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IRRN instructions for contributors

The objective of the *International Rice Research Notes* (IRRN) is to expedite 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 quarterly in March, June, September, and December by the International Rice Research Institute; annual subject and variety indexes are also produced.

The IRRN is divided into three sections: notes, news about research collaboration, and announcements.

NOTES

General criteria. Scientific notes submitted to the IRRN for possible publication must

- be original work,
- have international or pan-national relevance,
- be conducted during the immediate past three years or be work in progress,
- have rice environment relevance,
- 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 accepted. Examples are single-season, single-trial field experiments. All field trials should be repeated across more than one season, in multiple seasons, or in more than one location as appropriate. All experiments should include replications and an internationally known check or control treatment.

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.

IRRN categories. Specify the category in which the note being submitted should appear. Write the category in the upper right-hand corner of the first page of the note.

GERMPLASM IMPROVEMENT
genetic resources
genetics
breeding methods
yield potential
grain quality
pest resistance
  diseases
  insects
  other pests
stress tolerance
  drought
  excess water
  adverse temperature
  adverse soils
  other stresses
integrated germplasm improvement
  irrigated
  rainfed lowland
  upland
  deepwater
  tidal wetlands
seed technology

CROP AND RESOURCE MANAGEMENT
soils
soil microbiology
physiology and plant nutrition
fertilizer management
  inorganic sources
  organic sources
crop management
integrated pest management
  diseases
  insects
  weeds
  other pests
water management
farming systems
farm machinery
postharvest technology
economic analysis

ENVIRONMENT
SOCIOECONOMIC IMPACT
EDUCATION AND COMMUNICATION
RESEARCH METHODOLOGY

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. Do not cite references or include a bibliography. Restrain acknowledgments.

Manuscripts must be in English. Limit each note to no more than two pages of double-spaced typewritten text. Submit the original manuscript and a duplicate, each with a clear copy of all tables and figures. Authors should retain a copy of the note and of all tables and figures.

Apply these rules, as appropriate, in the note:

- Specify the rice production ecosystems as irrigated, rainfed lowland, upland, deepwater, and tidal wetlands.
- Indicate the type of rice culture (transplanted, wet seeded, dry seeded).
- If local terms for seasons are used, define them by characteristic weather (wet season, dry 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 genetic background for new varieties or breeding lines.
- For soil nutrient studies, include a standard soil profile description, classification, and relevant soil properties.
- Provide scientific names for diseases, insects, weeds, and crop plants. Do not use common names or local names alone.
- 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.
- Use generic names, not trade names, for all chemicals.
- Use international measurements. Do not use local units of measure. Express yield data in metric tons per hectare (t/ha) for field studies and in grams per pot (g/pot) for small-scale studies.
- Express all economic data in terms of the US$. Do not use local monetary units. Economic information should be presented at the exchange rate US$:local currency at the time data were collected.
- 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 abbreviations or symbols used in tables or figures in a footnote, caption, or legend.

Tables and figures. Each note can have no more than two tables and/or figures (graphs, illustrations, or photos). All tables and figures must be referred to in the text; they should be grouped at the end of the note, each on a separate page. Tables and figures must have clear titles that adequately explain the contents.

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Review of notes. The IRRN editor will send an acknowledgment card when a note is received. An IRRI scientist, selected by the editor, reviews each note. Reviewer names are not disclosed. Depending on the reviewer's report, a note will be accepted, rejected, or returned to the author(s) for revision.

NEWS ABOUT RESEARCH COLLABORATION

General. The section facilitates the timely communcation to rice scientists of collaborative activities from consortia, networks, collaborating groups, national agricultural research systems, institutions, countries, and other groups.

Items accepted: general news and current update items about consortia, networks, country and regional projects, conference and workshop recommendations, and other information of interest to IRRN readers, such as new projects, work plans, memorandums of understanding, and highlights of collaborative projects in progress.

Items not accepted: routine housekeeping information for collaborative groups, research notes, new variety releases, work and trip reports, and personal items.

Length. Limit submissions to one page of double-spaced typewritten text.

Submission. Send contributions to the editor at any time. To be printed in a specific issue, items must be received two and a half months in advance of cover date. Items for the March issue, for example, should be received by 15 Dec.

ANNOUNCEMENTS

General. The section includes announcements of upcoming conferences, symposia, workshops, training courses, meetings, and other activities; new rice-related publications, series, and videos; and a calendar of events.

Format and submission. Same as for news items. Announcements of workshops, meetings, and conferences need to be received at least 6 months before the date of the event.

OTHERS

Comments. If you have comments or suggestions about the IRRN, please write to the editor. We look forward to your continuing interest in IRRN.

Mailing address. Send all notes, news, announcements, and other correspondence to the Editor, IRRN, IRRI, P.O. Box 933, Manila 1099, Philippines. Fax: 63-2-81 8-2087.

Contents

Genetic Resources

Seed scarcity and rapid extinction of deepwater rice (DWR) cultivars in Bangladesh

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DWR used to be the most important crop in the low-lying deltas of Bangladesh. In the late 1960s. more than 500 traditional DWR cultivars were grown on 21% (2.1 million ha) of the nation's rice area. The cultivars had been developed over hundreds of years to suit the specific agroecosystetns of diverse DWR areas.

As irrigation facilities in DWR areas expanded with the installation of low-lift pumps and shallow and deep tubewells during the 1970s and 1980s, farmers could grow modern cultivars during the boro season (winter). As a result, the area under DWR in 1990 was reduced to 0.9 million ha , a 56% reduction over 20 yr.

On-station and on-farm research and observations in farmers' fields have shown that both boro rice and DWR can be grown on the same land with careful planning. A visit in April 1992 to a few DWR areas in the Jamuna floodplain in Mirzapur and Deldwer of Tangail district indicated that farmers did not grow much DWR after modern variety (MV) boro because of the unavailability of DWR seed. Only one of more than 50 farmers selling rice in a remote local market had DWR seed, despite high demand. In the past, DWR seed was abundant at seeding time (Mar/Apr) in the villages and local markets.

We asked groups of farmers to recall the proportion of low-lying areas occupied by different major cropping patterns, and the name of DWR cultivars grown during the 1960s and of those growing at present. In the past, the DWR-based cropping pattern dominated (62%), followed by a jute-based pattern (38%) (Table 1). Expansion of MV boro during the past 20 yr reduced DWR, jute, and nonrice winter crops such as pulses and oilseeds.

The present DWR-based pattern occupies about 8% of the land, the jute pattern 9%, and MV boro pattern 83%. The number of DWR cultivars was also reduced (Table 2). More than 60% of the cultivars grown in the 1960s have already disappeared. The late-maturing cultivars, which had rapid elongation ability and were suitable for growing in very deep water (>250 cm), have been affected severely.

Scarcity of DWR seed and rapid extinction of cultivars have also been observed in other Bangladesh DWR areas. To increase rice production and to preserve the immense genetic diversity of the traditional DWR cultivars, immediate government intervention is needed for the collection, multiplication, and distribution of DWR seed in the MV boro rice-occupied DWR areas. ■

Table 1. Lands occupied by major cropping patterns in the 1960s and in 1991 based on farmer interviews in selected areas of Tangail district, Bangladesh.

Site	Cropping pattern [a]	Cropped area [b] (%) 1960s	1991
Shubullar beel (Mirzapur), about 3000 ha	DWR/DWR+aus - rabi/fallow	75	4
	Jute - rabi	25	6
	Boro - fallow/mustard	-	90
Dubail (Deldwer), about 3500 ha	DWR/DWR+aus - rabi/fallow	60	5
	Jute - rabi	40	10
	Boro - fallow/mustard	-	85
Moushakatalia (Deldwer), about 2000 ha	DWR/DWR+aus - rabi/fallow	50	15
	Jute - rabi	50	10
	Boro - fallow/mustard	-	75

[a] Boro = winter rice, aus = summer rice, rabi = nonrice winter crops. [b] - = area under boro (local cultivars) was almost nil.

Table 2. Traditional DWR cultivars grown in the 1960s and in 1991 in selected areas of Mirzapur and Deldwer upazilas of Tangail district, Bangladesh.

Water depth	Cultivar: 1960s or earlier	1991
Shallow to medium (50-150 cm)	Boron Bawalia Senna Bawalia Bawalia Digha Deshi Digha Horinga Digha Lokhi Digha Senna Digha Depho Kertikjul Kertik Kaika Rajpal Shonmoti	Boron Bawalia Senna Bawaila Bawalia Digha Deshi Digha Senna Digha Depho
Deep (150-250 cm)	Chamara Dhola Digha Ejol Digha Hejol Digha Haskol Digha Sonna Digha Lokhi Kajol Raja Mondol	Chamara Dhola Digha Hejol Digha Haskol Digha
Very deep (<250 cm)	Bugral Hamubhanga Haskol Boron Kaitormoni Shuli Boron Sheali Boron	None

Genealogy of Brazilian upland rice varieties

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Until 1989, most of Brazil's more than 4 million ha of upland rice were planted to varieties IAC25, IAC47, IAC164, and IAC165, developed by the Instituto Agronomico de Campinas (IAC).

The National Rice and Beans Research Center (EMBRAPA/CNPAF) began in 1976 an upland rice breeding program that targeted subecosystems that have irregular rainfall distribution and acid soils, and are prone to diseases, such as blast. The 12 varieties now available as a result of this program are planted on more hectares in the uplands than IAC varieties. The genealogical tree of these varieties is presented in the figure.

The varieties improved by IAC were developed from immediate parents Dourado Precoce, IAC1246, and IAC 1391, which originated from crosses among Brazilian land races Yola, Jaguari, Iguape Agulha, Perola, and Pratao. The EMBRAPA/CNPAF program combined these lines with African germplasm 63-83, OS6, and LAC23 to exploit variability and to broaden the genetic base. Upland and irrigated germplasm lines were also crossed; Cuiabana which was released in 1985, is the result of this effort. This new gene pool combined several desirable traits and allowed the selection of improved lines.

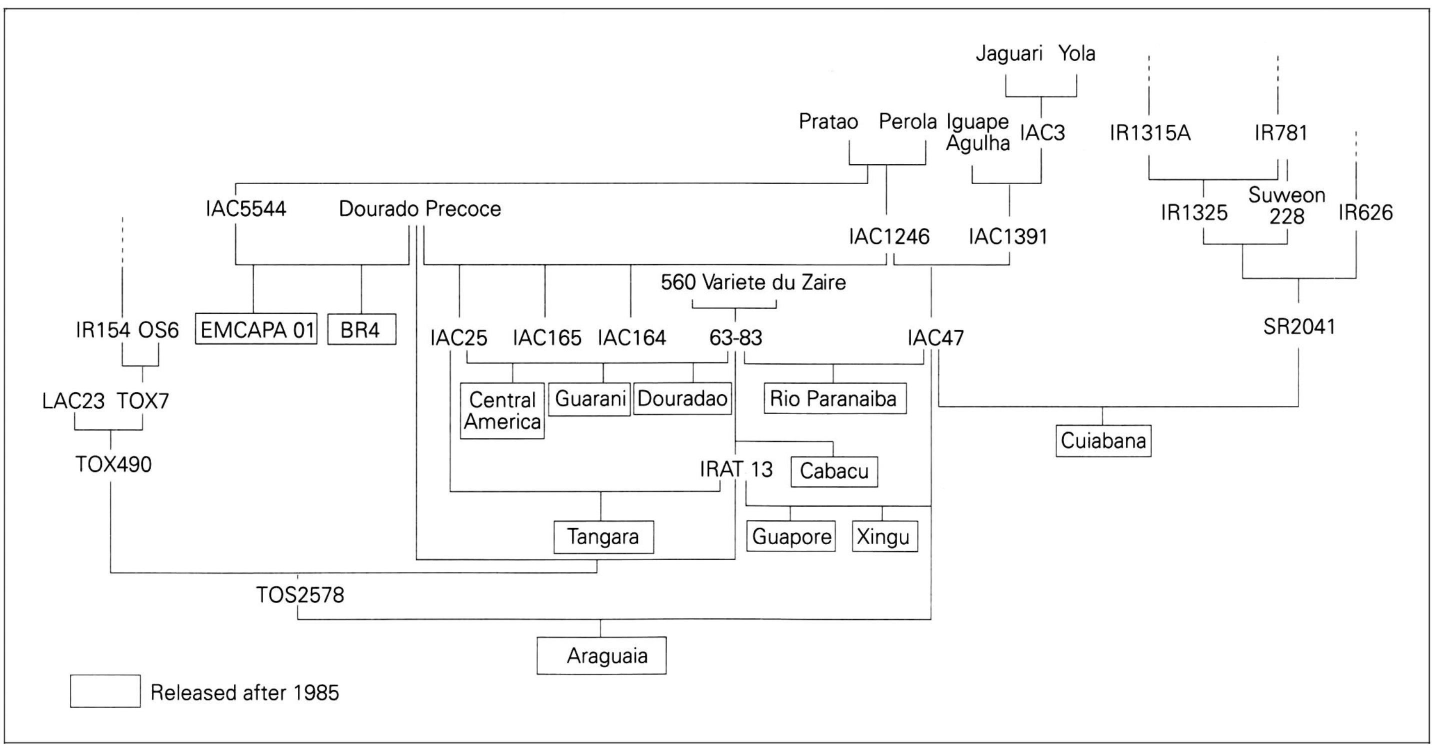
The genetic variability of the varieties released by IAC is narrow and concentrated in major traits. such as tolerance for drought and wide adaptation to upland acid soils environments. At one time the selection criteria concentrated on these two traits. But for Cuiabana and Araguaia, traits such as grain quality and plant type from the irrigated lines were incorporated. The two cultivars, are, however, inferior to the others for the two traits emphasized by the program.

These results indicate that the EMBRAPA/CNPAF breeding program needs to broaden the genetic base to keep making progress. Selection criteria need to be adjusted to avoid losing efficiency for the major proposed objectives. ■

IRRN REMINDER

Routine research. Reports of screening trials of varieties, fertilizer, cropping method, and other routine observations using standard methodologies to establish local recommendations are not accepted. Examples are single-season single-trial field experiments. All field trials should be repeated across more than one season, in multiple seasons, or in more than one location as a appropriate. All experiments should include replications and an internationally known check or control treatment.

Origin of Brazilian upland rice varieties.



Genetics

Combining ability and heterosis for some physiological traits in rice

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We crossed modern rice genotypes IR8, IR36, IR42, IR46, IR68, and IR21015-80-3-3-1-2 (OM86) from IRRI, and OM80 and OM201 from Vietnam in a half-diallel set. The plot was laid out in randomized complete block design with three replications during the 1991 wet season. Single seedlings of parents and F_1s were transplanted at 20- × 20-cm spacing and received 80-40-0 kg NPK/ha. In eight selected crosses we assessed heterosis and heterobeltiosis for yield, leaf area index (LAI), net assimilation rate (NAR), crop growth rate (CGR), leaf area duration (LAD), high density grain index (HDI), and harvest index (HI).

HDI was calculated as the number of high density grains (more than 1.20 specific gravity) divided by spikelets/panicle.

High significant mean squares of all traits for both general combining ability (GCA) and specific combining ability (SCA) indicated the importance of both additive and nonadditive gene action. However, the SCA^2 were higher than the GCA variances (GCA^2), suggesting the prevalence of nonadditive gene effects for CGR, NAR, HDI, HI, and grain yield (Table 1).

The general predictability factor for LAI was high (above 0.70) at maximum tillering and ripening, indicating that additive gene action was more important than nonadditive gene action for this trait.

The predictability factors were less than 0.50 for the remaining characters, thus showing the equal importance of both types of gene actions in the inheritance of these traits.

OM80 appeared to be the best combiner for yield; IR46, OM80, IR68, and OM86 for LAI at heading, IR36 for NAR (panicle initiation to heading); OM201 for NAR (heading to harvest);

Table 1. Components of variance and predictability factor.[a]

Character	s^2GCA	s^2SCA	Predictability factor
Yield	52.1	129.6	0.44
LAI			
Maximum tillering	0.09	0.02	0.91
Heading	20.8	52.2	0.44
Ripening	21.9	10.1	0.81
NAR			
Maximum tillering to heading	34.4	75.5	0.22
Heading to ripening	0 99	2.20	0.47
CGR			
Maximum tillering to heading	1.27	3.59	0.41
Heading to ripening	10.5	46.6	0.31
LAD			
Maximum tillering to heading	549.0	1413.0	0.43
Heading to ripening	924.0	2126.0	0.46
HDI	763.0	1923.0	0.44
Panicles/hill	12.0	27.9	0.46
Filled grains/panicle	1381.1	3050.3	0.47
100-grain weight	107.2	267.3	0.44
HI	0.05	0.11	0.44

[a] Predictability factor 2 s^2GCA/(s^2GCA+ s^2SCA)

Table 2. Percent heterosis (H) and heterobeltiosis (HB) for selected crosses.[a]

Cross		Yield	LAI (heading)	NAR 1	NAR 2	CGR 1	CGR 2	LAD 1	LAD 2	HDI	HI
IR36/OM80	(H)	60.5 **	76.5**	–8.6	49.2**	–22.6	116.7**	63.6**	67.3**	3.7 ns	–14.8
	(HB)	43.7 **	53.0**	–13.0	46.1**	–41.1	93.4**	39.6**	45.5**	–1.8	–23.3
IR36/IR68	(H)	63.6 **	17.3*	34.9**	19.2*	–37.2	–16.6	9.6*	6.5*	2.0 ns	5.0*
	(HB)	62.0 **	–11.2	21.7**	–18.8	–49.9	–48.9	–15.4	–18.6	–4.5	–11.7
IR36/IR46	(H)	60.9 **	48.0**	–22.2	–29.4	–19.1	–30.2	45.5**	41.8**	9.4*	–9.9
	(HB)	57.3 **	32.9**	–34.0	–52.1	–32.2	–52.6	32.3**	31.2**	6.9*	–16.7
IR8/IR46	(H)	60.4 **	31.7**	–21.6	–37.8	–5.1	2.6 ns	31.8**	34.1**	11.9*	–3.0
	(HB)	62.5 **	31.2**	–36.8	–53.8	–24.2	–22.5	31.5**	32.7**	6.2*	–3.9
IR8/OM201	(H)	46.7 **	–16.9	35.7**	–27.5	66.7**	1.6 ns	–15.4	–4.7	11.4*	38.3**
	(HB)	37.5 **	–30.2	9.4*	–45.9	27.7**	–23.9	–29.6	–16.3	4.8*	30.0**
OM80/IR42	(H)	30.3 **	–20.8	29.2**	–0.9	12.8*	–13.7	–23.0	–21.1	3.2 ns	13.4*
	(HB)	21.1 **	–31.6	19.8**	–7.1	–16.1	–16.1	–27.5	–26.3	–0.2	12.2*
OM80/OM201	(H)	23.0 **	–2.8	31.9**	8.0*	26.6**	13.4*	–6.1	–3.6	–8.6	15.2*
	(HB)	6.8 *	–15.9	17.0**	–27.3	18.3**	–18.1	–17.0	–10.8	–10.7	10.4*
IR46/IR42	(H)	51.9 **	27.0**	–18.3	–69.1	–26.5	–63.6	23.9**	22.1**	4.4*	12.0*
	(HB)	49.1 **	9.4*	–22.2	–78.5	–40.1	–73.0	9.2*	7.3*	4.3*	9.8*

[a] 1 = maximum tillering to heading, 2 = heading to ripening. * and ** = significant at the level of 0.05 and 0.01, respectively. ns = nonsignificant.

IR8, IR36, and IR46 for CGR (panicle initiation to heading); and IR36, IR42, and OM201 for HI.

Heterosis and heterobeltiosis for these traits in the selected crosses are presented in Table 2. Heterosis over midparents for yield ranged from 23 to 63.6%; heterosis over better parents ranged from 6.8 to 62.5%. Most of the F_1 means of HDI deviated slightly from parental and mid-parental values in all crosses, indicating the absence of heterosis for the trait.

HI obtained high positive values in the divergent genotype cross of IR8/OM201. We also observed heterosis in the desirable direction in LAI, NAR, and CGR, from heading to ripening, in some crosses. ■

Breeding Methods

Ability of some cytoplasmic male sterile (CMS) lines of rice to produce hybrid seed

T. P. M. Bobby and N. Nadarajan, Agricultural Botany Department, Agricultural College and Research Institute, Madurai 625104, India

We evaluated the ability of some CMS lines to establish satisfactory seed set with restorer (R) lines. A crossing block with 10 CMS and 5 restorer lines was laid out in a randomized block design with two replications during 1990 wet season. A line × tester model of crossing was used to make 50 crosses.

In both replications, each A line was flanked by a R line on both sides (1 :2 ratio of A to R lines). Three staggered plantings of R lines at 5-d intervals were made to produce the continuous pollen supply that would ensure synchronized flowering of A and R lines. For each row, 15 plants for both A and R lines were maintained at 20- × 20-cm spacing. We grew a row of Purple Puttu between crosses to intercept pollen.

We allowed the plants to outcross naturally. We aided pollination by tapping the R lines with bamboo sticks and passing ropes across the lines during anthesis. The hybrid seeds here collected at maturity from A lines. We used the mean seed set of 15 plants in each A line for the analysis.

The analysis of variance for seed set in a randomized block showed significant differences among the 50 crosses (see table). TNMS37 A/ ARC 11353 R recorded the maximum seed set (24.8%), followed by V20 A/ IR54 R (24.4%). The line TNMS37 A crossed well with all R lines except IR36 R (2.25%); it had a mean seed set of 12.3%. When the mean seed set percentages of the R lines—in combination with all the A lines—were compared, IR46 R had the highest mean seed set of 12.3%, followed by IR54 R with 12%.

