/S. Kam

Note: Schedules are subject to change. Changes will be reflected in the Training Center's online calendar. Please go to the Training Center site which can be found at the IRRI home: http://www.cgiar.org/irri for the latest information. Or e-mail p.marcotte@cgiar.org, or write to: Dr. Paul Marcotte, Head, Training, Center, MCPO Box 3127, Makati City 1271, Philippines.

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.

Send manuscripts, correspondence, and comments or suggestions about IRRN by mail or email to:

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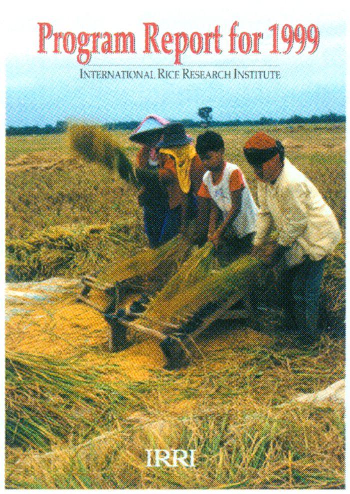

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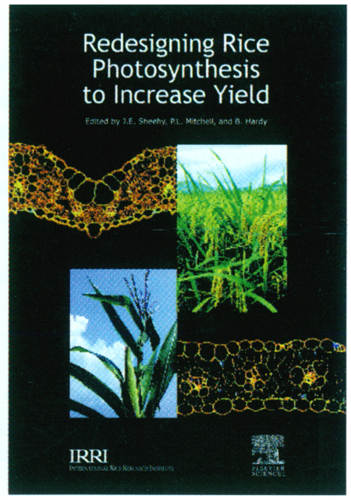

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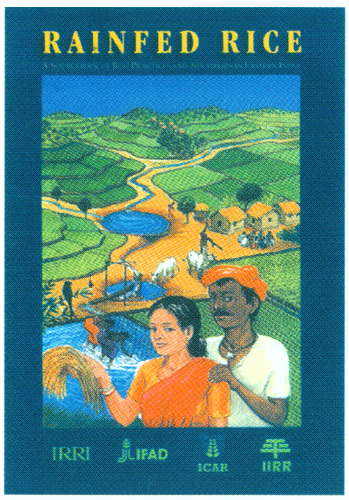

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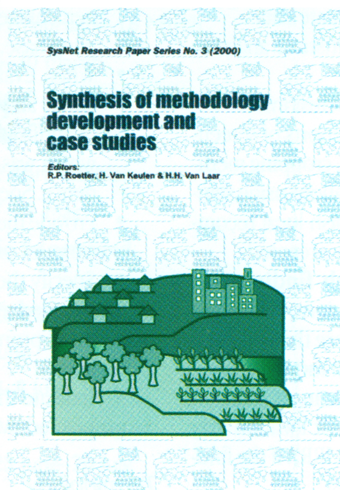

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