Because R lines combine differently with different male sterile lines, it is recommended that the parents be selected on the basis of seed set in individual crosses rather than on their overall performance. In this context, the hybrids TNMS37 A/ARC11353 R, V20 A/IR54 R, and IRS4756 A/IR54 R are the best combinations to produce increased hybrid seed. ■

Seed set in A/R crosses by natural outcrossing.

Male sterile line	Seed set (%)					
	ARC11353 R	IR36 R	IR9761-19-1 R	IR46 R	IR54 R	Mean
IR54753 A	13.40	5.60	2.19	17.70	7.84	9.35
Intan Mutant A	4.83	5.70	5.02	4.60	5.40	5.11
Z.S. 97 A	9.80	12.99	10.74	15.51	8.60	11.53
Pushpa A	13.40	5.29	4.30	6.90	12.90	8.56
Mangala A	6.40	2.26	0.39	12.14	6.00	5.44
IR54756 A	6.09	14.70	2.44	11.70	21.14	11.21
Improved Sona A	16.09	6.60	7.35	18.40	9.06	11.50
TNMS37 A	24.75	2.25	13.46	14.97	11.21	13.33
ADCMS-1-A	9.09	10.95	14.00	18.15	13.45	13.13
V20 A	12.25	15.45	3.90	2.40	24.36	11.67
Mean	11.61	8.18	6.38	12.25	12.00	–

SE (d) = 1.44
LSD = 2.89

Genetic analysis of yield components in rice involving CMS lines

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Success in breeding for quantitative traits depends upon the gene action involved for the traits concerned and the nature of the gene effects controlling the character.

We conducted a study to deduce the nature of gene action governing the traits that are economically important in rice. We used a line × tester method of mating. Ten cytoplasmic male sterile (CMS) lines (IR547S3, IR547S6, V20, ZS97, Intan mutant, Pushpa, Mangala, Improved Sona, TNMS37, and ADCMS- 1) were used as the lines. Five restorer lines (IR36, IR46, IRS4, IR9761-19-1, and ARC11353) served as the testers.

Ratio of GCA and SCA variances.

Character	GCA variance (s^2A)	SCA variance (s^2D)	Ratio of $s^2A:s^2D$
Days to 50% flowering	7.03	11.43	0.62
Plant height	0.29	27.26	0.01
Productive tillers	0.09	1.56	0.06
Boot leaf area	1.77	16.26	0.11
Panicle exsertion	0.48	1.30	0.37
Panicle length	0.05	1.76	0.03
Grains per panicle	92.90	186.34	0.50
100-grain weight	0.001	0.02	0.05
Grain yield	2.98	5.75	0.51

We evaluated the resulting 50 hybrids using a randomized block design with three replications. Each genotype was planted in two 6-m-long rows using a spacing of 20 x 20 cm. Thirty plants per row were maintained. We observed and recorded the important quantitative traits of 20 randomly selected plants in each replication for all hybrids. We subjected the data to analysis of variance and calculated the combining ability variance.

For all the characters studied (see table) the specific combining ability (SCA) variance was greater than the general combining ability (GCA) variance, indicating the predominance of nonadditive gene action for these traits. This suggests that recurrent selection techniques and diallel selective mating could be used to improve these traits.

Because rice is a self-pollinated crop, it would be desirable to have multiple crosses and to make selections in the advanced generations and biparental mating for greater genetic improvement. Further, the prevalence of nonadditive gene action implies that all these characters could be improved through heterosis breeding. ■

Identifying japonica-type wide compatibility (JWC) restorers for developing indica/japonica hybrids

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To exploit indica/japonica heterosis, JWC lines have been developed from crosses of WC donor 02428 and japonica cultivars. We crossed 18 JWC lines with two contrasting cytoplasmic male sterile (CMS) lines derived from Hong Lian (HL) and wild abortive (WA) CMS sources to identify JWC restorers that can be used to develop indica/japonica hybrids.

We evaluated the F_1s for both pollen and spikelet fertility in Nanjing (32° N) in 1990-91.

Seven of the 18 JWC lines are efficient restorers for both HL and WA CMS lines. Another seven are good maintainers for both CMS lines. Of the remaining four testers, JW_5 and JW_{14} are good restorers for WA CMS lines and maintainers for HL CMS lines. In contrast, JW 15 and JW20 are restorers for HL CMS lines and maintainers for WA CMS lines (see table).

Results suggest that of the 18 testers, the seven maintainers for both CMS lines could be used as backcrossing parents to develop WC CMS lines. The seven common restorers could be used to develop indica/japonica intersubspecific hybrids. Additionally, a partial inverse restorer-maintainer relationship exists between HL and WA CMS lines. This suggests that different Rf gene(s) may exist for restoring fertility to the two CMS lines. If the two CMS sources are used in hybrid rice breeding, the chance of selecting restorers for either of them would increase. ■

The ability of japonica wide compatibility lines to be restorersfor HL and/or WA CMS lines. Nanjing, China, 1990-91.

Tester restorer line	Tester CMS source[a] HL		WA	
	Pollen	Seed set	Pollen	Seed set
JW1	F	N	F	N
JW2	CS	PS	S	PS
JW3	F	N	F	N
JW4	F	N	F	N
JW5	S	PS	F	N
JW7	CS	PS	CS	PS
JW8	CS	PS	CS	PS
JW10	F	N	F	N
JW12	CS	PS	CS	PS
JW13	CS	PS	CS	PS
JW14	CS	PS	F	N
JW15	F	N	CS	PS
JW16	F	N	F	N
JW17	CS	PS	CS	PS
JW18	F	N	F	N
JW20	F	N	CS	PS
JW28	CS	PS	CS	PS
1082 R	F	N	F	N

[a]F = fertile (>90% pollen fertility), S = sterile (1-30% pollen fertility), CS = completely sterile (<1% pollen fertility), N = normal (>75% seed set), and PS = partially sterile (50% seed set).

Identification of restorers and maintainers for cytoplasmic male sterile (CMS) line V20 A

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As research to develop hybrid rice intensifies, an urgent need exists to screen and identify restorers and maintainers for CMS line V20 A.

We crossed V20 A with 89 cultures—locally released varieties and elite and IRRI cultures—and obtained 89 F_1s at the Regional Research Station (RRS), Mandya, during the 1992 dry season. Hybrids and their parents were transplanted during the following wet season in rows of 30 plants spaced at 15 × 20 cm. Ten plants from each hybrid were labeled. We earmarked three panicles from each plant.

Florets from the upper part of the panicles were collected before flowering. We used KI to stain for pollen fertility. Two panicles from the same plant were bagged before flowering. We calculated spikelet sterility as the percentage of filled grains.

We designated male parents of the hybrids that showed 100% pollen sterility

Table 1. Maintainers and restorers[a] for V20 A at RRS, Mandya, Karnataka, India, 1992.

Male parent	Maintainer or restorer	Male parent	Maintainer or restorer
ES18	M	IRBPHN 89	R
Pragathi	M	Doddbyra	PR
Mutshell	M	CR 213-1002	R
Kembasadi	M	BRB11-461	PR
Karolina	R	T2934	PR
Kumbara	R	BPT 4339	PR
Kempavadi	R	BR51-91-7	PR
Bhavani	R	BR51-46-5	PR
Salumpikit	R	IET11668	M
Vani	R	IET9801	M
China 6	R	IET11683	M
Hurigidda	PR	IET10897	M
Mahaveera	PR	IET10857	M
Akashi	PR	IET10408	M
Vikram	PR	IET7511	M
Mangala	PR	IET11689	M
Kirwana	PR	IET11691	R
Shakti	PR	IET10410	R
Maratibatha	PR	IET10892	R
Mahsuri	PR	IET10891	R
Bilikagga	PR	IET2934	R
BKB	PR	IET10890	R
PSP5-2-2	PR	IET5656	R
Pushpa	PR	IET7191	R
Tellahamsa	PR	IET8116	R
IET10882	PR	IR51315-4-5	R
IET10409	PR	IR9876-211-26	R
IET9831	PR	IR9852-18-1	R
IET10884	PR	IR9511-122-3	R
IR28237-31-3-2-1	M	IR31429-18-4	R
IR28178-111-1-2-3	M	IR28210-68-4	PR
IR31916-9-2	R	IR18353-33-1	PR
IR30864	R	IR29692-71-2-2-2	PR
IR22107-41-1-2	R	IR9469-62-4	PR
IR25861-35-3-3	R	IR21916-128-3	PR
IR25167-9-4	R	IR18356-932-4	PR
IR19661-1-3	R	IR22107-14-2-1	PR
IR31358-90-2	R	IR28178-28-6	PR
IR25924-92-1-3	R	IR21819-20	PR
IR26	R	IR20226-24-7	PR
IR13240-32-6	R	IR32420-130-1-3	PR
IR21178-39-4	R	IR5294-67-3-6	PR
IR21573-2-1-22	R	IR2863-39-2-8	PR
IR25683-8-4-6	R	IR27280-39-9	PR
IR13419-1 13-3	R		

[a]M = maintainer, R = restorer, PR = partial restorer.

Table 2. Frequency of restorers and maintainers in cultures of Indian and IRRI origin.

Source	Maintainers (no.)	Restorers (no.)	Partial restorers (no.)	Total (no.)
IRRI	2	21	14	37
India	12	16	24	52

and more than 99% spikelet sterility as maintainers. Restorers were those showing more than 90% pollen and spikelet fertility. The rest were partial restorers.

Among the 89 cultures tested, 14 were maintainers, 37 restorers, and 38 partial restorers (Table 1). The frequency of maintainers was greater in Indian cultures than in IRRI cultures (Table 2). ■

Using androgenesis in indica rice breeding

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The frequency of whole plantlet induction through androgenesis is still very low in indica rice: about 1%, based on anther number. While increasing the frequency to 1.7%, we studied the application of androgenesis to breeding.

After surface sterilization, anthers of indica rice hybrids were cultured on N6 medium to which 2 mg 2,4-D/liter was added to induce calli, and then on N6 + Kin 2 + NAA 0.5 + IAA 0.5 mg/liter to regenerate plantlets. Progenies of the doubled haploid plants (H2) were assessed for yield potential, resistance to pests, and grain quality, and then testcrossed with male sterile lines to screen for restorers.

We examined 654 pollen lines (H2) derived from hybrid rice and found that the frequency of homozygous diploids was 88.6%. Statistical analysis revealed that the characters within one line are relatively uniform and stably heritable. Among different lines, broad genetic recombinations occur. We conclude that using androgenesis in indica rice breeding is feasible.

Gan Zhao Xian No. 11, an early-maturing indica that was registered in 1990, is an example of a variety that was successfully bred through anther culture of hybrid rice Shan You No. 2. Duration is only about 105 d and yield about 5.6-6 t/ha. It has high cold tolerance at the seedling stage and uniform heading and ripening.

Restorer line 2374, which has good restoring ability and strong combining ability, was bred from progenies of Shan 2 H2 (a pollen line)/Jian 30. This line gives strong heterosis in crosses with Xie Qin Zhao A, Di Gu A, and a photoperiod-sensitive genetic male sterile line. The hybrid rice Xie 2374, which was registered in 1990, has high yield potential, broad adaptability, and broad resistance to diseases and insects.

HR1004 was bred through anther culture of CPSLO 17/Skybonnet (F_1). It has high grain quality, wide compatibility, and CMS restoring ability. Protein content is up to 12.9% and amylose content is 17.4%. Grain is long and thin (length:width ratio is 3.6), and not chalky. When it was crossed with Xie Qin Zhao A or Chang Fei 22 A, the hybrid showed high quality in grain appearance and edibility.

Using androgenesis of indica rice to induce pollen plantlets and improve varieties is an effective breeding path. Further studies are needed, however, to improve the frequency of green plantlet induction in indica rice. ■

Identification of cytoplasmic male sterile (CMS) sources in rice through reciprocal crosses

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Many rice varieties of different origins were crossed during 1988-90. Some seed parents have shown a dramatic cytoplasmic effect on F_1 fertility when crossed with pollen parents.

We used tester parents PAL, 2159, 029,02428, Ys 8072, Ys 8804, LH422, and Reed rice (Table 1) to make reciprocal crosses in 1991. Each cross was planted in a single row of 15 plants with 25- × 20-cm spacing in Nanjing (32° N). The F_1 pollen fertility was checked.

We observed significant reciprocal difference in both pollen and spikelet fertility in four of the six reciprocal crosses involving PAL as the seed parent (Table 2). A similar difference existed in two of the three crosses involving Reed rice as maternal parent. The six crosses with either PAL or Reed rice cytoplasm were completely sterile in both pollen fertility and seed setting of bagged panicles. The corresponding crosses with either PAL or Reed rice as pollen parents showed normal fertility.

The natural outcrossing rate varied greatly among crosses showing fertility in F_1. The outcrossing rate of PAL/2159 and Reed rice/2159 was high and significantly higher than that of PAL/029, PAL/02428, PAL/Ys 8072, and Reed rice/Ys 8072 (Table 2). Because 2159 seems to have enhanced outcrossing, 2 159 may be used as a maintainer to develop PAL and Reed rice CMS lines.

The remaining three reciprocal crosses of PAL/LH422, PAL/Ys 8804, and Reed rice/LH422 were highly fertile (Table 2). Results suggest that LH422 has Rf gene(s) that can restore fertility for PAL and Reed rice sterile cytoplasm, and Ys 8804 for PAL. CMS sources PAL and Reed rice and the restorers reported in Table 2 seem to be promising material in hybrid rice breeding. ■

Table 1. Characteristics of parents used in crosses.

Parent	Varietal group[a]	Pedigree or origin	Remarks[b]
2159	I	NJ11/IR29	
PAL	I	Palgarh 31-1-3	
Reed rice	I	Reed-llke wild rice(?)/IR24	
029	J	Luai//IR8/Nongkeng 58///IR36////ASD7	WC
02428	J	Jipangdao/Pangxiegu	WC
Ys 8072	J	0201729	WC
Ys 8804	J	Nankeng 351020	WC
LH422	M	Hunan Hybrid Rice Center, China	WC

[a] I = indica, J = japonica, M = intermediate. [b] WC = wide compatibility.

Table 2. Pollen fertility and percent seed setting in reciprocal crosses of rice varieties.

Cross	Pollen[a]	Seed setting (%)	
		Bagged panicles	Natural outcrossing
2159/PAL	F	88.63 ± 7.31	85.29 ± 8.13
PAL/2159	CS	0	65.59 ± 7.88
029/PAL	F	72.46 ± 8.91	78.51 ± 7.10
PAL/029	CS	0	16.78 ± 9.01
02428/PAL	F	75.38 ± 7.21	79.18 ± 6.76
PAL/02428	CS	0	10.33 ± 5.72
Ys 8072/PAL	F	68.78 ± 7.83	79.44 ± 3.83
PAL/Ys 8072	CS	0	32.38 ± 15.44
LH422/PAL	F	75.60 ± 6.82	74.38 ± 0.14
PAL/LH422	F	78.23 ± 4.32	72.29 ± 3.83
Ys 8804/PAL	F	74.21 ± 3.78	77.60 ± 5.39
PAL/Ys 8804	F	64.28 ± 8.11	62.23 ± 11.99
2159/Reed rice	F	78.43 ± 3.78	88.01 ± 4.37
Reed rice/2159	CS	0	57.39 ± 4.75
Ys 8072/Reed rice	F	65.32 ± 4.58	68.88 ± 7.48
Reed rice/Ys 8072	CS	0	28.18 ± 13.07
LH422/Reed rice	F	64.21 ± 4.33	63.41 ± 5.62
Reed rice/LH422	F	73.78 ± 5.31	75.32 ± 4.73

[a] F = fertile (>90% fertility), CS = completely sterile (<1% fertility).

Large-grain somaclonal variants in IR26

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We have been researching ways to improve restorer lines by using somaclonal variation to better exploit rice heterosis. A series of somaclonal variants with useful characteristics have been obtained. One is the large-grain variants from IR26, which once was an important restorer in the hybrid rice area in the Yangtse Valley of China.

The IR26 large-grain variants have different plant heights and growth durations. They were obtained by culturing immature panicles as explants and selecting from the R_2. These variants are now in the R_7 generation.

Two of the variants (variant-35 and variant-41) are superior to IR26 in 1,000-grain weight and grains/panicle (see table). These increases were to some extent at the expense of fertility. Grain weight/plant of the variants, which was an average of 10 randomly sampled plants, was higher than that of IR26.

Chromosome observation of root tip and pollen mother cell of the variants showed no change in chromosome number. However, peroxidase isozyme analysis showed a different electrophoretic pattern between variants and the parent. The two variants have one more band than the parent. The variants and the parent also had stoichiometrical differences in some bands.

To identify the usefulness of these variants as restorers, they were crossed with Zhenshan 97 A. We compared the performance of the F_1 hybrids of Zhenshan 97 A/Variant 41 with that of Zhenshan 97 A/Milyang 46, a leading local hybrid. Zhenshan 97 A/Variant 41 performed better than the check. The large grain characteristic of the variant was expressed in the F_1.

These large-grain variants can be used in hybrid rice breeding programs. ■

Performance of IR26 large-grain somaclonal variants.

Variant	Plant height (cm)	Panicles/ plant (no.)	Spikelets/ panicle (no.)	Grains/ panicle (no.)	Fertility (%)	1000-grain weight (g)	Grain weight (g/plant)	Days to heading
IR26	88.4	12.5	97.5	90.3	92.6	25.7	26.8	80
Variant 41	96.2	11.7	138.4	97.3	70.5	41.3	40.3	85
Variant 35	87.9	13.7	120.5	91.5	75.8	35.7	38 6	79
Zhenshan 97 A/ Milyang 46	89.2	16.1	112.4	92.9	82.8	27.6	32.7	82
Zhenshan 97 A/ Variant 41	101.4	14.3	161.1	118.7	73.7	30.8	45.7	81

Physiological traits of selected maintainers in hybrid rice breeding

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Identifying physiologically elite maintainers may help in their conversion to effective cytoplasmic male sterile lines through backcrossing programs.

We studied photosynthetic rate, dry matter production, and yield of 21 effective maintainers from IRRI during the 1990 wet season under field conditions where 60 kg N/ha was applied. The experiment was laid out in a randomized complete block design with three replications. Seedlings were transplanted in the main field in 3-m^2 plots, spaced at 15 × 10 cm. We took samples to assess leaf area index (LAI) at flowering, and total dry matter (TDM) at 35 d, flowering, and harvest. Photosynthetic rate was measured on flag leaves with the LI-6000 Photosynthesis

Physiological traits of selected maintainers from IRRI. CRRI, Cuttack, India, 1990 wet season.

Maintainer	Flowering			Total dry matter (g/m^2)			Yield (g/m^2)	HI (%)
	Photosynthetic rate (mg CO_2/ dm^2 per h)	SLW (mg/ dm^2)	LAI	35 d	Flowering	Harvest		
V20 B	36.2	324	2.18	123	355	698	284	40
Ai-Nan-Tsao	35.2	317	1.78	118	350	477	201	42
Sernaigincha 61-54	44 7	410	3.56	141	570	753	355	47
IR 101 76-2-4-6-2	44.8	434	2.17	175	381	580	195	34
IR19723-2-2-1	40.2	424	2.89	164	552	860	335	39
IR19728-9-2-2-3-3	37.3	379	1.58	170	396	850	276	32
IR19728-9-32-3-3	40.4	389	3.11	128	542	813	373	46
IR19743-40-3-2-3	33.8	347	2.20	145	332	825	377	46
IR19774-8-3-1-1	39.3	377	2.78	119	428	772	348	45
IR19774-23-2-1-3	43.3	406	2.15	143	387	760	379	49
IR19791-8-3-2	42.0	383	2.51	135	453	790	370	46
IR19791-12-1-2-2-2	48.3	425	2.04	235	433	767	340	44
IR19805-12-1-3-1-2	41.1	412	2.00	145	334	753	291	39
IR19806-8-1-3-2	46.3	423	3.38	184	438	771	300	39
IR19816-8-1-3-2	47.1	432	2.03	124	381	880	428	48
IR19819-31-2-3-1-1	38.2	378	3.05	106	473	758	347	45
IR19891-12-3-2-1	47.7	416	2.14	137	413	650	279	43
IR22107-120-1	38.4	350	3.06	221	484	1012	466	46
IR28138-43-3-1-3-2	44.2	393	2.17	135	473	866	336	38
IR28142-6-3-2-2-2	47.1	444	2.55	133	474	933	448	48
IR33955-8-1-1	30.4	396	3.19	130	487	1083	485	45
Mean	41.2	393	2.50	148	435	793	339	43
LSD (0.05)	4.3	38	0.21	18	80	23	25	-

System at near saturated light (1000 µE/ m^2 per s).

The high-photosynthetic rate entries IR19791-12-1-2-2-2 and IR19891-12-3-2-1 had low LA1 (see table). IR19806-8-1-3-2 and Sernaigincha 61-54, however, recorded moderate photosynthetic rate with high LAI, implying high crop photosynthesis. Photosynthetic rate is significantly associated ($r = 0.727^{**}$) with specific leaf weight (SLW), suggesting the usefulness of SLW as a preliminary selection parameter for high photosynthetic rate entries.

IR22107-120-1 showed vigor in TDM production at early and late growth stages. IR33955-8-1-1 and IR28142-6-3-2-2-2 had high TDM produced at flowering and harvest. These three maintainers combined high TDM and harvest index (HI), resulting in superior grain yield. The postflowering TDM was strongly related to grain yield ($r = 0.880^{**}$).

When transferred into male sterile cytoplasm, maintainers such as IR33955-8-1-1, IR22107-120-1, and IR28138-43-3-1-3-2 may provide effective CMS lines for developing heterotic rice hybrids. ■

Fertility of Zhenong 1S, a promising photoperiod-sensitive genic male sterile (PGMS) japonica rice

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Breeding a good PGMS rice is a critical step in the development of a two-line system for commercial hybrid rice production.

Zhenong 1 S, derived from the cross of Nong Ken 58S and Xiushui 24 (a leading common japonica variety in Zhejiang Province, China), was officially identified as an elite PGMS japonica rice in Oct 1991 in Hangzhou.

In 1990, Zhenong 1S was grown on 5 sowing dates: 20 Apr, 10 May, 30 May, 19 Jun, and 9 Jul. After 30 d, 60 seedlings for each sowing date were transplanted at 23.3- × 23.3-cm^2 spacing in the field. During heading, the percentage of abortive pollens was determined under the microscope with 1% I_2-KI solution. After maturity, seed setting under selfed conditions was recorded (Table 1).

We also studied the effect of photoperiod and temperature on the fertility of Zhenong 1S in artificially controlled conditions at the China National Rice Research Institute, Hangzhou, in 1990-91 (Table 2).

When Zhenong 1S headed before 1 Sep, the percentage of abortive pollen was above 99.4% and the rate of self-seed setting was 0%; when it headed after 17 Sep, pollen sterility and spikelet fertility were 14.1% and 34.2%, respectively (Table 1). The heading period (1-9 Sep) was a critical period for

Table 1. Fertility of Zhenong 1S under field conditions in Hangzhou, China, 1990.

Sowing date	Transplanting date	Heading date	Av abortive pollen (%)	Av self-seed setting (%)
20 Apr	20 May	17 Aug	100.00	0.0
10 May	9 Jun	24 Aug	99.95	0.0
30 May	29 Jun	1 Sep	99.56	0.0
19 Jun	19 Jul	9 Sep	92.65	6.9
9 Jul	8 Aug	17 Sep	14.07	34.2

Table 2. Effects of photoperiod and temperature on the fertility of Zhenong 1S under artificially controlled conditions, 1990-91.

Photoperiod, temperature: h	°C	Observed panicles (no.)	Self-seed setting (%)	Self-sterility (%)
		Zhenong 1S		
14.75	29.7	28	0.0	100.0
	25.7	28	0.3	99.7
	23.5	25	0.0	100.0
14.00	29.7	23	0.0	100.0
	25.7	29	1.9	98.1
	23 5	30	3.8	96.2
13.25	29.7	27	1.8	98.2
	25.7	30	22.7	77.2
	23.5	30	35.4	64.6
		W6 154s (check)		
14.75	29.7	28	0.6	99.4
	25.7	20	47.8	55.2
	23.5	29	40.9	59.1
14.00	29.7	24	0.6	99.4
	25.7	25	26.6	73.4
	23.5	27	22.7	77.3
13.25	29.7	31	1.3	98.7
	25.7	24	25.9	74.1
	23.5	12	37.1	62.9

the fertility change of Zhenong 1S. This indicates that the change from sterility to fertility for Zhenong 1S is stable and clear under field conditions in Hangzhou (35° 05' N).

The sterility of W6154S, which is being widely used for two-line hybrid rices in China, is primarily controlled by higher temperature (29.7 °C) and not by longer photoperiod (Table 2). Therefore it has limited use in hybrid seed production.

The self-sterility rate of Zhenong 1S under long photoperiod (14.75 h) is above 99.7%, regardless of temperature. Under short photoperiod (13.25 h), the self-seed setting rate of Zhenong 1S increases as temperature falls. This confirms that under long photoperiod, Zhenong 1S is completely sterile, but fertility is induced under short photoperiod (13.25 h) with lower temperature (2.5.7 °C). ■

Evaluation of male sterile lines with Honglien cytosterility

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A 4 × 4 incomplete diallel cross involving four male sterile lines of Honglien-type Cong-Guang 41 A, Zhao-Tai A, Qing-Lu A, and Qing-Er A, and restorer lines Te-Qing 2, Qi-Ja-Zhan, Zhen-Gui-Ai, and Qing-Lu-Ai was carried out in 1990 to study the combining ability of the male sterile lines and their biological properties.

We planted the 16 hybrids in a randomized block design with three replications in the early season (from Mar to Ju1 1991) under irrigated conditions. Sixty seedlings were transplanted at 16.7- × 20-cm spacing in each plot.

Cong-Guang 41 A was a good general combiner for plant height, individual plant yield, 1,000-grain weight, total spikelets per panicle, number of full grains per panicle, and seed set percentage, but not for number of effective panicles per hill (Table 1). Qing-Er A was a poor combiner for seed set percentage, suggesting that it was not easily restored.

Cong-Guang 41 A was tallest; Qing-Er A was shortest. Cong-Guang 41 A had large panicles and few spikelets enclosed in the leaf sheath. Qing-Er A was high in stigma exsertion rate, followed by Cong-Guang 41 A (Table 2).

Cong-Guang 41 A appears to be a superior male sterile line compared with the other lines. ■

Table 1. General combining ability effects of the male sterile lines. Guangdong, China, 1991.

Male sterile line	General combining ability (%)						
	Plant ht	Individual plant yield	1000-grain wt	Total spikelets/ panicle	Full grains/ panicle	Seed set	Effective panicles/ hill
Qing-Lu A	2.46	6.21	0.50	–3.68	–3.73	1.92	4.73
Qing-Er A	–8.42	–17.10	–4.63	–9.34	–16.58	–6.78	4.62
Zhao-Tai A	2.31	1.54	2.14	–0.83	0.61	0.72	–1.98
Cong-Guang 41 A	3.64	9.26	1.94	13.84	19.67	4.14	–9.01
LSD (P = 0.05)	4.51	0.99	1.28	11.98	11.70	5.33	1.88

Table 2. Agronomic characters of the male sterile lines. Guangdong, China, 1991.

Male sterile line	Plant ht (cm)	Panicles/ hill (no.)	Spikelets/ panicle (no.)	Length (cm) of panicles enclosed in leaf sheath	Spikelets enclosed/ panicle (no.)	Leaves/ main culm (no.)	Stigma exsertion rate (%)
Qing-Lu A	85.3	10.3	148.0	4.56	3.8	15.11	23.47
Qing-Er A	69.0	9.0	128.2	4.61	4.0	15.54	65.38
Zhao-Tai A	84.0	10.0	117.8	5.09	5.1	14.50	32.16
Cong-Guang 41 A	93.0	7.3	210.5	5.26	1.9	15.00	43.16
LSD (P = 0.05)	5.34	2.4	13.6	ns[a]	2.3	0.78	8.56

[a]Nonsignificant.

L-proline-mediated, high-frequency regeneration in rice cultivar IR66

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We initiated calli cultures from seeds of rice cultivar IR66. The dehulled seeds were washed with distilled water and then surface-sterilized in 0.1% $HgCl_2$ solution for 5 min. Seeds were washed three times with sterile distilled water and placed in 150-ml Erlenmeyer flasks containing 30 ml of solid medium. The culture medium for calli induction consisted of basal Murashige and Skoog (MS) medium supplemented with 2,4-D (2 mg/liter), coconut water (l0%, vol/vol), and sucrose (3%, wt/vol). The cultures were incubated at 26 ± 2°C under continuous light of about 2,000 1x. The calli obtained were subcultured on calli induction medium at an interval of 21 d.

After two subcultures, calli were transferred to medium that had L-proline incorporated into it at 0.1, 0.3, 0.5, and 1.0 mg/liter and incubated for 21 d. The proline-treated calli were then transferred to regeneration medium composed of basal MS salts supplemented with IAA (1.0 mg/liter) and BAP (0.3 mg/liter).

Green spots appeared in the calli while being incubated for 21 d. The spots developed slowly and there were not as many in the calli not treated with proline. We transferred the spots to either solid or liquid medium having the same composition as that of the regeneration medium. Filter paper was used to transfer the spots to the liquid medium.

Untreated calli not only developed green spots slowly, but their regeneration capacity was also less than that of the treated calli (see table). Results were similar when we transferred untreated calli to liquid regeneration medium. We observed a very high frequency (30-50%, 100-150 plantlets per culture vessel) of regeneration capacity in calli treated with low concentrations (0.1 or 0.3 mg/liter) of L-proline and transferred to liquid medium. High proline-treated calli, however, failed to regenerate on either liquid or solid media. ■

Regeneration capacity of IR66 calli as influenced by different treatments.

Treatment	Regeneration[a]	
	Solid medium	Liquid medium
Control	16-35 (15)	16-35 (15)
L-proline : 0.1 mg/liter	Clusters of small plantlets without further growth	30-50 (100-150)
L-proline : 0.3 mg/liter	Clusters of small plantlets without further growth	30-50 (100-150)
L-proline : 0.5 mg/liter	No regeneration	No regeneration
L-proline : 1.0 mg/liter	No regeneration	No regeneration

[a] Figures in parentheses are the number of regenerated plantlets per culture vessel.

Performance of Punjab CMS lines in Cuttack, India

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We grew cytoplasmic male sterile (CMS) lines PMSl A to PMS 10 A from a wild abortive source and their isonuclear maintainers from Kapurthala, Punjab, in the field during 1991 dry season (DS) and wet season (WS). The experiment was part of a collaborative project with the Punjab Agricultural University, Ludhiana, India. We recorded pollen sterility, spikelet sterility in bagged panicles, plant height, days to 50% flowering, and panicle exsertion from unreplicated rows of 30 plants for each of the CMS and maintainer lines.

Of the 10 CMS lines, PMS3 A, PMS4 A, PMS5 A, PMS8 A, and PMS 10 A were completely pollen sterile, had reduced white anthers, and did not set any seed in bagged panicles in either season (see table). PMS 1 A was completely sterile during DS and PMS7 A was sterile during WS. PMS2 A, PMS6 A, and PMS9 A were unstable.

All CMS and maintainer lines were of medium duration. Most of the CMS lines flowered 2-4 d later, had shorter plants and poorer panicle exsertion than their maintainers (see table), perhaps because of the influence of their cytoplasmic factor. CMS lines were free from major diseases and pests.

Stable PMS lines PMS3 A, PMS4 A, PMSS A, PMSR A, and PMS10 A may be useful in developing hybrid rice for the shallow rainfed ecosystem of eastern India because of their semitall stature, stiff straw, and medium duration. ■

Evaluation of Punjab CMS and maintainer lines at CRRI, Cuttack, Orissa, India, 1991 DS and WS.

CMS or maintainer line	Pedigree of B line	Pollen sterility (%)		Spikelet fertility (%)		Plant height (cm)		Days to 50% flowering		Panicle exsertion (%)
		DS	WS	DS	WS	DS	WS	DS	WS	
PMS1 A		100	76.0	0	21.4	74	59	105	92	64.3
PMS1 B	Phulpattes 72/Jaya			79.3	84.1	88	83	105	89	100
PMS2 A		95	15.9	2.8	77.6	74	117	106	96	84.3
PMS2 B	Phulpattes 72/ Mutant 15	–	–	79.9	82.6	89	121	105	93	100
PMS3 A		100	100	0	0	77	63	106	94	72.1
PMS3 B	Basmati Mutant	–	–	83.0	87.6	90	83	104	92	100
PMS4 A		100	100	0	0	77	67	109	103	77.5
PMS4 B	IR8/Sigadis//NS200	–	–	67.9	79.4	83	78	109	100	100
PMS5 A		100	100	0	0	67	80	110	105	79.8
PMS5 B	PB134/Pb 133	–	–	79.3	75.2	85	85	109	105	100
PMS6 A		81.7	70.8	20.4	24.0	71	76	111	106	97.2
PMS6 B	PB 134/Pb 133	–	–	68.9	85.1	89	82	110	105	100
PMS7 A		75.7	100	30.4	0	71	62	111	104	73.6
PMS7 B	IR305-3-17-13/ IR661-1-140-3	–	–	74.0	80.9	88	78	107	102	100
PMS8 A		100	100	0	0	79	80	105	105	76.9
PMS8 B	IR747-82-6-31 IR665-40-6-3	–	–	76.7	71.8	91	85	102	104	100
PMS9 A		71.3	70.0	10.9	10.4	90	76	106	103	83.7
PMS9 B	PAU169-49-3-1-1/ PAU29-295-3-28	–	–	85.5	84.9	94	84	102	103	100
PMS10 A		100	100	0	0	74	69	107	91	78.5
PMS10 B	RP2B-849	–	–	71.8	68.4	87	74	103	90	100

Discovery of a recessive tall somatic mutant with wide compatibility in *Oryza sativa* L.

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A recessive tall somatic mutant with wide compatibility, 02428h, was created by somatic culture of mature embryos from japonica 02428. Elongated upper first and second internodes caused the tallness. The R_3 and R_4 height segregation, derived from the R_2 semidwarf plant line, fit a 3 semidwarf:1 tall ratio. The F_1 height of the cross 02428h and semidwarf 02428 in 1990 was the same as that of 02428 (88 cm). The F_2 height also fit the 3 semidwarf:l tall ratio (see table). The results indicate that a single recessive gene controls the long culm mutation.

02428h was also crossed in 1990 with indica varieties IR36, Nanjing 11, and 3037. The F_1 plants of all three had high fertility, with an average of 81.34%, indicating that the mutant 02428h maintained the wide compatibility of 02428. 02428h will be very useful in rice interspecific and intersubspecific hybrid seed production. ■

Plant classification of progenies of long-culm mutant 02428h, 1990.

Generation	Total plants (no.)	Normal semidwarf type (no.)	Tall type (no.)	Semidwarf: tall	Probability
R_2	40	29	11	0.033	0.75-0.90
R_3	85	63	22	0.004	0.95-0.99
R_4	44	32	12	0.03	0.75-0.90
F_2	651	489	162	0.0005	0.95-0.99

Performance of experimental rice hybrids in Bangalore, Karnataka, India

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We evaluated 11 hybrids of varying durations against local checks Jaya, Rasi, IR20, and Mangala at the Main Rice Research Station, Hebbal, Bangalore, during the 1991 wet season. We transplanted 30-d-old seedlings at 15- x 15-cm spacing on 7 Aug 1991 in 7.9-m^2 plots laid out in a randomized block design with three replications.

IR58025 A combinations generally outperformed IR62829 A and V20 A hybrids. ORI 002, IR58025 A/IR35366-62- 1-2-2-3 R, and ORI 001 yielded higher than others (see table). Estimates in relation to checks of comparable duration revealed standard heterosis of 38.5% for OR1 002 (130 d), 41.0% for IR58025 A/IR35366-62-1-2-2-3 R (1 28 d), 20.0% for IR58025 A/IR9761 - 19- 1 R (117 d), and 36.3% for IR58025 A/ IR29723-143-3 R (124 d).

The same hybrids have performed well with standard heterosis of 7.1-35.4% at Mandya, Karnataka, and are being grown in farmers' fields for verification. ■

Performance of experimental hybrids at Bangalore, Karnataka, India, 1991 wet season.

Hybrid, check	Duration (d)	Plant ht (cm)	Panicles (no./m^2)	Spikelets (no./panicle)	Spikelet sterility (%)	Grain yield (t/ha)	Standard heterosis (%) over			
							Jaya	Rasi	IR20	Mangala
Hybrid										
V20 A/IR30864	116	69	315	146	48.6	3.2	–61.9	–27.2	–43.8	–36.0
IR62829 A/IET11691	110	99	470	146	74.4	3.8	–54.7	–13.6	–33.3	–24.0
I R62829 A/IR30864	130	82	400	157	71.1	3.0	–64.2	–31.8	–47.3	–40.0
V20 A/IRBB7	120	57	398	92	21.1	4.7	–44.0	6.8	–17.5	–6.0
IR58025 A/IR29723-143 -3 R	124	76	459	168	45.2	6.0	–28.5	36.3	5.2	20.0
IR58025 A/IRBB4	138	79	418	202	32.3	5.9	–29.7	34.0	3.5	18.0
IR58025 A/IR9761-19-1 R	117	77	420	154	41.0	6.0	–28.5	36.3	5.2	20.0
IR58025 A/IR35366-62-1-2-2-3 R	128	81	494	116	53.2	6.2	–26.1	41.0	8.7	24.0
ORI 001	137	81	430	172	47.7	6.2	–26.1	41.0	8.7	24.0
ORI 002	130	83	401	168	27.1	7.9	–5.9	79.5	38.5	58.0
ORI 005	140	78	405	191	50.7	4.1	–51.1	–6.8	–28.0	–18.0
Check										
Jaya	140	92	384	147	24.2	8.4				
Rasi	126	88	392	162	7.6	4.4				
IR20	138	83	576	167	26.9	5.7				
Mangala	118	72	416	73	14.2	5.0				
LSD						0.4				
CV (%)						9.8				

Breeding male sterile rice lines with droopy leaves

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RGS20 is an ideal donor in developing male sterile lines with droopy leaves. It was crossed with leading maintainers having erect leaves. Results confirmed that a single recessive gene controls the droopy leaf trait.

In F_2, B_1F_2 and B_2F_2, the droopy-leaf plants with the desired characters were selected and backcrossed to erect-leaf B lines to identify droopy-leaf B lines. The droopy leaf trait was then incorporated into a wild abortive (WA) background by backcrossing to the droopy B. Some promising droopy leaf male sterile lines with WA cytoplasm and improved agronomic traits were released in 1990.

Panicles of the droopy leaf A line are all located in the upper leaves, which favors the receipt of foreign pollen. Thus, more hybrid rice seed can be produced with less effort by using the droopy-leaf male sterile lines because producers do not have to cut flag leaves and spray gibberellin. ■

Suspension initiation in indica rice requires proline

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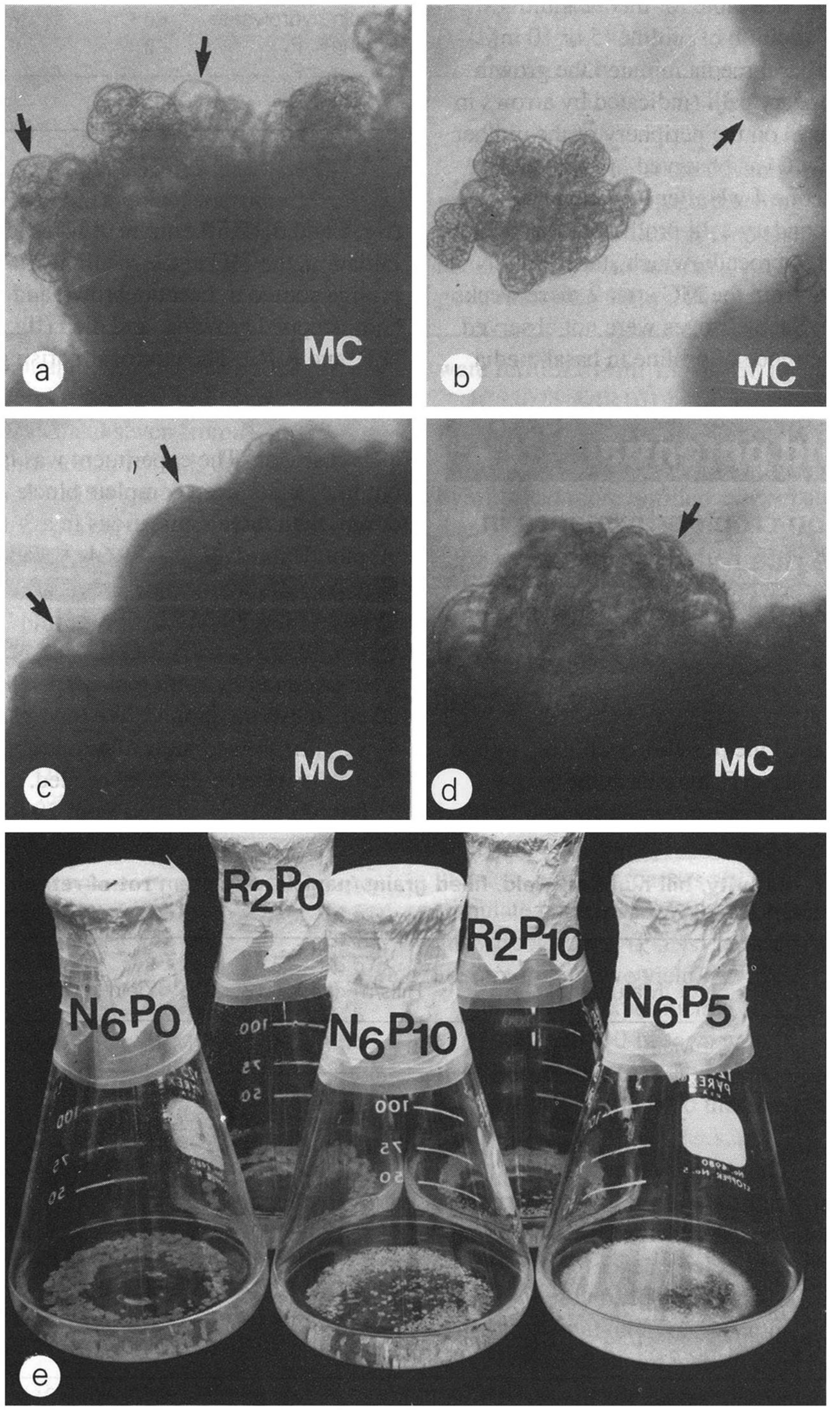
Suspension cultures are frequently used as starting material for protoplast isolation. We manipulated the suspension initiation medium to produce a fast-growing embryogenic line needed for successful protoplast culture.

Dehulled IR72 seeds were sterilized in 70% vol/vol ethanol for 1 min and 2.62% vol/vol sodium hypochlorite. They were inoculated in a plastic petri dish (100 × 15 mm) containing 20 ml modified MS medium for callus induction. The cultures were incubated in the dark at 25 ± 1°C for 3 wk. Calli were subcultured for 2 wk before suspension initiation.

We selected the friable, smooth, light yellow calli (the group of densely cytoplasmic cells as observed in an inverted microscope) to initiate suspension. About 2 g calli were placed in a 125-ml Erlenmeyer flask containing 30 ml liquid medium. We used two sets of basal medium, N6 and R2. Each set



Effect of proline on the initiation of suspension in indica rice. With proline: a) Prolific growth of secondary calli. b) Separation of microcalli from MC.
Without proline: c) Poor initiation of secondary calli. d) Unsustained growth of secondary calli. e) Necrotic MC in N_6P_0, R_2P_0; light yellow, smooth, friable microcalli in N_6P_{10}, R_2P_{10} 8 wk after initiation; finer microcalli in about 20-wk-old suspension in N_6P_5.

had three proline levels: 0, 5, and 10 mM as P_0, P_5, and P_{10}, respectively.

Cultures were placed on a gyrotary shaker (120 rpm) in the dark at 25 ± 1°C. About 3/4 of the liquid medium was replaced 2x/wk for the first 3-4 wk and weekly thereafter. The smaller calli with light yellow smooth surfaces were selected and transferred to another flask containing fresh medium. The cultures were maintained in the same medium until they were ready for protoplast isolation. See table for media additives.

The addition of proline (5 or 10 mM) in both basal media initiated the growth of secondary calli (indicated by arrows in the figure) on the periphery of the mother callus (MC) as observed in an inverted microscope 4 wk after initiation (fig. a). The secondary calli proliferated well and formed microcalli, which started to separate from the MC after 2 more weeks (fig. b). Such changes were not observed in the absence of proline in basal media (fig. c and d). Furthermore, 8 wk after initiation, the MC in the medium without proline started to become brown and hard, stopped growing, and died (fig. e, N_6P_0 and R_2P_0). The microcalli arising from the MC in medium with proline were still light yellow, smooth, and friable, with about 3-4 mm diameter, and became finer as the culture aged (fig. e, N_6P_{10}, R_6P_{10}, and N_6P_5). ■

Media additives.

Additive	Concentration[a] (mg/liter)		
	MS	N_6	R_2
Nicotinic acid	0.5	0.5	0
Pyridoxine HCl	0.5	0.5	0
Thiamine HCl	0.1	1.0	1.0
Myo-inositol	100	0	0
2,4-dichlorophenoxyacetic acid	2.0	1.0	1.0
Sucrose	30000	0	0
Maltose	0	30000	30000
Agarose (Sigma type I)	5500	0	0
Glycine	2.0	2.0	0
Casein hydrolysate	1000	0	0
Proline P_0	–	0	0
P_5	–	575.5	575.5
P_{10}	–	1151.0	1151.0

[a]At pH 5.8.

Yield potential

Ratoon crop performance in some rice hybrids

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We studied the possibility of using ratoon crops in some F_1 hybrids at the Sukamandi field station during the 1988-89 wet season. The experiment was laid out in a randomized complete block design with three replications in a 3- × 5-m^2 plot. Hybrids V20 A/IR64, V20 A/IR46 R, V20 A/Krueng-Aceh, V20 A/M66b, V20 A/IR28178, and V20 A/IR25912 and check Dodokan were ratooned by cutting mature stalks at 20 cm above the ground. We topdressed 40 kg N/ha immediately after cutting. The plots were irrigated as needed.

Ratoon hills/m^2 ranged from 20 for V20 A/Krueng-Aceh to 25 for V20 A/IR25912. Yields ranged from 0.76 t/ha for V20 A/Krueng-Aceh to 1.27 t/ha for V20 A/IR28178, about 14-22% of the main crop yield (Table 1).

Number of filled spikelets/panicle of the ratoon crop varied from 69.3 for V20 A/Krueng-Aceh to 97.6 for V20 A/IR25912, about 62-92% that of the main crop. The ratoon of hybrid V20 A/IR46 showed the maximum number of panicles/hill at 11.95. The 1,000-grain

Table 1. Maturity, hill number, yield, filled grains/panicle, and stem rot of ratoon and main crops of some rice hybrids. Sukamandi, Indonesia, 1988-89 wet season.[a]

Hybrid, check	Maturity (d)		Hills/m^2 (no.)		Yield (t/ha)		Filled grains/ panicle (no.)		Stem rot[b]	
	Main	Ratoon	Main	Ratoon	Main	Ratoon	Main	Ratoon	Main	Ratoon
V20 A/IR25912	122	62 (51)	25	25 (100)	4.1	1.3 (31)	105.38	97.62 (92)[a]	3	5
V20 A/IR46	120	62 (52)	25	25 (100)	5.1	0.9 (17)	107.20	79.87 (74)	3	5
V20 A/IR64	114	60 (53)	25	25 (100)	4.1	1.1 (27)	104.66	92.35 (88)	3	5
V20 A/Kr. Aceh	114	60 (53)	25	20 (80)	5.6	0.8 (14)	111.20	69.30 (62)	3	7
V20 A/IR28178	113	57 (50)	25	25 (100)	5.9	1.3 (22)	115.85	90.21 (77)	3	5
V20 A/M66b	109	60 (55)	25	25 (100)	5.9	0.8 (14)	115.21	76.20 (66)	3	7
Dodokan	101	53 (52)	25	21 (84)	5.1	0.9 (17)	102.91	80.50 (78)	1	1
LSD (0.05)	3	4			0.4	0.1	15.19	35.58		
CV (%)	1.1	2.7			3.4	2.6	5.7	17.4		

[a]Figures in parentheses are % of main crop. [b]Based on *Standard evaluation system for rice*

Table 2. Panicles/hill, panicle exsertion, 1000-grain weight, and plant height of ratoon and main crops of some rice hybrids. Sukamandi, Indonesia, 1988-89 wet season.[a]

Hybrid, check	Panicles/hill (no.)		Panicle exsertion (%)		1000-grain weight (g)		Plant height (cm)	
	Main	Ratoon	Main	Ratoon	Main	Ratoon	Main	Ratoon
V20 A/IR25912	13.5	10.00 (74)	104.05	77.65 (74)	26.13	20.07 (76)	116.0	68.6 (59)
V20 A/IR46	13.3	11.95 (89)	105.35	77.03 (73)	22.35	20.42 (92)	104.2	66.6 (64)
V20 A/IR64	12.5	9.35 (74)	105.70	85.79 (81)	28.10	20.34 (73)	111.6	71.7 (64)
V20 A/Kr. Aceh	16.4	11.25 (68)	93.00	86.99 (93)	29.15	22.64 (78)	116.6	73.5 (63)
V20 A/IR28178	13.1	8.80 (67)	109.51	80.83 (73)	26.05	20.24 (78)	113.5	64.7 (57)
V20 A/M66b	14.9	10.50 (70)	111.20	78.33 (70)	28.05	21.07 (76)	118.4	71.0 (60)
Dodokan	15.7	10.45 (66)	113.50	71.35 (63)	28.55	23.25 (82)	104.2	72.2 (69)
LSD (0.05)	3.6	3.81	7.55	2.98	5.66	6.58	3.7	3.6
CV (%)	10.4	14.7	2.9	1.5	8.7	12.9	1.3	2.1

[a] Figures in parentheses are % of main crop.

weight of the ratoon crop was about 76-78% of that of the main crop. Plant height ranged from 64.7 cm for V20 A/IR28178 to 73.5 cm for V20 A/Krueng-Aceh (Table 2). *Helminthosporium sigmoideum* incidence on the hybrids was 6-50%, while that on Dodokan was only 1 %. V20 A/IR25912, V20 A/IR64, and V20 A/IR28178 yielded significantly more than the check.

F_1 hybrids offer some advantages for use in the ratoon crop. In breeding programs for hybrid rice, emphasis should be given to selecting parents with good ratooning ability. ■

Yield and yield components of some new rice hybrids derived from IR58025 A and IR62829 A in Indonesia

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We evaluated 15 IRRI rice hybrids of which eight were derived from IR58025 A and seven from IR62829 A, three Indonesian hybrids derived from IR62829 A, IR64, and Way-Seputih in a yield trial during the 1991 dry season in Kuningan. Single seedlings were transplanted at 20- x 20-cm spacing in 3- x 5-m^2 plots with three replications. Plots were fertilized with 135-50-50 kg NPK/ha.

IR58025 A/IR10198, IR58025 A/IR15324, and IR58025 A/Pusa 150 yielded as much as IR64 and Way-Seputih. The hybrids had more unfilled grains/panicle than IR64 (see table). ■

Yield components of some new rice hybrids. Kuningan, Indonesia, 1991 dry season.

Hybrid, variety	Yield (t/ha)	Maturity (d)	1000-grain wt (g)	Filled grains/ panicle (no.)	Panicles/ hill (no)	Panicle length (cm)	Plant height (cm)	Unfilled grains/ panicle (no.)
IR64	5.9	135	20.41	61.11	16.9	19.8	68.9	13.42
IR58025 A/IR10198	5.9	136	21.59	81.28	16.23	20.6	77.7	24.20
IR58025 A/IR15324	5.4	127	22.61	74.33	14.96	20.3	77.1	24.81
Way-Seputih	5.2	136	22.62	88.34	12.53	16.9	77.4	24.13
IR58025 A/Pusa 150	5.2	130	21.40	79.04	15.43	18.2	74.8	36.57
IR58025 A/IR40750	5.0	141	20.24	79.97	14.9	18.2	81.3	45.46
IR62829 A/Pusa 150	4.9	127	19.43	44.19	19.4	16.6	66.0	23.5
IR58025 A/IR37839	4.7	136	21.34	63.14	16.23	19.6	78.4	23.65
IR62829 A/IR28238	4.7	127	18.02	71.18	15.2	16.5	73.9	32.70
IR62829 A/IR40750	4.5	130	19.11	46.70	19.93	17.9	67.8	28.29
IR58025 A/IR54742	4.4	143	21.92	75.90	11.23	20.4	86.0	54.15
IR62829 A/M66b	4.1	127	20.22	53.50	16.26	17.2	69.6	31.17
IR62829 A/IR15324	4.0	127	20.65	70.04	14.17	18.7	75.5	31.33
IR62829 A/IR10198	3.9	127	19.62	74.53	11.43	18.2	74.5	36.50
IR62829 A/IR54	3.4	136	21.31	39.49	19.7	18.2	67.8	32.0
IR62829 A/IR29723	1.8	130	21.50	26.02	17.13	16.0	68.4	64.55
IR62829 A/IR64	1.7	130	20.52	28.47	18.53	18.2	67.4	39.80
IR58025 A/IR29723	1.6	141	23.74	45.58	13.4	18.6	75.9	74.95
IR58025 A/IR32809	1.1	136	23.78	68.49	13.13	18.8	74.2	57.6
IR62829 A/IR32809	1.0	130	22.98	25.38	17.36	18.3	62.7	44.03
cv (%)	14.0	-	3.8	20.0	16.9	8.5	3.4	26.9
LSD (0.05)	0.9	-	1.29	15.38	4.28	2.52	4.08	16.13

An innovative approach to improve rice yield

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In areas where rice production has stagnated and demand continues to increase, new approaches are needed to stimulate production. We applied plant growth regulators (PGRs) to rice in an attempt to improve yield.

The 100-m^2 experimental and control plots had thirty 10-m rows with 0.2-m spacing between rows and 1 -m spacing between plots, replicated three times. High-yielding PR 106 seeds, treated with streptocycline and methoxy-ethyl-mercury chloride, were sown in mid-May and transplanted in late Jun. The foliar sprays of PGRs (Table 1) were applied weekly from early Aug to Oct using the manufacturers' recommended dose. The control plot was sprayed weekly with quantities of water equivalent to the recommended doses.

The chlorophyll content, plant height, and biomass were measured. Rice was harvested at maturity, and its yield recorded (Table 1), and characteristics analyzed (Table 2).

Spraying with PGRs promoted rice yield. The percent increase in the yield over control showed that PGR-H, CSL, and Aminos gave comparable bioefficacy.

PGRs Vipul, Paras, and 110-R are classified as long-chain aliphatic alcohols; CSL, Aminos, and PGR-H as modified amino acids. A correlation between these characteristics and bioefficacy suggests that the latter PGRs promote larger biomass and more chlorophyll, which lead to efficient photosynthesis and higher productivity.

The number of sprays (nine) used in the experiment was high to establish the utility of PGRs; dose and frequency of spraying still need to be optimized.

Rice from higher yielding PGRs was analyzed for nutritional and commercial characteristics (Table 2). Most of the nutritional characteristics were comparable, except for an increase in protein content, which is highly desirable. Reduced breakability during polishing also has commercial significance. Large-scale PGR spray trials in various agroclimatic zones and using different rice varieties are suggested to establish PGR utility for increasing rice production. ■

Table 1. Chlorophyll content, leaf dry weight, plant height, and yield profiles of rice sprayed with various PGRs, Patiala, India.[a]

Plant growth regulator	Chlorophyll		Dry leaves		Height		Yield		
	mg/g	±SD	g	±SD	cm	±SD	kg	±SD	Increase (%) over control
PGR-H	1.55	0.04	1.19	0.03	112	4.0	25.4	2.4	41
CSL	1.34	0.05	1.11	0.05	103	3.0	25.1	1.7	39
Aminos	1.32	0.05	1.12	0.04	106	4.7	24.5	2.0	36
Vipul	1.17	0.03	1.02	0.05	98	8.3	24.0	3.3	33
110-R	1.22	0.01	1.04	0.01	100	6.3	21.0	1.8	17
Paras	1.18	0.01	1.04	0.00	102	2.3	20.4	2.3	13
Control	1.10	0.02	1.01	0.03	98	6.2	18.0	3.2	

[a] Data from 30 samples (10/plot)

Table 2. Nutritional and commercial characteristics of rice grain.

Plant growth regulator	Characteristic (%)						
	N	Protein	Minerals	Moisture	Water[a]	Germination	Breakables
PGR-H	1.3	8.1	0.4	9.2	4.0	92	17
CSL	1.4	8.8	0.5	9.8	4.2	92	25
Aminos	1.3	8.1	0.5	9.3	4.3	93	21
Control	1.1	6.9	0.5	9.2	3.9	89	17

[a] Estimated as residual dry weight after soaking 100 g in 500 ml demineralized water for 16 hat ambient temperature.

A path coefficient analysis of rice panicle traits

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We evaluated the effects of panicle characters on grain yield in 20 high-yielding genotypes during rabi (Sep-Jan) 1991-92. We planted the genotypes in three rows of 10 plants each at 20- × 10-cm spacing in a randomized block design with three replications. Panicle traits and grain yield were recorded for the main tillers of 10 randomly selected plants for each entry in each replication. We used path coefficient analysis to assess the direct and indirect influence of various panicle characters on grain yield.

Direct (underlined) and indirect effects of panicle traits on grain yield in rice[a], Tamil Nadu, India, 1991-92 rabi.

Character	Panicle length	No of primaries	No of secondaries	Primary length	Secondary length	Filled grains/ primary	Filled grains/ secondary	Chaffy grains/ primary	Chaffy grains/ secondary	Total filled grains	Total chaffy grains	Genotypic correlation with yield
Panicle length	–0.263	–0.137	–0.492	0.285	0.074	–0.252	0.156	–0.054	–0.245	1.828	–0.176	0.724**
No. of primaries	–0.146	–0.246	–0.483	0.118	0.009	0.175	0.212	–0.087	–0.166	1.469	–0.350	0.505*
No of secondaries	–0.193	–0.177	–0.671	0.252	0.036	–0.214	0.264	–0.105	–0.404	2.082	–0.107	0.763**
Primary length	–0.213	–0.083	–0.481	0.351	0.083	–0.409	0.100	0.016	–0.204	1.858	–0.232	0.787**
Secondary length	–0.129	–0.015	–0.160	0.194	0.150	–0.223	–0.016	–0.066	–0.187	0.757	0.141	0.445*
Filled grains/ primary	–0.107	0.070	–0.232	0.232	0.054	–0.618	–0.059	–0.007	–0.260	1.250	0.207	0.530*
Filled grains/ secondary	0.108	0.137	0.467	–0.093	0.006	–0.097	–0.380	0.071	0.276	–0.844	0.087	–0.261
Chaffy grains/ primary	0.031	0.046	0.152	0.012	–0.022	0.010	–0.059	–0.463	0.760	–0.464	–1.220	–0.291
Chaffy grains/ secondary	0.078	0.049	0.327	–0.087	–0.034	0.194	–0.126	0.425	0.829	–1.020	–1.136	–0.502*
Total filled grains	–0.210	–0.158	–0.611	0.286	0.050	–0.338	0.140	–0.094	–0.370	2.284	–0.103	0.875**
Total chaffy grains	–0.034	–0.063	–0.053	0.060	–0.015	0.094	0.024	0.412	0.687	0.171	–1.370	–0.087

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

Grain yield had high positive significant association with all of the characters except filled grains of secondary branches, chaffy grains of primary branches, and total chaffy grains (see table). Among the panicle traits, total filled grains, primary length, and secondary length showed both positive association as well as direct effect on yield. Number of secondary branches and panicle length had significant positive correlation with yield, but they exhibited negative direct effect on yield.

The indirect effects of panicle length, number of primary and secondary branches, primary length, secondary length, and number of filled grains of primary branches through total filled grains were found to be very high and positive. Number of filled grains of secondary branches had a negative direct effect on yield and negative correlation with yield, while secondary length had a positive correlation with yield.

Filled grain should be emphasized because of high positive correlations, very high direct effects, and positive indirect effects on yield through many traits. Plant type for high yield in rice should have lengthy panicles, a high number of filled grains, and long primary and secondary branches. ■

Pest resistance-diseases

Geographical distribution of varieties resistant to rice tungro disease (RTD)

R. C. Cabunagan and H. Koganezawa, IRRI

A rice viruses data base (RVDB), developed at IRRI in 1990, organizes information about resistance to RTD, rice ragged stunt virus, and rice grassy stunt virus. The system enables researchers to access current information about rice accessions that have been evaluated for virus resistance and are stored in the International Rice Germplasm Center (IRGC).

Analysis of the updated data for RTD resistance in the RVDB showed that 15,795 accessions (20.5% of the IRGC collection) had been tested before 1989 for RTD resistance as infection rate. Among them, 560 (3.5%) are resistant (less than 30% infection).

Most of the resistant varieties originated in South Asia, particularly in Bangladesh, India, and Pakistan (see table). Of the 273 resistant varieties from India, 259 were ARC lines; 32 of the 63 varieties from Pakistan were Basmati lines. Although the percentage of resistant accessions from lndonesia is low, some important resistant varieties, such as Utri Merah, Utri Rajapan, and Balimau Putih, originated in this country.

We used the mass screening method to evaluate untested varieties originating from Bangladesh, Pakistan, and Sri Lanka. Of the 3,656 accessions tested, 355 (9.5%) are resistant to RTD. The results show that a higher percentage of resistant materials was obtained when mass screening was concentrated on varieties originating from a particular country of origin rather than on varieties at random.

Evaluation of untested varieties originating from India and Indonesia is in progress. ■

Frequency count of accessions resistant to RTD, by geographical region.

Origin	Tested (no.)	Resistant no.	Resistant %
		1963-89	
East Asia	946	4	0.4
Southeast Asia	5,274	52	1.0
Cambodia	63	0	0.0
Indonesia	1,517	25	1.6
Laos	753	0	0.0
Malaysia	361	7	1.9
Myanmar	811	2	0.2
Philippines	878	10	1.1
Thailand	393	2	0.5
Vietnam	497	6	1.2
South Asia	7,590	490	6.5
Bangladesh	2,956	149	5.0
Bhutan	33	0	0.0
India	3,101	273	8.8
Nepal	40	1	2.5
Pakistan	758	63	8.3
Sri Lanka	702	4	0.6
West Asia	125	3	2.4
Africa	1,275	9	0.7
South America	161	0	0.0
North and Central America	226	1	0.4
Oceania	20	0	0.0
Europe	27	0	0.0
Unknown	151	1	0.7
Total	15.795	560	3.5
		1990-91	
South Asia			
Bangladesh	2,150	263	12.2
Pakistan	283	18	6.4
Sri Lanka	1,223	79	6.5
Total	3,656	360	9.8

Effect of plant age on IR-BB21 resistance to *Xanthomonas oryzae* pv. *oryzae* (Xoo)

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Genetic resistance is the most effective and economic means of controlling bacterial blight (BB) of rice caused by Xoo. The dominant resistance locus *Xa-21* was identified in the wild rice *Oryza longistaminata,* and the near-isogenic line IR-BB21 was generated by introducing this locus into IR24. This locus was previously reported to confer resistance to all Philippine races of Xoo. We evaluated the ability of the *Xa-21* locus to confer resistance to the BB pathogen in both seedlings and adult rice plants.

Seeds at two stages during the development of IR-BB21 (GSK80 and IR-BB21) were collected on two occasions to ensure cultivar authenticity. IR-BB10 (carrying Xa-10), IR-BB21 (carrying *Xa-21*), and IR24 were grown in the greenhouse at about 30/25°C (day/night) temperatures.

Strains PXO99A (azacytidine-resistant derivative of PXO99, race 6) and PXO86 (race 2) of the Philippine Xoo isolate were grown for 48 h in terrific broth, a bacterial culture medium used for

Table 1. Reaction of 14-d-old rice seedlings to infiltration with *Xanthomonas oryzae* pv. *oryzae* strains.

Cultivar	Reaction[a]	
	PXO99A	PXO86
IR-BB10	W	HR
IR-BB21	W	W
IR24	W	W

[a] W = water soaking, HR = hypersensitive reaction.

Table 2. Length of lesions induced by *Xanthomonas oryzae* pv. *oryzae* strains on adult rice plants 15 d after inoculation.

Cultivar	Plant age (d)	Lesion length[a] (cm)	
		PXO99A	PXO86
IR-BB10	45	14.3 a	1.0 b
IR-BB10	60	14.9 a	1.9 b
IR-BB21	45	1.4 b	2.3 b
IR-BB21	60	2.2 b	2.7 b
IR24	45	14.1 a	12.8 a
IR24	60	13.8 a	14.2 a

[a] In the same column, means followed by the same letter are not significantly (P=0. 01) different according to Fisher's protected LSD.

growing certain strains of *E. coli.* It contains (per liter) 12 g bacto tryptone, 24 g yeast extract, 4 ml glycerol, 2.31 g KH_2PO_4, and 12.5 g KH_2PO_4. Cells were collected by centrifugation and resuspended in sterile water to obtain an inoculum concentration of 10^8 cfu/ml.

Fifteen plants of each cultivar were inoculated with strain PXO86 or strain PX099A. Adult plants were inoculated at 45 or 60 d after seeding (DAS) using the leaf-clip method. Seedlings were inoculated at 14 DAS using the leaf-clip method or by localized infiltration of bacteria into leaves.

Plant reaction to Xoo was measured 4 d after inoculation (DAI) for seedlings. Susceptibility is indicated by water soaking reaction and resistance by hypersensitive reaction. Reactions of adult plants were assessed by measuring lesion length 15 DAI for 20 leaf samples per cultivar-strain combination. All experiments were conducted at least twice.

All cultivars at the seedling stage were susceptible to strain PX099A, and IR-BB21 and IR24 were susceptible to strain PXO86 (Table 1). A hypersensitive resistance response was observed on IR-BB10 inoculated with PXO86.

Lesion lengths on IR24 adult plants inoculated with PX099A or PXO86 were typical of those for a susceptible reaction (Table 2). Lesion lengths on IR-BB 10 inoculated with PX099A were similar to those on IR24, but lesions induced by PXO86 on IR-BB 10 were significantly shorter than those on IR24. Lesions induced by either Xoo race on adult plants of IR-BB21 were significantly shorter than those observed on susceptible IR24 (Table 2).

Adult rice plants resistant to Xoo have markedly shorter lesions than do susceptible cultivars. These results indicate that the *Xa-21* resistance locus confers adult plant resistance to Xoo, but seedlings containing this locus are not appreciably resistant to the BB pathogen. ■

Virus detection in varieties resistant to tungro (RTD)

R. C. Cabunagan, Z. M Flores,
E. C. Coloquio, and H. Koganezawa, IRRI

Rice varieties Utri Merah (IRGC 16680) and Balimau Putih (IRGC 17204) do not show clear RTD symptoms even if infected. We traced the infection of rice tungro bacilliform virus (RTBV) in inoculated plants by enzyme-linked immunosorbent assay (ELISA) for 5 wk. Varieties TKM6 (resistant to RTSV), Gam Pai 30-12-15 (resistant to vector), and TN1 (susceptible) served as checks.

About 80 plants/variety were planted individually in clay pots, enclosed in mylar cages, and inoculated at 21 d after sowing using 5 *Nephotettix virescens* adults/plant for a 24-h inoculation access time. We took a 4-cm-long sample weekly from the 2d or 3d youngest expanded leaf of each plant. The samples were homogenized in 0.1 M phosphate buffer containing 0.14 M NaCl and 0.05% tween 20 at 10x dilution. Samples were tested following the normal ELISA procedure.

Utri Merah and Balimau Putih had a relatively high RTBV infection at 1 wk after inoculation (WAI). We detected RTBV in some plants only at 2 WAI; later, RTBV became undetectable in these infected plants (see table). The concentration of RTBV examined by ELISA was always lower in these varieties than in other varieties.

Detection of RTBV in some rice varieties by ELISA at 5 weekly intervals after inoculation (WAI).

Detection pattern of RTBV in individual plants[a] at given WAI					Plants (no.) showing detection pattern in				
1	2	3	4	5	Balimau PMS5	Utri A	TKM6	Gam Pai 30-12-15	TN1
+	+	+	+	+	2	0	28	7	78
–	+	+	+	+	0	0	48	37	0
–	–	+	+	+	0	0	1	9	2
+	–	–	–	–	40	45	0	0	0
+	+	–	–	–	16	7	0	0	0
+	+	+	–	–	1	0	0	0	0
+	–	+	–	–	1	0	0	0	0
+	–	–	–	+	1	0	0	0	0
+	–	+	+	+	1	0	0	0	0
+	+	+	–	+	1	0	0	0	0
–	+	–	–	–	8	5	0	0	0
–	–	–	–	–	8	23	2	27	0
Total					79	80	79	80	80

[a] + = positive detection and- = negative detectlon in individual plants at each WAI. For example, ++ ––– means that RTBV was detected at 1 and 2 WAI, but not at 3-5 WAI in the same plant.

RTBV was, however, detectable in TKM6, Gam Pai 30-12-15, and TN1 throughout the period after its detection. The results indicate that the virus concentration in Utri Merah and Balimau Putih was reduced over time to below the level of detection and is the reason why past tests done at 3-4 WAI showed low infection rates of RTBV. The results also suggest that Utri Merah and Balimau

Relationship between phenylalanine ammonialase (PAL) activity and blast (B1) resistance in rice

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We randomly selected seedlings of 30 rice cultivars at the three-leaf stage. They were surface-sterilized in 0.1 % HgCl, for 5 min at room temperature, and then rinsed five times in sterile distilled water. Leaves were cut off and crushed by hammering individually in boric acid buffer (pH 8.8), each liter supplemented with 0.5 g polyvinyl pyrolidone. The mixture was centrifuged three times at 5,000 rpm for 25 min at 4 °C. Then 0.5 ml of the supernatant was mixed in a test tube with 3.5 ml of a reaction mixture that contained 20 mmol L-Phe 3 ml/liter and allowed to rest for 60 min at 30 °C. The absorbance of the mixture at 290 nm was recorded using a UV 120-02-01 model Ultraviolet-spectrophotometer (Shimadzn Ltd. Co., Japan). The experiment was replicated four times.

The correlation coefficient was nonsignificant at 5% probability level for PAL activity and Bl resistance in rice cultivars (*Standard evaluation system for rice* [SES] scores of 0-3) on the qualitative scale based on lesion type, but it was significant at 1% probability (scores of 4-9) on the quantitative scale based on the percentage of leaf area affected. This indicates that PAL activity increased as the B1 resistance score decreased from 4 to 9 (see table). ■

Relationship between Bl resistance scores and PAL activity in rice seedlings.

Cultivar	Score [a]	PAL activity (OD_{290}/g fresh wt per h)
Toride 1	0	0.435
Zhaiyeqing 8	1	0.429
Xiangzaoxian 1	1	0.416
IR52	2	0.423
IR62	3	0.431
Sanerai	3	0.423
Jinwan 1		0.421
Jinyou 1	3	0.417
Yangdao 2	3	0.416
IR29	3	0.389
Correlation coefficient		–0.4475 ns [b]
Teqing	4	0.420
Zhefu 802	4	0.404
IR58	4	0.400
Erjiufeng	4	0.393
Zaoxian 143	4	0.390
Lunhui 422	4	0.387
6188	4	0.372
M112	5	0.378
77-175	5	0.345
Jinxi 14	6	0.381
Hongyun 33	6	0.381
Jinzao 6	6	0.363
Erjiuai	6	0.346
73-07	6	0.342
Shenghong 16	7	0.374
22	7	0.359
Guichao 2	8	0.353
Menggudao	9	0.325
Hong 410	9	0.314
LJXTHG	9	0.309
Correlation coefficient		–0.8398** [c]

[a] Based on SES Scale of 0.9. [b] Nonsignificant at 5% probability level. [c] Significant at 1% probability level.

Efficiency of natural selection for bacterial sheath rot (BSR) in bulked families

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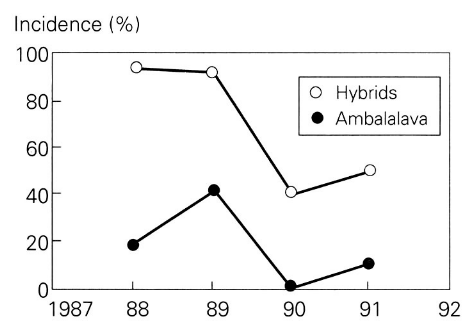
BSR, induced by *Pseudomonas fuscovaginae* Tanii, Miyajima, et Akita, was earlier reported on rice only in the northern part of Hokkaido, Japan. It was discovered in Burundi in 1982. This disease has since been identified in Madagascar and Latin America in rice, sorghum, maize, and wheat. In rice, BSR causes poor panicle exsertion, leading to sterility of the nonexserted part of the panicle.

BSR is particularly damaging to modern varieties with the sd_1 gene and partially explains the poor performance of fixed varieties in the International Rice Cold Tolerance Nursery. We compared Ambalalava, a tall, fixed, variety that is well-adapted to BSR, with two F_5, F_6, F_7, and F_8 bulked populations from 1988 to 1991 at the same site at 1,550 m asl.

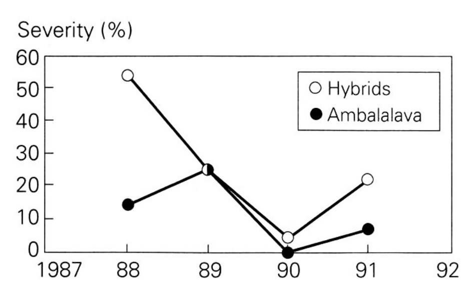
The two populations were grown at the site in 1987, but BSR pressure was very low. BSR incidence was measured as the percentage of partially exserted panicles in a sample of 10 pots with three replications. Severity was estimated by the difference in weight between 25 sampled panicles with and without disease (mean of three replications).

Yield loss is measured by the incidence multiplied by severity of BSR.

1. BSR incidence in Burundi, 1988-91.



2. BSR severity in Burundi, 1988-91.



The fluctuation of incidence on control Ambalalava reflects the year-to-year climatic variation; the lower the temperatures, the higher the incidence (Fig. 1). The incidence on bulk populations was very high and did not change between 1988 and 1989, although yield loss decreased from 55 to 25%, which was the level of the control. Natural selection eliminated the individuals that showed a high severity in 1988 (Fig. 2).

In 1990, no incidences or losses occurred on Ambalalava. The incidence in the hybrids stayed at the same level as Ambalalava in the preceding year, but with only 4% of the losses (Fig. 1). Incidence increased 10% for the hybrids the following year, resulting in increased losses of 8% for Ambalalava and 22% for the hybrid families.

The differences of scale between the two groups are due to the sd_1 gene. It has a critical threshold of incidence that leads to losses of 30-40% in modern varieties. Good panicle exsertion is needed to lessen BSR losses. We are using IR50, which has the *eui* (elongated uppermost internode) gene, in our breeding program to obtain modern varieties that are more resistant to BSR. ■

IRGC 100139, an accession of *Oryza glaberrima* sensitive to rice tungro spherical virus (RTSV)

P. O. Cabauatan and H. Koganezawa, IRRI

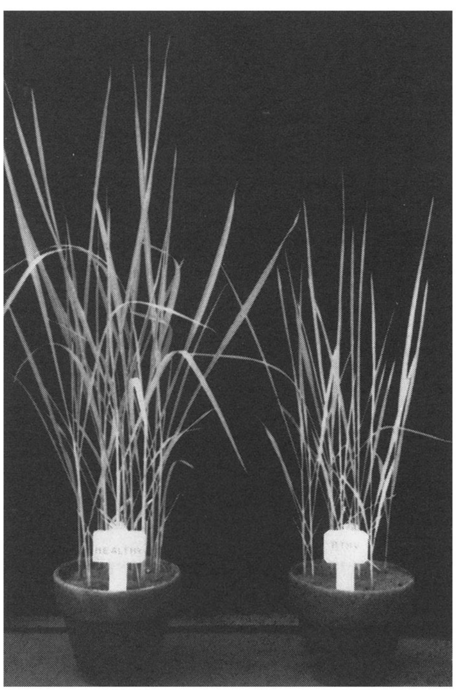
RTSV is a latent virus of rice. About 1,200 rice accessions have been tested at IRRI for RTSV, but none of them were sensitive enough to show distinct symptoms of RTSV infection.

We tested four accessions of *O. glaberrima* for sensitivity to RTSV by inoculating 7-d-old seedlings with one adult green leafhopper (GLH) *Nephotettix virescens* (Distant)/plant for 24 h in a test tube. The infected plants showed marked stunting, reduced tillering, and pale green leaves at 3-4 wk after inoculation (see figure). Flowering was delayed and panicles were short with few, small grains. Inoculation infected 80-90% of plants.

IRGC 100139 is the first rice accession of *O. glaberrima* identified at IRRI that consistently showed distinct symptoms when infected with RTSV. IRGC 100139 is also a good virus source. When adult GLH had 3 d access to RTSV-infected IRGC 100139 plants, more than 80% of the insects transmitted the virus to either TN1 or IRGC 100139. The results indicate that RTSV can be maintained and propagated in IRGC 100139.

At present, RTSV is detected in plants by enzyme-linked immunosorbent assay or by latex test. These tests are expensive and are not available in most laboratories in developing countries. The tests could be eliminated by using IRGC 100139 as an indicator plant for RTSV. The accession can be used to monitor RTSV-carrying leafhoppers caught in the field and for survey of RTSV occurrence in regions where no tungro symptoms are visible. ■

Healthy (left) and RTSV-infected (right) *O. glaberrima* plants at 21 d after inoculation.



Resistance to rice tungro spherical virus (RTSV) in rice germplasm

R C. Cabunagan, Z M. Flores, and H Koganezawa, IRRI

We used the mass screening test to determine resistance to rice tungro disease (RTD) of about 16,000 accessions of the International Rice Germplasm Center (IRGC). We selected 510 accessions that showed resistance to RTD and tested for resistance to rice tungro spherical virus (RTSV) using forced inoculation in test tubes and enzyme-linked immunosorbent assay (ELISA).

Plants were inoculated by confining a 6-d-old seedling with three viruliferous green leafhoppers (GLH) in a test tube for 24 h. Inoculated seedlings were transplanted into pots and grown in a greenhouse. Serological indexing was carried out 30 d after inoculation by taking 10-cm-long pieces from the 2d or 3d youngest leaf of each of the 40 plants/ accession.

When inoculated with rice tungro bacilliform virus (RTBV) and RTSV, only one accession showed a RTBV infection rate of less than 10%. while 251 accessions (49%) showed a RTSV infection rate below 10%; I47 accessions (29%) were not infected with RTSV.

We further evaluated 134 accessions with RTSV-infection rate below 10% by inoculating them with RTSV alone to confirm their resistance. Results revealed that 115 accessions (86%) had an RTSV infection rate below 10%. Seventy-six accessions were not infected with RTSV in the two experiments (see table on next page).

These results indicate that many varieties are available to serve as sources of resistance to RTSV. Some accessions that had low RTSV infection rates in both experiments and GLH resistance (resistance score <5) were omitted from the table because they may show RTSV resistance caused by vector resistance. ■

Rice varieties showing resistance to RTSV infection.

IRGC acc. no.	Variety [a]	RTSV infectton (%)		IRGC acc. no.	Variety [a]	RTSV infection (%)	
		Exp. 1	Exp. 2			Exp. 1	Exp. 2
177	Adday Sel.	0	0	26789	Shalya*	0	0
180	Adday Local Sel.	0	0	26791	Sham Rosh	0	0
4021	Binicol*	0	0	26813	Gogoj	0	0
5999	Pankhari 203*	0	1	27529	Bhoilush*	0	0
7366	PI 184675-2*	0	0	27779	Bara Pashawari 390	0	0
8261	Padi Kasalle	0	8	27781	Bara 413*	0	0
11062	G378	0	0	27787	Basmati Nahan 381	0	3
11751	Habiganj DW 8	0	0	27798	Basmati 1	3	0
12203	ARC6064*	0	0	27799	Basmati 43 A*	0	0
12274	ARC6561	0	0	27800	Basmati 93*	3	0
12310	ARC7007*	0	0	27803	Basmati 107*	0	0
12428	ARC10312	0	3	27804	Basmati 113*	0	0
12437	ARC10343	0	0	27805	Basmati 122*	0	0
14504	IR580 420-1-1-2	0	0	27814	Basmati 208*	0	0
14527	Barah	0	0	27818	Basmati 242	0	0
14649	Gendjah Melati	0	5	27821	Basmati 370 A*	0	0
14703	CPA86805-2*	0	0	27828	Basmati 376*	0	0
15769	Lawangeen*	0	6	27829	Basmati 377	0	0
16680	Utri Merah	3	0	27830	Basmati 388	0	0
16684	Utri Rajapan	0	0	27832	Basmati 405	0	3
19680	ARC10963	0	0	27833	Basmati 406	0	0
20600	ARC7321	0	0	27835	Basmati 427*	0	0
21164	ARC10980	0	0	27836	Basmati 433	0	0
21310	ARC11315	0	3	27856	Begumi 302	0	0
21337	ARC11346	5	3	27869	Chahora 144	0	0
21342	ARC11353	0	3	27870	Chahora 148	0	0
21473	ARC11554*	0	0	27872	Chahora 292	0	0
21474	ARC11555	0	0	27873	Chahora 382	0	0
21745	ARC11920	0	0	27916	Dhanlu 254	5	5
21958	ARC12170	0	0	27943	Hansraj 54*	0	0
22176	ARC12596	9	0	27946	Hansraj 62	0	0
22199	ARC12620	0	3	27947	Hansraj 189	0	0
22215	ARC12636	0	0	27948	Hansraj 197	0	3
22307	ARC12746	0	0	27951	Hansraj 365 A	0	0
22331	ARC12778	0	0	28102	P590	0	0
26253	Nep Bap	0	0	28320	Toga 286 A*	0	0
26295	Bale Betor*	0	0	28341	9*	0	0
26316	Birpala*	0	3	28450	361 *	0	0
26410	Pala Bhir	0	3	28522	Gundrikbhog	6	0
26418	Shada Muta*	0	0	28867	AUS4	0	0
26495	Konek Chul	0	0	31746	Bish Katar*	5	0
26527	Shuli 2	0	0	36731	Firro E (1)	0	0
26560	Bharat*	0	0	37215	Matichakma	0	0
26582	Buchi 2	0	0	37337	Urman Sardar	0	2
26622	Gia Dhan*	0	5	37430	Ghigos	0	0
26633	Gurdol*	0	5	37482	Kanakchul	0	0
26663	Kaisha Binni*	3	0	37488	Kashiabinni*	0	0
26703	Kurki*	0	0	37491	Katijan*	0	0
26715	Lao Bhug*	0	0	37761	Maliabhangor 1096	0	0
26784	Sakor	0	5	49996	Ovarkondoh	0	0

[a] Asterisk indicates the possibility that apparent RTSV resistance may be due to vector resistance.

Pest resistance—insects

Screening entries in the International Rice Whitebacked Planthopper Nursery (IRWBPHN) 1991 for resistance to whitebacked planthopper (WBPH) in Ludhiana, India

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Sixty-seven entries, including two of TN1, of the ninth IRWBPHN were screened for resistance to WBPH *Sogatella furcifera* (Horvath) under

Promising entries with resistance to WBPH in IRWBPHN 1991. Ludhiana, India, 1991.

Entries scoring 3.0
IR12665-7-1-3-6
IR15527-21-2-3
IR31429-14-2-3
IR31785-58-1-2-3-3
IR2035-117-3
IR43342-10-1-1-3-3
Entries scoring 3.7
ARC6248 (local check)
Baggi Munji 22
BR4-34-13-5
BR850-9-1-1
B3906 D14-ST-1 6-48-3
GH305
IR65
Entries scoring 4.3
IR13475-7-3-2
IR35366-40-3-3-2-2
IR43491-140-1-2-3
Entries scoring 5.0
Bamla Red 310-6
CR94-13
IR28526-44-1-1
IR29429-13-3-B-1-4
IR35293-125-3-2-3
IR35366-28-3-1-2-2
IR35366-62-1-2-2-3
IR39334-31-2-2-2
IR39357-45-3-2-3
IR60
Rami chudi
RP1442-2-2-3-5-1
RP1579-28-54
UPRH193
WC1240

glasshouse conditions with three replications. Local resistant check ARC6248 was included.

We evaluated the entries using the 0-9 scale of the *Standard evaluation system for rice* when susceptible check TN1 died.

Twelve entries were scored as resistant (3.0-3.7), 18 were moderately resistant (4.3-5.0), 28 susceptible (5.7-7.0), and 7 highly susceptible (7.7-9.0). Promising entries are listed in the table. ■

Screening rice varieties and lines for resistance to yellow stem borer (YSB) based on preference or nonpreference and antibiosis

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We screened 16 varieties and lines for resistance to YSB *Scirpophaga incertulas* in a cage in 1990. We transplanted five seedlings of each entry with a spacing of 25 cm between plants and 35 cm between varieties. The experimental design was completely randomized. We collected three replications of adult female moths from fields and kept them on Basmati 370 in a separate cage for oviposition. Each tiller was artificially infested 30 d after transplanting with two first-instar larvae that had been collected from the egg masses.

Five tillers with deadhearts from each variety were randomly dissected and larvae removed and weighed at 20 d after infestation.

We studied preference or nonpreference mechanism of resistance by randomly placing all entries in a wooden cage in three replications. Test material was exposed to oviposition by 100 female YSB moths early in the morning. We counted the egg masses laid on varieties and lines after 2 d.

TKM6, Basmati 385, and 4321 had the fewest deadhearts and whiteheads of the test entries (see table). TKM6 and Basmati 385 exhibited the nonpreference and antibiosis mechanism of resistance. 4321 showed preference and antibiosis behavior for YSB. Basmati 370, Basmati 198, and 4439 were susceptible to YSB. Other varieties and lines were moderately resistant to YSB. Resistant varieties exhibited nonpreference and antibiosis mechanism of resistance. ■

Performance of 16 varieties and lines under antibiosis and preference/nonpreference mechanism of resistance. [a] **Punjab, Pakistan, 1990.**

Variety or line	Av deadhearts (%)	Av weight of 5 larvae (mg)	Egg mass (av no.)
Basmati 385	15.91 ef	0.187 f	2 de
Basmati 370	44.66 a	0 277 d	6 c
4048	31.07 abcde	0.285 cd	4 cd
Basmati 198	36.73 abcd	0.300 abc	4 cd
6129	40.37 abc	0.310 a	4 c
PK2773-1-2-3	22.98 cdef	0.289 bcd	3 de
1053-2-4	38.22 abcd	0.301 abc	4 cd
4439	37.06 abcd	0.302 ab	9 b
4029-1	26.79 abcdef	0.285 bcd	10 e
4029-2	42.83 ab	0.310 a	4 cd
PK729-15-7	24.66 cdef	0.311 a	4 cd
1053-1-2	28.65 abcdef	0.301 abc	3 de
50189-8-6	25.78 bcdef	0.290 bcd	1 e
4321	17.66 ef	0.240 e	14 a
4048-3	22.19 def	0.302 ab	4 cd
TKM6	11.61 f	0.182 f	10 e
	LSD = 18.07		LSD = 2.58

[a]In a column, means followed by a common letter are not significantly different at the 5% level by DMRT

Changes in brown planthopper (BPH) biotypes in the Mekong Delta of Vietnam

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BPH is one of the important insect pests of rice in southern Vietnam. In 1988-91, popular varieties IR36, IR66, IR42, MTL 61 (IR19728), and MTL 58 (IR13240-108-3-2-2)—all of which have the *bph* 2 resistance gene—were hopperburned in many areas of the Mekong Delta.

We collected seven BPH field populations from different agroecological areas of the Mekong Delta in 1991 to determine the changes in BPH biotype using the modified bulk seedling test. Check varieties were seeded in 20-cm rows, 5 cm apart, in 60- × 40- × 10-cm seedboxes and replicated three times. Test entries were infested 7 d after seeding with seven second- and third-instar nymphs per seedling. We visually rated damage using the *Standard evaluation system for rice* 0-9 scale when the susceptible check TN1 had died.

All BPH populations studied killed TN1. Mudgo *(Bph 1)* was susceptible to all seven BPH populations. The resistance of ASD7 *(bph* 2) broke down, indicating that BPH biotype 2 had developed a new distinct biotype that was not similar to biotype 3 from IRRI. Rathu Heenati *(Bph 3)* and Ptb 33 (digenic gene) were still resistant to all populations. Babawee *(bph 4)* was moderately susceptible or susceptible to all BPH populations (Table 1 on next page).

BPH virulence in the Mekong Delta is apparently increasing because of natural adaptive selection. Reactions of different populations in various areas were relatively similar. It appears that a new biotype, the "Mekong Delta BPH population." has developed.

To clarify the new biotype reaction, we compared it with biotypes of some Asian rice-growing countries. The new BPH biotype is completely different from those in the Philippines, Bangladesh, Sri Lanka, and India (Table 2 on next page). ■

Table 1. Reaction[a] of some susceptible and resistant check varieties to 7 BPH populations in the Mekong Delta, Tiengiang, Vietnam, 1991.

Variety	Gene for resis-tance	BPH population													
		Chau Thanh, Tiengiang		Longho, Cuulong		Chauthanh, Bentre		Caolanh, Dongthap		Thoalson, Angiang		Gionggieng, Kiengiang		Baclieu, Minhhai	
		Score[b]	Reaction	Score	Reaction	Score	Reaction	Score	Reaction	Score	Reaction	Score	Reaction	Score	Reaction
TN1	None	9.0	S	9.0	S	9.0	S	9.0	S	9.0	S	9.0	S	9.0	S
Mudgo	*Bph 1*	7.6	S	5.6	S	7.6	S	7.6	S	7.0	S	7.6	S	7.6	S
ASD7	*bph 2*	7.6	S	7.6	S	8.3	S	7.0	S	7.0	S	8.3	S	8.3	S
Rathu Heenati	*Bph 3*	1.0	R	1.0	R	1.0	R	1.0	R	1.0	R	1.0	R	1.0	R
Babawee	*bph 4*	5.6	S	5.0	MS	6.3	S	5.6	S	5.0	MS	7.0	S	6.3	S
Ptb 33	*bph 2, Bph 3*	1.0	R	1.0	R	1.0	R	1.0	R	1.0	R	1.0	R	1.0	R

[a] R = resistant, MS = moderately susceptible, *S* = susceptible. [b] Score = av of 3 replications.

Table 2. Reaction[a] of some susceptible and resistant check varieties to BPH biotypes in Asia and the Mekong Delta, Vietnam.

Variety	Gene for resistance	IRRI, Philippines[b]			Bangladesh[b]	Sri Lanka[b]	India[b]		Mekong Delta, Vietnam[c]
		Biotype 1	Biotype 2	Biotype 3			Hyderabad	Cuttack	
TN1	None	S	S	S	S	S	S	S	S
Mudgo	*Bph 1*	R	S	R	S	S	S	S	S
ASD7	*bph 2*	R	R	S	S	S	S	S	S
Rathu Heenati	*Bph 3*	R	R	R	R	R	S	S	R
Babawee	*bph 4*	R	R	R	R	R	R	S	S
Ptb 33	*bph 2, Bph 3*	R	R	R	R	R	R	R	R
ARC10550	*bph 5*	S	S	S	R	R	R	R	–

[a] R = resistant, S = susceptible. [b] Data from O. Mochida and E. A. Heinrichs, 1980 [c] Data from N. L. Chau, Nguyen Cong Thuat, and Vu Thi Chai, 1991.

Rice resistance to leaffolder (LF) in tidal wetlands

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We field-tested 22 promising lines for resistance to LF in the tidal wetlands of Tarantang, South Kalimantan, during the 1991-92 wet season.

Seedlings of each line were transplanted 21 d after seeding at 25- × 25-cm spacing in a 20-m^2 plot with three replications. Recommended agronomic practices were followed. We evaluated LF damage 45 d after transplanting.

Line IR24637-38-2-2 is resistant and other lines are moderately resistant (see table). ■

Reaction of promising lines to LF. Tarantang, South Kalimantan, Indonesia, 1991-92 wet season.

Line	Score[a]	Reaction[b]	Line	Score[a]	Reaction[b]
IR24637-38-2-2	1	R	IR13426-19-2	3	MR
IR21567-9-2-2-3-1-3	3	MR	IR11288-B-B-69-1	3	MR
IR31429-14-2-3	3	MR	B5344-Sm-61-2-1	3	MR
IR31432-7-2	3	MR	B5332-3d-Mr-2-4	3	MR
IR51500-AC9-7	3	MR	B6992d-99-KA-2	3	MR
IR9884-54-3-1E-PI	3	MR	IR33353-64-1-3-1	3	MR
IR15865-430-3-1-3	3	MR	IR36	5	S

[a] Scored using 0-9 scale of *Standard evaluation system for rice.* [b]R = resistant, MR = moderately resistant, S = susceptible.

Reaction of IR varieties to the brown planthopper (BPH) population in Raipur, Madhya Pradesh, India

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Twenty-one IR varieties were tested against a BPH *Nilaparvata lugens* population in a glasshouse at Raipur in 1991.

Ten-d-old seedlings of those varieties, susceptible check TN1, resistant check PTB33, and ASD7 and Mudgo were infested with 4- to 6-d-old BPH nymphs. We rated the injury of each seedling when more than 90% of the TNI were dead.

Only IR62 and IR64 are resistant, IR34, IR36, and IRS6 are moderately

Reaction of IR varieties to BPH population at Raipur, MP, India, 1991.

Variety	Seedings tested (no.)	Replications (no.)	Av damage score [a]	Remark [b]
IR8	58	3	8.0	S
IR20	38	2	8.5	S
IR22	37	2	9.0	S
IR24	33	2	9.0	S
IR26	33	2	9.0	S
IR28	31	2	7.6	S
IR30	34	2	5.6	S
I R34	84	5	4.9	MR
IR36	62	4	4.8	MR
IR38	57	3	9.0	S
IR40	77	4	9.0	S
IR42	75	4	9.0	S
IR43	37	2	9.0	S
IR45	70	4	9.0	S
IR46	42	3	7.02	S
IR48	55	3	9.0	S
IR50	57	3	9.0	S
IR52	59	3	8.5	S
IR56	100	6	4.2	MR
IR62	91	5	2.5	R
IR64	19	6	1.8	R
PTB33	83	5	1.7	R
TN1	160	10	9.0	S
ASD7			9.0	S
Mudgo			9.0	S

[a] By the *Standard evaluation system for rice.* [b] R = resistant, MR = moderately resistant, and S = susceptible

resistant, and 16 other varieties are susceptible to the BPH population at Raipur (see table).

IR36, with the *bph-2* gene derived from CR94-13, is moderately resistant, but ASD7, which also possesses the *bph-2* gene, is highly susceptible to BPH at Raipur; this indicates IR36 may possess several other minor genes that confer resistance to BPH. Corollary to this, IR34 has the *Bph-1* gene derived from TKM6 and is moderately resistant to BPH but resistant to biotypes 1 and 3 and susceptible to biotype 2 at IRRI. Mudgo *(Bph-1)* is highly susceptible to the Raipur BPH population.

Many of the varieties tested (IR26, IR28, IR30, IR38, IR40, IR42, IR43, IR45, IR46, IR48, IR50, and IR52) are susceptible to the Raipur BPH population, but resistant to biotypes 1 and 2 or 3 at IRRI. We conclude that the Raipur BPH population is different from that at IRRI and attacks a wider array of cultivars. ■

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Resistance of rice varieties and lines to whitebacked planthopper (WBPH) *Sogatella furcifera*

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WBPH has become a serious pest of rice in the Punjab, Pakistan, although it was only a minor pest in early 1980. It begins to attack rice the 3d wk of Sep and causes considerable damage until harvest. The pest attack was severe in 1991 at RRI's farm and in farmers' fields.

We screened 69 IRRI varieties and lines during 1991 for resistance to WBPH under field conditions. Seedlings were transplanted on 12 Jul into two rows with 20 hills each and replicated three times. Recommended crop management practices were followed. No plant protection cover was provided. Test entries were scored using the *Standard evaluation system for rice* (see table).

Results indicate that 3 1 varieties and lines are resistant, 10 moderately resistant, 9 moderately susceptible, 15 susceptible, and 3 highly susceptible to WBPH (see table). ■

Resistance of rice varieties and lines to WBPH. Punjab, Pakistan, 1991.

Variety or line	Score[a]	Rating[b]
Baggi Mun 122	7	S
Bamia Red 310-6	7	S
BRC16-127-4-1	1	R
BRC16-127-4-2	1	R
BR4-34-13-5	1	R
BR850-9-1-1	1	R
B3906 D-14-ST-16-48-3	1	R
B3906 F-13-13-ST-37	3	MR
CWA762069	1	R
IR13475-7-3-2	1	R
CR94-13	7	S
GH305 (Acc. 66838)	1	R
IR12665-7-1-3-6	1	R
IR13429-150-3-2-1-2	7	S
IR15527-21-2-3	7	S
IR28526-44-1-1	1	R
IR29429-5-3-5-1-4	3	MR
IR31429-14-2-3	7	S
IR31785-58-1-2-3-3	9	HS

continued on next page

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Variety or line	Score [a]	Rating [b]
IR2035-117-3	1	R
IR31805-20-1-3-3	3	MR
IR32843-92-2-2-3	1	R
IR32876-54-2-2-2	1	R
IR33059-26-2-2	3	MR
IR33380-60-1-2-2	3	MR
IR33383-23-3-3-3	3	MR
IR34686-179-1-2-1	1	R
IR35293-125-3-2-3	5	MS
IR35366-28-3-1-2-2	1	R
TNI	7	S
IR35366-40-3-3-2-2	7	S
IR35366-62-1-2-2-3	1	R
IR35546-17-3-1-3	5	MS
IR39334-31-2-2-2	5	MS
IR39357-45-3-2-3	9	HS
IR43342-10-1-1-3-3	1	R
IR43491-140-1-2-3	1	R
IR43524-55-1-3-2	1	R
IR43526-523-1-1-1	1	R
TNI	7	S
IR60	7	S
IR65	7	S
Khaira Basant (Acc. 61 1691)	7	S
Khao Kad Bow (Acc 64384)	1	R
Ramic Hudi (Acc. 64045)	1	R
RP1057-184-5-3-2	1	R
RP1442-2-2-3-5-1	7	S
RP1579-1864-70-33-54	7	R
RP1579-28-54	1	R
IR1552	5	MS
RP1579-52	5	MS
RP2068-16-9-5	1	R
RP2068-18-3-5	3	MR
RP2068-18-4-5	3	MR
RP2068-18-4-7	1	R
RP2068-32-2-3	1	R
RP2068-32-6-1	1	R
RP2084-2-3-1	3	MR
Suweon 339	5	MS
Tainung Sen Glutinous	5	MS
UPRH151 (Acc. 6160)	9	HS
UPRH193 (Acc. 61637)	9	HS
YSSI (Acc. 663931)	1	R
ZHEL I (Acc 74587)	3	MR
3000	1	R
9101 (Acc. 74588)	5	MS
IR6	7	S
KS282	7	S

[a] 0 = no visible damage, 1 = partial yellowing of first leaf, 3 = first and 2d leaf partially yellow, 5 = pronounced yellowlng and some stunting, 7 = wiltlng and severe stunting, and 9 = all test plants died. [b] HR = highly resistant, R = resistant, MR = moderately resistant, MS = moderately susceptible, S = susceptible, and HS = highly susceptible.

Evaluation of brown planthopper (BPH)-resistant rice varieties for resistance to Angoumois grain moth (AGM)

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AGM *Sitotroga cerealella* Oliver causes severe damage to stored rice in China. We evaluated rice varieties with resistance to BPH *Nilaparvata lugens* Stå1 for their resistance to AGM.

AGM were reared on wheat seeds in the laboratory. The moisture content of rice seeds was adjusted to 13%. Five seeds, which served as one replication, were infested with 100 AGM eggs. The

Resistance of rice varieties to AGM and BPH.

Variety	AGM				BPH	
	Emerging adults (%)	Susceptibility index	Grain weight loss (%)	Damage [a] scale	Damage [b] scale	Reaction
ASD7	9.8	6.21	3.7	R	1.0	R
CR94-13	7.8	5.55	1.8	R	1.7	R
IR13240-108-2-2-3	8.3	5.65	3.5	R	1.0	R
IR19256-88-1	8.5	5.88	1.5	R	1.0	R
IR46	9.5	6.52	1.9	R	1.0	R
IR58	3.3	3.06	0.1	R	0.3	R
IR60	3.0	3.57	0.1	R	0.3	R
Kau 1727	3.0	2.32	2.6	R	1.0	R
Ping You Zhan	9.0	6.12	3.1	R	5.0	MR
San Ye Zhan	9.8	5.49	1.9	R	1.7	R
Suweon 294	4.2	3.66	2.5	R	1.0	Pi
Tie Liu Ai	4.0	4.10	3.0	R	4.2	MR
Balamawee	12.8	7.01	7.3	MR	1.0	R
Bao Xuan 2	11.0	8.25	2.5	MR	3.7	MR
BG 367-4	18.0	7.82	6.9	MR	0.5	R
C1321-9	14.0	8.06	3.9	MR	1.7	R
C1322-28	11.3	7.40	4.8	MR	1.7	R
C701045	14.5	8.46	4.4	MR	1.0	R
Gao Mei Zhan	19.5	8.64	6.1	MR	1.7	R
Hong Yuan	19.7	8.48	9.6	MR	1.0	R
IR4432-52-6-4	10.5	6.78	7.1	MR	1.7	R
IR13427-40-2-3-3	12.5	6.22	5.3	MR	1.0	R
IR26	15.5	7.52	6.4	MR	1.7	R
IR36	13.3	7.29	7.9	MR	3.0	R
Mudgo	17.0	8.71	6.6	MR	1.0	R
Pratap	13.8	6.99	2.7	MR	1.0	R
Yue Nan Xiang Mi	14.3	8.35	4.4	MR	2.3	R
7105	22.5	8.61	13.4	S	1.0	R
82-44-4	22.0	11.52	6.1	S	2.3	R
Duo Long	35.5	9.59	9.0	S	3.0	R
Hu Jing Kang	40.0	10.10	15.5	S	3.0	R
IR21141-24-2	30.7	11.13	6.5	S	1.0	R
Jar 80047	23.8	8.24	8.8	S	3.0	R
Qi Gui Zao 25	23.0	11.83	7.5	S	3.0	R
RNR 3070	21.3	9.55	4.8	S	1.0	R
San Gui Zhan 1	40.0	10.31	12.3	S	2.3	R
San Huang Zhan 2	38.0	10.93	10.6	S	3.0	R
Shan Ke 2	37.0	10.48	12.9	S	3.7	MR
Tai Nuo Xuan (C712068)	25.0	7.14	10.7	S	1.0	R
Triveni	23.5	9.23	6.8	S	2.3	R
Xin Hui Zhan 1	43.5	13.73	8.9	S	1.0	R
Xin Hui Zhan 2	24.0	10.36	4.9	S	1.0	R
Xin Jin Zhan 1	24.1	12.35	5.7	S	5.0	MR
Xin Jin Zhan 2	24.5	10.83	5.0	S	1.0	R

[a] R = resistant. MR = moderately resistant. [b] Based on a plant damage rating of 1-9 where 0-3.5 = R, 3.6-5 = MR.

samples were stored at 20°C and 75% relative humidity after infestation. The experiment was laid out in a split-plot design with four replications.

Resistance was evaluated on three parameters: emerging adults, susceptibility index (SI), and weight loss. The emerging adults were removed each day and counted. Seed weight loss was calculated by weighing seed before and after the experiment.

SI was based on the formula

$$SI = \frac{\text{natural log number of emerging adults}}{\text{average development period}} \times 100$$

Susceptibility was scored as % emerging adults where resistant (R) = <10%, moderately resistant (MR) = 10-20%. and susceptible = >20%.

Twelve of 44 BPH-resistant rice varieties tested were rated R and 15 were MR to AGM (see table). The new variety Hong Yuan, which is a cross of the good agronomic variety Hong Zhan and resistant donor Suweon 294. is R to BPH and MR to AGM. Hong Yuan yielded an average 6 t/ha, indicating that the resistance was heritable and easily recombined with other agronomic traits. ■

Stress tolerance—excess water

Plant elongation at three seedling ages in some rice varieties

J. L. Dwivedi, D. Senadhira, and
D. HilleRisLambers, IRRI

Experiments using three seedling ages (2, 3, and 4 wk with 9, 21, and 21 entries, respectively) were laid out in a completely randomized design with three replications to assess variation in plant elongation ability induced by flooding. The objective was to select the most appropriate seedling age for use in work on the genetics of elongation ability.

Seedlings were submerged for 7 d in 100 cm of water in a glasshouse tank. Plant height was recorded before and after flooding, and the difference was used to calculate plant elongation.

Seedlings in each age group survived. Entries differed significantly in plant elongation. Percent increase in elongation after flooding was highest in the 2-wk seedlings (see table), perhaps because older seedlings were taller than younger ones and needed comparatively less elongation to survive at the 100-cm flooding depth. Leaf sheaths and blades contributed considerably to plant elongation (data not presented).

To compare the relevance of results. we used previous knowledge that IR11141-6-1-4 and IR11288-B-B-69-1 are elongating modern varieties (MVs), whereas IR36, IR42, BKNFR76106-16-0-1, and FR13A are nonelongating MVs. Better selection of elongating MVs and nonelongating MVs was obtained from the 4-wk treatment. The difference in average elongation between these groups was greater at 4 wk (6.3 cm) than at 3 wk (3.0 cm) (see table). ■

Plant elongation at 3 seedling ages following 7 d of submergence.

Variety	Plant elongation (cm) at			Elongation score in previous test
	2 wk	3 wk	4 wk	
Elongating types				
Saingar	–	37	13	1
Barogar	–	37	20	1
LMN111	–	42	21	1
Jalmagna	24	27	36	1
NDGR407	25	–	–	1
Chakia 59	–	34	16	3
IR40905-11-3-1-5-3-3	–	25	16	3
NC492	–	28	20	3
Baisbish	26	23	21	3
NDGR150	22	22	7	5
FRG15	–	24	9	5
Madhukar	–	20	10	5
NDGR207	15	21	12	5
Elongating MVs				
IR11141-6-1-4	17	16	12	5
IR28273-R-R-R-39-28	–	17	18	5
IR11288-B-B-69-1	13	12	11	5
Nonelongating MVs				
Ghoghari	–	18	10	7
Shayma	–	15	9	7
IR42 (susceptible check)	14	9	8	9
FR13A	–	13	5	9
BKNFR76106-16-0-1	–	8	5	9
IR36	11	9	7	9
Mean Increase (%)	46.9	37.9	18.7	
CV (%)	9.2	17.6	25.0	

Optimum water depth for testing fast elongating deepwater rice (DWR) varieties

J. L. Dwivedi, D. Senadhira, and
D. HilleRisLambers, IRRI

We conducted an experiment to determine the optimum water depth for testing the ability for fast elongation in

Table 1. Analysis of variance for percent elongation in 12 varieties at 5 water depths and control.

SV	DF	MS[a]
Replications	2	32.0 ns
Water depth (d)	5	3013.1**
Error (a)	10	18.6
Varieties (v)	11	1861.0**
Depth x variety (d x v)	55	113.9**
Error (b)	132	17.8

CV (a) = 18.0%, CV (b) = 17.6%

[a] ** = significant at 1% evel, ns = not significant.

Table 2. Varietal means for percent elongation at various water depths.

Variety	Elongation (%)						
	80 cm	90 cm	100 cm	110 cm	120 cm	Control (no water)	Variety mean
Nonelongating dwarf							
BKNFR76106	7.9 h	7.5 e	9.2 d	11.4 e	7.7 f	2.8 b	7.8
IR42	18.4 fg	16.6 d	21.3 c	17.9 de	10.8 hi	3.7 ab	14.8
Nonelongating tall							
IR28273-R-R-R-29-38-2-3-3	13.9 gh	8.2 e	13.5 d	12.0 e	18.0 fgh	7.9 ab	12.3
NDGR207	34.5 bc	25.1 c	27.7 c	32.8 c	19.0 efg	4.0 ab	13.9
Elongating MV							
IR11141-6-1-4	25.9 de	23.9 c	24.8 c	18.1 de	23.2 def	5.4 ab	20.2
IR11288-B-B-69-1	21.4 ef	19.7 ed	28.7 c	15.1 e	15.4 gh	9.1 ab	16.8
IR40905-11-3-1-5-3-2	19.9 efg	22.5 cd	28.0 c	24.7 d	17.8 fgh	9.9 b	19.5
Bhatin	32.6 cd	40.7 a	38.3 b	35.9 bc	32.3 bc	4.5 ab	30.7
LMN111	48.0 a	44.8 a	48.4 a	37.4 bc	25.8 cde	9.4 ab	35.6
Fast elongating							
Baisbish	38.6 bc	41.3 a	41.8 a	50.3 a	35.6 ab	2.9 ab	36.2
Barogar	40.5 b	33.9 b	45.8 a	41.8 b	29.8 bcd	9.1 ab	33 5
Kalaungi	37.3 bc	32.5 b	51.5 a	42.1 b	41.8 a	10.9 a	36.0
Depth mean	28.2	26.4	31.5	28.3	23.1	6.1	23.9

DWR seedlings. We classified 12 varieties as nonelongating dwarf, nonelongating tall, elongating modern variety (MV), elongating tall, and fast elongating. Plants were raised in 5-cm-deep plastic pots, having 5-cm² surface area. The experiment was laid out in a split-plot design with three replications. Five water depths were in the main plots and the 12 entries were in the subplots.

We submerged 3-wk-old seedlings in a concrete tank where water depths of 80, 90, 100, 110, and 120 cm were maintained using a stair arrangement. Water depth was measured from the soil surface of the pots to the water surface. Percent elongation was calculated.

Varieties differed significantly in percent elongation at various water depths (Table 1). Elongation rate was greatest in Baisbish, Kalaungi, LMN111, and Barogar at almost all water depths. IR11141-6-1-4 and IR40905-11-3-1-5-3-2 showed moderate elongation (Table 2).

We recorded relatively more elongation at 100 cm for floating and DWR varieties. The overall percent elongation, irrespective of variety, was a1so highest (31.5%) at the 100 cm water depth. For genetic studies, 100 cm of water appears to be deep enough to test for elongation ability at an early stage.

The trend for decreasing elongation at 100 and 120 cm water depths may be due to the inability of plants to emerge from these depths. Alternatively, other adverse factors may exist that affect the ability of plants to elongate in deep water (120 cm) but not in shallow water (80-100 cm). Lower light irradiance could be one factor; this requires further experimentation. ■

Elongation of deepwater rice during horizontal orientation of shoots in shallow water

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Elongating and nonelongating varieties were grown in three sets in completely randomized block design with three replications in tanks at IRRI. Plants were spaced at 30 cm with 90 cm between rows to prevent plants from shading each other. Elongated internode number was <1 and length <5 cm for all varieties at the beginning of the treatments.

In the first set of experiments, the water level was raised to 50 cm 6 wk after seeding. The tank was full at this level. A horizontally placed iron bar was used to submerge all leaves that were above the water. The bar was moved across the top of the tank 2-3 times/wk to stimulate kneeing and to keep plants completely submerged as they grew. By the end of the experiment, the bar had been moved about 60 cm from the initial position. Using this procedure, all plants, including nonelongating varieties, were submerged but stayed alive.

The second set of the varieties were maintained in an upright position (URP) in 50 cm water and the third set was used as control without deep water treatment. Internode number and length were recorded on 10 randomly selected plants/replication from the three treatments.

Varieties in the horizontally placed (HP) treatment differed significantly in internode length (Table 1), with highest values recorded in Jalmagna, Baisbish, and NDGR417 followed by NDGR150, IR111288-B-B-69-1, and NDGR207 (Table 2). Internode length was minimum for IR42 and IR36. A similar trend in internode length occurred in URP treatment (Table 2). However, HP plants had significantly greater internode length relative to those in URP (Table 2) and the control. NDGR207 elongated similarly under both treatments, possibly because of its tall but relatively nonelongating nature.

Table 1. Analysis of variance for internode length (cm) and number of internodes.

Sources of variation	DF	Mean sum of squares[a]	
		Internode length (cm)	Internodes (no.)
Treatment	26	2756.8**	11.3**
Main factor (M)	2	2940.2**	46.3**
Subfactor (S)	8	8014.1**	21.3**
M × S	16	1053.3**	1.9**
Error	54	29.9	0.3
CV (%)		7.1	8.1

[a] ** = significant at 1% level

Table 2. Length and number of internodes in horizontal placement (HP) and upright position (URP) of shoots in water at 50 cm depth.[a]

Variety	Length of internodes (cm)				Elongated internodes (no.)				Elongation score in >100 cm water [b] (from previous test)
	Control	HP	URP	Difference (HP-URP)	Control	HP	URP	Difference (HP-URP)	
				Floating rice					
Jalmagna	97 a	134 a	101 a	33**	7.0 a	11.7a	7.7 a	4.0**	1
Baisbish	78 c	109 b	87 b	22**	6.0 b	11.0 a	7.0 ab	4.0**	1
NDGR417	88 b	111 b	101 a	10**	6.0 b	9.0 b	6.7 bc	2.3**	1
				Elongating modern variety					
NDGR150	60 d	79 c	68 c	11*	5.0 cd	7.0 b	5.3 d	1.7**	5
IR11141-6-1-4	38 e	58 d	39 d	19**	6.0 b	7.3 c	6.3 b	1.0**	5
IR11288-B-8-69-1	42 e	62 d	50 d	12**	5.7 bc	7.3 c	6.0 bc	1.3**	5
				Traditional deepwater					
NDGR207	61 d	62 c	65	–3 ns	4.3 de	6.7 c	4.3 e	2.4*	5
				Nonelongating modern variety					
IR36	26 f	43 e	28 f	15*	4.0 e	5.0 d	4.0 e	1.0**	9
IR42	21 f	37 e	25 c f	12*	4.0 e	5.0 d	4.0 e	1.0**	9
Av	57	77	62	15	5.3	7.8	5.8	2.0	
Comparison 2-M*S mean									
LSD (0.05)	7.63	0.83							
LSD (0.01)	10.16	1.11							

[a] *, ** = significant at 5% and 1% levels, respectively, ns = not significant. In a column, figures followed by different letters signtficantly differ at the 5% level by DMRT. [b] By the *Standard evaluation system for rice.*

The greater total internod lenghts in HP treatments may be done to a more severe treatment when the submergence bar is moved 60 cm, relative to the 50-cm water depth increase in the URP treatment. This is consistent with the number of internodes from horizontally oriented shoots, which was greater than for URP plants.

Among the floating rices, plants in HP produced 9-12 internodes and those in the URP produced 7-8 internodes. The elongation scores of these varieties evaluated at >1-m water depth at Ghagharaghat, India, were comparable to those of HP shoots (data not presented).

The findings indicate that the horizontal orientation method sufficiently induced elongation and can be used to test plants for elongation potential. An advantage of this method is that deep flooding is not needed to test for internode elongation so it can be used to screen varieties or segregating populations. These benefits will need to be evaluated with respect to the greater surface area required for horizontal placement of plants. ■

Stress tolerance — adverse temperature

Chlorophyll fluorescence analysis (CFA) for assessing cold tolerance at anthesis in Nepalese indigenous rice genotypes

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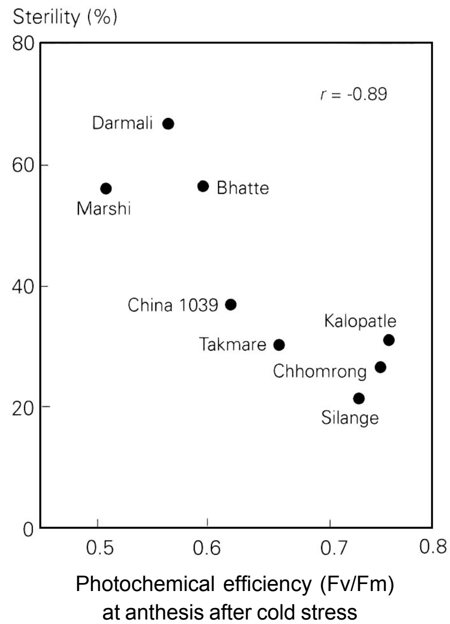
We screened eight rice genotypes (seven indigenous and one exotic) from the Himalayan region for sterile-type cold tolerance at anthesis using CFA (see table). The objective was to determine whether chlorophyll fluorescence, measured after a short period of chilling at the critical booting stage, would correlate with spikelet sterility.

During the process of photosynthesis, chlorophyll fluorescence is re-emitted from the chlorophylls associated with the

Cold tolerance ranking of rice cultivars at Pokhara, Nepal.

Variety	Altitude (m asl)	Field ranking for cold tolerance[a]	Origin
Chhomrong	1400-2000	CT at all growth stages	Nepal
Silange	1500-1800	CT at all growth stages	Nepal
Seto Takmare	1500-1700	CT at reproductive phase	Nepal
Rato Darmali	1600-1700	CT at late anthesis stage	Nepal
Kalopatle	1400-1500	CT at reproductlve phase	Nepal
Bhatte	1200-1500	CWT at vegetative phase	Nepal
China 1039	1000-1200	CT at late anthesis stage	India
Marshi	900-1200	CS at all growth stages	Nepal

[a] CT = cold tolerant, CWT = cold water tolerant, and CS = cold sensitive.



Relationship between chlorophyll fluorescence (Fv/Fm) measured after 5 d of chilling treatment at 17 °C and spikelet sterility (%) for 8 rice genotypes. Pokhara, Nepal.

reaction centers photosystem II (PSII). The onset of chilling injury in leaves is accompanied by a decrease in chlorophyll fluorescence. The ratio of variable fluorescence (Fv) to maximal fluorescence (Fm), termed as photochemical efficiency of PSII (Fv/Fm), is directly related to its quantum efficiency and is therefore used as a good diagnostic probe for measuring cold stress. A healthy leaf generally gives a Fv/Fm value of about 0.80.

We grew the rice genotypes under glasshouse conditions (28/18 °C) until the booting stage. Plants were chilled for 5 d at 17 °C under a 10/14 h day/night cycle in a growth chamber, taken back to the glasshouse, and kept there at 23 °C to complete the crop cycle. Plants were given plant food Champax Formula No. 2 at 0.714 g/liter of tap water.

We measured chlorophyll fluorescence of the flag leaves after 5 d of chilling using a CF1000 fluorometer. Panicle sterility and other agronomic parameters were measured at harvest.

A significant negative correlation (r = -0.89) between Fv/Fm at booting and spikelet sterility (%) was found (see figure). This indicates that Fv/Fm can be used to predict spikelet fertility and is therefore a useful tool in screening for cold tolerance at anthesis.

Cold-tolerant varieties Silange, Chhomrong, Sinjali, Kalopatle, and Takmare had higher photochemical efficiency under chilling stress and the least spikelet sterility of the varieties tested. Cold-sensitive cultivars, such as Marshi, had smaller Fv/Fm values and the greatest degree of sterility (56.3%). Darmali and Bhatte, both known for cold tolerance at tillering, exhibited poor tolerance at anthesis (see figure).

Results from both field and growth chamber experiments suggest that relative ranking for cold tolerance can be based on absolute Fv/Fm values recorded after cold stress.

Further studies are planned in Nepal using this technique to study cold tolerance in segregating populations and in the International Rice Cold Tolerance Nursery. ■

Efficiency of natural selection against cold-induced sterility in bulked families

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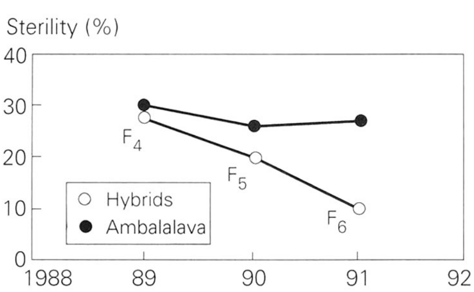
ISABU identified Yunnan 3 in 1980 as a relatively well-adapted variety for swamps at 1,300 to 1,650 m above sea level (m asl). Growing rice at this altitude is important for Burundi as it is a densely populated country (206 humans/km^2). International Rice Cold Tolerance Nursery results, however, were disappointing. A breeding program was initiated to improve varietal diversification.

The isotherms of the area vary between 16 and 22 °C with frequent night temperatures as low as 10 °C. Cold-induced sterility is the major constraint.

We bulked reciprocal crosses in rapid generations at 800 m asl. Some families (Facagro 57 and Facagro 59) with narrow variability were subjected to natural selection in F_{4-6} at 1,550 m asl at the 16 °C isotherm. The yields of the Facagro 57 and 59 families progressed annually, partly because of lowered sterility. Facagro 57 originated from B2980b-Sr-2-6-2-3-2/IR24312-RR- 19-3-B (45.7 and 83.7% parental sterility, respectively). Facagro 59 originated from IR24312-RR-19-3-B/NR10041-66-3-1 (83.7 and 70.8% parental sterility, respectively).



Sterility of families derived from 2 hybrids subjected to natural selection from F_4 to F_6 at 16 °C isotherm.

Sterility was estimated using a sample of 25 disease-free panicles (three replications) from the same site in a pluriannual trial that included Ambalalava, a well-adapted variety at 1,500 to 1,700 m asl in Madagascar.

The figure illustrates the evolution of sterility. F_{4-6} trials showed sterility levels below that of Ambalalava.

The level attained in 1991 is one of normal sterility, showing the polygenic nature of cold tolerance that prolonged action until F_8; the parents are evidently not adapted, but they are good breeding lines for cold tolerance.

The bulk population method is efficient for determining this kind of selection. ■

Stress toleranace—adverse soils

Screening rice for tolerance for salt stress and submergence

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Low-lying areas along the creeks of Andamans are regularly submerged with tidal seawater, particularly during the wet season. Suitable rice varieties are needed for successful cultivation.

We screened 30 salt-tolerant rice varieties and salt-tolerant checks Pokkali and Nona Bokra using close spacing under simulated conditions in fiberglass tanks.

The tanks were filled with soil supplemented at the rate of 60 kg N/ha (half as basal and half as topdressing) as urea and 30 kg of K as muriate of potash. Soil electrical conductance was adjusted to 6.0 ± 1 dS/m and soil pH to 5.0. Plants were submerged up to the leaf tips for 1 wk at both the active vegetative phase and panicle initiation stage with saline water (EC = 5 dS/m ± 0.5).

Sixteen of the genotypes survived to yield grain (see table). Although tolerant check Pokkali gave more yield, the other tolerant check Nona Bokra died at the vegetative phase. All varieties were less than 1 m tall except IR51485-2B-20-2B and RD15. RD15 had the most panicle-bearing tillers/plant (3.1). IET10682, closely followed by IR47449-3B-9-2B, had the greatest panicle length. Percent grain sterility was highest in IR9884-54-3-IE-P1.

IET10682, CR 1009, IR51337-2B-3-2B IR4819-77-3-2, IR47441-3B-1-2B, B2443B-KN-10-1-1-1, IR37003-15-3-3-3, IR51485-2B-20-2B and Pokkali showed good phenotypic indices at the vegetative phase as indicated by scores of 1-3 (see table). But only IR51485-2B-20-2B, IR47441-3B-1-2B, BR2443B-KN-10-1-1-1, and Pokkali had the same high scores at maturity. The tolerant check Pokkali outperformed the others at both the vegetative and ripening phases. No phenotypic characteristic was consistently correlated with salt tolerance (see table).

Varieties IR51485-2B-20-2B and IR47441-3B-1-2B are promising for areas where salinity is a problem at both the seedling and maturity stages. ■

Performance of some salt-tolerant rice varieties under 1 wk of submergence in saline water (EC = 5 dS/m).

Variety	Source	Plant height (cm)	Panicle-bearing tillers/plant (no.)	Panicle length (cm)	Grain sterility (%)	Seed yield/plant (g)	Salt tolerance[a]	
							Vegetative phase	Ripening phase
IR51485-2B-20-2B	IRRI, Philippines	132.3	2.0	23.6	7.0	7.4	3	1
IR47441-3B-20-2B	IRRI, Phllippines	80.0	3.0	20.0	25.1	6.0	2	2
Pokkali (check)	India	76.0	2.1	20.3	10.7	5.6	1	2
B2443B-KN-10-1-1-1	Indonesia	83.2	2.2	19.0	5.9	5.3	3	2
IET11353 (IR16294-C59-1-30)	IRRI, Philippines	87.7	2.0	20.3	33.8	4.1	4	4
IR47449-3B-9-2B	IRRI, Phillppines	90.5	2.2	24.0	23.1	3.7	9	5
IET10682	Directorate of Rice Research (DRR), Hyderabad, India	99.7	1.1	24.3	34.7	3.7	1	5
RD15	CSSRI Sub-station Canning, West Bengal, India	112.0	3.1	18.5	8.1	3.5	3	5
Cablak	IRRI, Philippines	77.2	2.5	19.5	39.2	3.3	8	5
C22	Phllippines	77.5	2.4	18.0	3.3	3.3	9	5
X73-3-9	Myanmar	80.6	1.8	18.6	11.4	2.7	4	6
IR37003-15-3-3-3	IRRI, Philippines	79.2	1.8	20.0	35.4	2.2	3	7
IET11355 (C200-BD25-16)	DRR, Hyderabad, India	97.0	1.6	15.0	13.0	2.2	4	8
IR51337-2B-3-2B	IRRI, Philippines	76.3	1.3	15.0	8.1	1.6	2	8
IR52471-2B-2-2B	IRRI, Philippines	67.0	1.0	18.2	27.0	1.5	4	7
IR9884-54-3-IEP1	IRRI, Philippines	80.0	2.0	20.2	43.9	1.2	7	7
IR4819-77-3-2	IRRI, Philippines	91.5	2.3	20.0	4.6	1.0	2	9
CR1009	India	84.0	2.2	19.0	9.8	0.7	1	9
Range		67.0-132.3	1.0-31	15.0-24.3	3.3-43.9	0.7-7.4		
Mean		87.31	2.033	19.63	19.11	3.27		
SE		3.6221	0.1323	0.5968	3.2006	0.4418		

[a] *Standard evaluation system for rice* 0-9 scale.

Intergrated germaplasm improvement—irrigated

Barkat, a cold-tolerant variety for the first crop in rice - rice rotations in mid-altitude valleys of Bhutan

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Rice double cropping in the mid-altitude (800-1,500 m) valleys of Bhutan is a recent practice. Cold tolerance at seedling stage is a prerequisite for varieties in the first (Feb-Jul) cropping season when the mean minimum temperature averages 6-8°C. Seedlings are raised using poly-tunnels that increase the air temperature by 2-4°C. Despite its cold tolerance and high yield, No. 11 (Takanenishiki), which is currently the only recommended variety for the first cropping season, is extremely difficult to thresh.

The National Variety Release Committee of the Department of Agriculture released in Sep 1992 cold-tolerant variety Barkat-developed in Kashmir, India, from the cross Shinei/ China 971—as an alternative to No. 11. Barkat is a semidwarf (90-95 cm) with white, bold grains. It matures earlier (155 d) than No. 11 (160 d) and it can be successfully direct seeded.

In station trials at CARD (1,300 m) during 1988-91, Barkat yielded at par with No. 11 (see table). Yield was nearly the same for the varieties in on-farm trials at 12 locations conducted over two seasons in 1991-92.

Grain yield, however, is not the primary consideration for farmers in these areas. The major advantage of Barkat over No. 11 is its threshability ease and earlier maturity, which is crucial in a rigid rice - rice rotation.

The rice double-cropped area is expected to increase with the release of Barkat. ■

Performance of Barkat in yield trials.

Trial	Grain yield (t/ha)	
	Barkat	No. 11 (check)
Sequential transplanting trial, 1988	3.1	3.3
Observation nursery, 1989	6.4	6.1
Initial evaluation trial, 1989	5.5	6.1
Advanced evaluation trial, 1990	3.6	4.2
Sequential direct seeding trial, 1991	3.2	3.0
On-farm trials, 1991-92 (12 locations)	4.1	4.2
Mean	4.3	4.5

Integrated germplasm improvement—rainfed lowland

Guyana 91, an improved rice variety for Guyana

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Rustic, which is highly susceptible to blast (B1), is grown on more than 66% of Guyana's riceland. A major objective of the National Rice Varietal Improvement Programme has been to develop a B1-resistant variety. IR44624- 127- 1-2-2-3, an improved IRRI line, was critically evaluated during 1990-9 1 at the NARI Coastal Plain Field Research Unit, in farmers' fields in all of the major rice-growing regions, and in the B1 screening nursery (Table 1). The line was released for general cultivation as Guyana 91.

Guyana 9 1 has high grain yield potential. It is B1 resistant and has quality characteristics comparable with those of Rustic (Table 2). It is recommended for cultivation in lowlands and in highly B1-prone areas. ■

Table 1. Performance of Guyana 91.

Trial	Grain yield (t/ha)		Increase over Rustic (%)
	Guyana 91	Rustic	
1990			
On-farm trial	7.2	6.4	12.8
1991			
Replicated yield trial	5.8	5.2	11.8
On-farm yield trial	5.3	5.0	5.2
Mean[a]	6.1	5.5	9.9

[a] Mean of 5 trials.

Table 2. Varietal characteristics of Guyana 91 and Rustic.

Character	Guyana 91	Rustic
Vegetative vigor	Good	Good
Resistance to lodging	Good	Good
Plant height (cm)	110	85
Senescence	Slow	Fast
Flag leaf	Long, erect	Short, intermediate
Panicle	Long, intermediate	Medium, intermediate
1000-grain weight (g)	26	25
Gram yield potential (t/ha)	6.5	6
Grain type (milled)	Extra-long, slender	Extra-long, slender
Grain length (milled) (mm)	8.0	8.2
Grain width (milled) (mm)	2.2	2.4
Milling recovery (%)	66	65
Brokens (%)	7.81	6.60
Chalkiness (%)	5.35	3.70
Threshing	Easy	Moderate
Grain dormancy	2 wk	None
Growth duration (d)	120	110
Resistance to blast	Resistant	Highly susceptible
Resistance to leaf sheath blight	Resistant	Highly susceptible

Seed technology

Anaerobic seeding with suitable germplasm

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In wet direct seeding in the tropics, germinated seeds are usually broadcast onto well-puddled soil. Crop establishment is generally unstable because young seedlings on the soil surface are exposed to many biotic and abiotic stresses, such as desiccation caused by direct exposure to air, washing away by heavy rain, and bird damage. Seeding in flooded soil (anaerobic seeding) solves the constraints described above but requires germplasm with vigorous seedling growth under lack of oxygen.

We have identified varieties with tolerance for anaerobic seeding from the more than 1,000 varieties we have screened since 1989.

We tested three tolerant varieties in soils collected from the experimental fields of IRRI (Maahas, Mollisol) and PhilRice (Bantog, Vertisol) to see if seedling establishment ability in different flooded soils is a stable varietal trait. The upland soil was sieved with mesh 40. The lowland soils were taken from the flooded fields, passed through steel screen with 5-mm openings to remove debris, and placed in containers for 1 d before planting to settle the soil particles.

Seeds of tolerant varieties International Rice Germplasm Center accession 6267 (ASD1 from India), 9080 (JC178 from India), and 13746 (Thaothabi from India), and controls IR8, IR36, and IR50 were germinated for 2 d at 30 ºC. Seventeen seeds/variety were planted in a row at a depth of 25 mm in containers (300 × 240 × 110 mm, with soil 80 mm deep). Soils were then submerged in 30 mm of water. The seedlings were grown in a temperature-controlled (29/21 ºC day/night) glass room under natural light for 14 d during 1992 dry season. The experiment was laid out in a split-plot design with four replications.

Emergence score, seedling height, and mesocotyl length were the mean for seedlings planted. Emergence score was recorded for individual seedlings as 0 = no emergence, 1 = coleoptile emerged on the soil surface, 2 = 1st leaf emerged, 3 = 2d leaf emerged, and so on.

The tolerant varieties had better emergence score. seedling height, and percent estahlishment in the three soils than did the controls (Table 1). Seedling establishment was better in Maahas upland soil, presumably because of higher redox potential. than in the lowland soils. Redox potential at 14 d after planting was 280 mV for upland soil and 110–140 mV for lowland soils.

Tolerant varieties had longer mesocotyls than the controls. Mesocotyl length is closely correlated with seedling establishment (Table 2). Percent and rate of germination of tolerant varieties were significantly higher than those of control varieties (98 and 94%, and 0.97 and 0.93, respectively), although they did not correlate with seedling establishment (Table 2).

The varietal trait of tolerance for anaerobic seeding is expressed in different soils. Incorporating this tolerance into modern varieties is a prerequisite for establishing anaerobic seeding technology. ■

Table 1. Seedling establishment from flooded soils.[a]

Soil source	Control variety	Tolerant variety	Difference
Emergence score			
Lowland, Maahas	0.29 b	0.79 b	0.51*
Lowland, Bantog	0.56 b	1.35 b	0.79**
Upland, Maahas	2.38 a	4.24 a	1.86**
Percent establishment			
Lowland, Maahas	7.4 b	19.6 b	12.3*
Lowland, Bantog	16.2 b	34.8 b	18.6**
Upland, Maahas	53.9 a	89.2 a	35.3**
Seedling height (mm)			
Lowland, Maahas	7.9 b	34.0 b	26.1*
Lowland, Bantog	13.6 b	47.3 b	33.7**
Upland, Maahas	92.1 a	276.4 a	184.3**
Mesocotyl length (mm)			
Lowland, Maahas	0.30 b	2.04 b	1.74**
Lowland, Bantog	0.72 b	3.33 b	2.62**
Upland, Maahas	2.27 a	8.71 a	6.43**

[a]For each parameter, means in a column having a common letter are not significantly different at the 5% level. Differences are significant at the 5% (*) and 1 % (**) levels.

Table 2. Correlation coefficient between the characters associated with seedling establishment.[a]

Character	Percent establishment	Seedling height	Mesocotyl length	Rate of germination	Percent germination
Emergence score	1.00**	0.99**	0.99**	0.55 ns	0.57 ns
Percent establishment		0.98**	0.98**	0.58 ns	0.57 ns
Seedling helght			0.98**	0.48 ns	0.53 ns
Mesocotyl length				0.61 ns	0.52 ns
Rate of germination					0.59 ns

[a]*,** = significant at 5 and 1% levels, respectively. ns = not significant.

Breaking of rice grain dormancy with thio-urea

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Photoperiod-sensitive varieties harvested during the wet season generally have a long dormancy period (60-90 d). Heat treatment is commonly used to break dormancy, but plant breeders need a faster method so that they can establish these varieties for a crossing program. We conducted research on methods to reduce the time for breaking seed dormancy.

We studied 14 lowland and deepwater varieties of varying dormancy and the nondormant check Khitish (see table). Seeds were collected from panicles within 30 d after harvest. They were soaked in 0.3% thio-urea for 4, 6, 8, 12, 16, 20, or 24 h. The untreated control was soaked 24 h in distilled water. After soaking, the seeds were thoroughly rinsed with distilled water and stored in petri dishes at 30 °C. Germination was considered positive if a healthy seedling was produced by 10 d after initiation of treatment.

Thio-urea had no adverse effect on germination of Khitish, even after the 24-h treatment. In the other varieties, we stopped counting for germination after it passed 95%; longer soaking periods had no ill effects.

In general, the lowland and deepwater varieties studied exhibited a wide range of dormancy. All lowland and most deepwater varieties broke dormancy with thio-urea treatment of 12 h or less (see table). Thio-urea treatment increased the germination of all the varieties tested.

Dormancy of FR13A and Dinesh was particularly difficult to break and required 20-24 h treatment to produce substantial germinability. This trait is probably related to the excellent submergence tolerance of these varieties. Seed dormancy is an advantage for them as water does not recede completely during their harvest.

The correlation between submergence (see table) and percent germination in untreated control was highly significant and negative (r = -0.78**). The dormant varieties had higher survival under submergence. There was a significant positive relationship between survival and thio-urea treatment duration needed to obtain at least 90%. germination (r = 0.70**). We conclude that thio-urea treatment of 24 h or less can be used safely and effectively to break dormancy of rice. ■

Germination of rice with and without thio-urea treatment at 10 d after initiation of treatments.

Variety	Survival under submergence [a]	Germination (%)							
		Untreated	At thio-urea treatment (0.3%) duration of						
			4 h	6 h	8 h	12 h	16 h	20 h	24 h
Lowland variety									
Mahsuri	45	85	95	98	-	-	-	-	-
IR42	25	65	86	86	98	-	-	-	-
Swarnadhan	35	46	56	69	96	-	-	-	-
Jogen	45	0	96	-	-	-	-	-	-
BR850-22-1-4	40	45	78	89	96	-	-	-	-
Biraj	35	0	30	53	58	96	-	-	-
Suresh	60	0	48	59	68	92	100	-	-
Deepwater variety									
Amulya	76	0	50	58	82	97	-	-	-
SF432	70	19	91	98	-	-	-	-	-
Nalini	72	0	28	36	44	93	-	-	-
Sabita	75	0	20	34	36	85	94	-	-
Matangini	70	0	16	29	43	96	-	-	-
Dinesh	77	0	0	0	0	12	53	91	-
FR13A	80	0	0	0	0	19	40	58	78
Nondormant check									
Khitish	15	97	98	100	100	100	100	100	100

[a] Data taken after 12 d complete submergence at 60 d after sowing.

Crop and resource management

Physiology and plant nutrition

Superior coleoptile elongation of rice varieties suitable for anaerobic seeding

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Poor seedling establishment is a serious constraint for wet seeded rice. Although pregerminated seeds are sown on the surface of puddled soil, some are accidentally covered with mud. These seeds are forced to grow with a limited supply of oxygen and may fail to establish.

Tolerant varieties for seedling establishment under anaerobic conditions were recently identified and recommended for direct seeding. This study aimed to characterize the postgermination growth habits of the tolerant varieties. Because ethylene stimulates coleoptile elongation, its endogenous production was also studied.

We tested tolerant varieties CO 25 (International Rice Germplasm Center accession no. 3697 from India), ASDl (6267, India), JC178 (9080, India), and

Postgermination growth and ethylene production of rice at 2 and 21% O_2.[a]

O_2 concn. (%)	Variety[b]	C_2H_4[c] (ppm)			Elongation[d] (mm/3 d)		
		1	2	3	Coleoptile	Root	Leaf
2	Control	0.18 a	0.11 a	0.12 a	12.5 a	1.6 a	0.0 a
	Tolerant	0.15 a	0.07 a	0.10 a	24.1 c	1.5 a	0.0 a
21	Control	0.56 b	0.62 b	0.54 b	15.6 b	11.0 b	5.7 b
	Tolerant	0.64 c	1.03 c	0.89 c	26.2 d	19.0 c	5.7 b

[a] In a column, means followed by a common letter are not significantly different at the 5% level by DMRT. [b] Control varieties = IR8, IR36, IR50, IR74; tolerant varieties = CO 25, ASD1, JC178, Taothabi. [c] Ethylene concentration in the flask at 1, 2, and 3 d after start of incubation. [d] Measured after start of incubation.

Taothabi (13746, India) and controls, IR8, IR36, IR50, and IR74.

A completely randomized design with three replications was used. Pregerminated seeds were placed in 25-ml Erlenmeyer flasks (35 seeds/flask), and incubated in 2 or 21% O_2 for 3 d. The CO_2 produced by the seeds during incubation was absorbed by 20% potassium hydroxide in a vial placed inside the flask. We measured the ethylene concentration in the flask every day to estimate endogenous ethylene production.

Seedling growth was retarded in 2% O_2 (see table). Root and leaf elongation and endogenous ethylene production were less in 2% O_2 than in 21% O_2.

The coleoptiles-of tolerant varieties elongated more than those of control varieties at 2% O_2. Because the endogenous ethylene production did not differ among varieties, other factors that were not studied might have caused the varietal difference in coleoptile elongation.

The tolerant varieties grew better and had longer roots and coleoptiles than the control varieties, even in 21% O_2. The tolerant varieties also produced more ethylene than did the control varieties.

It is known that standing water in ricefields contains dissolved O_2 from the atmosphere, while flooded soil-has little O_2. A seed germinating under anaerobic conditions in the soil must get O_2 by raising the tip of its coleoptile above the soil surface. The seed that fails to get O_2 will not develop roots and leaves, and will eventually die. The superiority of tolerant varieties in coleoptile elongation might be the reason why they are excellent for seedling establishment in flooded soil. This varietal trait could be used in breeding programs aimed to develop suitable varieties for direct seeding. ■

Root characteristics of rice genotypes with different drought responses

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Drought resistance has been associated with crop root characters. Drought-resistant upland rices have few but thick roots that penetrate deep layers during soil drying.

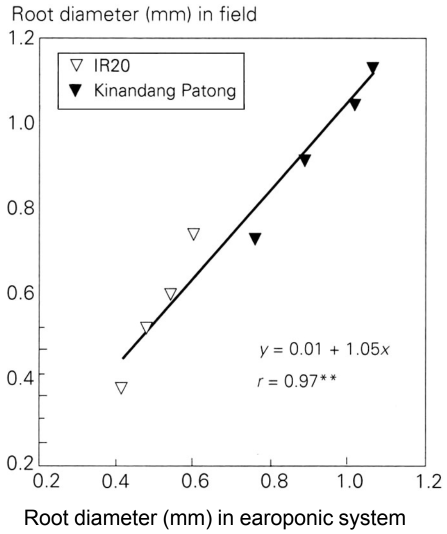
To evaluate the contribution of root characteristics to drought resistance, rice genotypes that differed in response to vegetative drought (as determined in previous field studies) were grown under well-watered upland field conditions and in an aeroponic system in a phytotron glasshouse (70% relative humidity, 29/21 ºC day/night temperature) at IRRI.

Root number, root length, and root diameter were measured on 45-d-old plants of eight genotypes grown in the aeroponic system. The root system was divided into four portions: u = upper, um = upper middle, dm = deeper-middle,

Root characteristics of rice genotypes with different drought responses in aeroponic and field experiments.

Genotype	Drought response	Roots (no./ plant)	Root diameter[a] (mm)				Total root length
			Upper	Upper-middle	Deeper-middle	Distal	m/plant
Aeroponics							
IR30716-B-1-B-6	Susceptible	36	0.99	0.91	0.78	0.65	33.4
IRAT 9	Susceptible	44	0.87	0.81	0.68	0.53	34.6
IR20	Susceptible	50	0.59	0.53	0.47	0.41	29.9
UPLRi-5	Moderately tolerant	35	0.95	0.89	0.73	0.58	49.5
Kinandang Patong	Moderately tolerant	33	1.04	0.99	0.87	0.75	50.0
IR43	Moderately tolerant	49	0.84	0.74	0.66	0.55	38.3
IR10120-72-1-4	Tolerant	45	1.10	1.02	0.91	0.79	55.1
IR9560-2-6-3-1	Tolerant	35	0.95	0.81	0.73	0.59	54.9
	LSD 0.05	12	0.09	0.15	0.13	0.18	4.7
			0-0.1 m	0.1-0.2 m	0.2-0.3 m	0.3-0.4 m	km/m^3
Field							
IR20	Susceptible	–	0.74	0.60	0.52	0.38	6.2
Kinandang Patong	Moderately tolerant	–	1.13	1.05	0.910.73		5.4
IR47686-6-1-2	Tolerant	–	1.23	1.11	0.92	0.83	5.6
	LSD 0.05		0.06	0.06	0.09	0.13	2 3

[a] Root diameter measured in four parts of roots in aereponically grown plants and in four soil layers for field-grown plants.



Root diameter of IR20 and Kinandang Patong in aeroponics and field experiments.

and d = distal. Twenty-five segments from each of the portions were laid on a flat surface and their widths measured with a micrometer to estimate root diameter.

Roots of field-grown plants of three genotypes were sampled at 33 d after emergence to determine root diameter and total root length. Roots were collected from four replications from depths of 0-0.1,0.1-0.2,0.2-0.3, and 0.3-0.4 m using a monolith soil sampler (0.20- × 0.20- × 0.40 m^3). Roots were washed and diameter was measured for 25-50 root segments from a random sample of 10 primary axes from each layer. Total root length was measured with an optical scanner for all roots on all layers.

Root number was not associated with drought response nor with root diameter (see table). Root diameter was greatest in drought-tolerant and least in susceptible lines or cultivars. Total root length under aeroponics appeared to be greater for drought-tolerant than for drought-susceptible rice genotypes, but the same was not true under field conditions.

Our observations, although confined to only a few lines and cultivars, confirm results of previous aeroponic studies on drought resistance, which also involved only a few genotypes. Root thickness is a relatively stable character; hence, there was high correlation (r = 0.97**) between root diameter measured in aeroponic- and field-grown rice (see figure). Thus it is possible to select for root thickness under aeroponics. As the trait also appeared to be related to drought response, aeroponic evaluation of root diameter may assist in selecting drought-tolerant rice genotypes. ■

Fertilizer management—inorganic sources

Response to P of some rice varieties in Assam, India

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We evaluated the performance of IR8, Jaya, Monoharsali, and Mahsuri at different P levels.

The soil is acidic with pH 5.5 (1:2 glass electrode method), sandy loam texture, 0.6% N (Kjeldahl method), 7 kg P/ha (Brays and Kurtz No. l), and 65 kg K/ha (neutral ammonium acetate method). We applied 0, 8.8, 17.6. and 26 kg P/ha basally as single superphosphate. 40 kg N/ha as urea, and 17 kg K/ha as muriate of potash. The experiment was laid out in a factorial randomized complete block design with three replications. We used the Vanado molybdate method to measure P uptake by plants at maturity.

Monoharsali yielded the most grain (Table 1). Grain yield of all varieties significantly increased as P increased.

Mahsuri was tallest with 26 kg P/ha, and IR8 had the heaviest roots. P uptake was greatest at 26 kg P/ha; it decreased as P decreased (Table 2).

P fertilizer-use efficiencies were 24.0, 21.8, and 18.8 kg grain/kg P applied at 8.8, 17.6, and 26 kg/ha. P-uptake efficiency decreased as fertilization increased. This might be due to the equilibrium effect of 40 kg N/ha and 17 kg K/ha. The correlation between grain yield and P uptake was highly significant (r = 0.85**), indicating that P uptake influenced yield. ■

Table 1. Interaction of variety and P level on yield of some rice varieties in Assam, India.

P level (kg/ha)	Yield (t/ha)				
	IR8	Jaya	Monoharsali	Mahsuri	Mean
0	2.6	2.7	3.1	3.0	2.9
8.8	3.0	3.1	3.8	3.5	3.3
17.6	3.3	3.4	4.1	4.0	3.7
26	3.4	3.7	4.3	4.5	4.0
Mean	3.1	3.2	3.8	3.8	–
LSD (0.05)	V = 0.1	P = 0.1	V × P = 0.45		

Table 2. Effect of P on several characters of some rice varieties. Assam, India.

Treatment	Plant height (cm)	Root weight (g/m^2)	P uptake (kg/ha)
Variety			
IR8	91.99	180.80	36.99
Jaya	100.04	113.53	44.62
Monoharsali	111.13	114.65	48.35
Mahsuri	112.73	117.37	49.53
LSD (0.05)	0.83	4.31	0.84
P level (kg/ha)			
0	100.29	84.76	32.16
8.8	101.55	104.27	43.90
17.6	105.08	129.93	48.29
26	108.96	135.38	55.13
LSD (0.05)	0.86	4.31	0.84

Fertilizer management—organic sources

Salinity tolerance of some *Azolla* spp.

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Soil salinity is a serious problem for rice culture in many coastal areas of southern India. If azolla is to be used in these areas, it must be screened for salinity tolerance.

In a greenhouse study, we tested the salinity tolerance of five *Azolla* spp. by artificially salinizing the soil to 5 and 8 dS/m. Soil (5 kg) in shallow pots (45 cm diam, 20 cm deep) with 10 cm standing water was inoculated with 5 g azolla (fresh weight). The experiment had three replications, with nonsalinized soil as control. The fresh weight of azolla fronds was recorded 30 d after inoculation (see table).

Soil salinity decreased biomass production in all of the species. *A. microphylla* and A. *mexicana* had greater tolerance for salinity than *A. pinnata* and *A.filicu1oides.* The study indicates the potential of *A. mexicana* and *A. microphylla* for use as a biofertilizer in saline rice soils. The mechanism for salinity tolerance of the two species needs further study. ■

Effect of salinity on the growth of azolla species.

Azolla species	Azolla (g fresh wt /0.16 m^2) at indicated soil salinity level (dS/m)			
	0.3 (control)	5.0	8.0	Mean.[a]
A. caroliniana	51.30	34.34	4.72	30.12
A. pinnata	49.80	35.37	2.77	29.31
A. filiculiodes	41.63	21.80	4.70	22.71
A. mexicana	72.10	50.07	18.60	46.72
A microphylla	81.40	51.53	21.73	51.65
LSD (P = 0.05)				
Azolla species	3.50			
Salinity levels	4.70			

[a] Mean of 3 treatments.

Rock phosphate is an effective P carrier for azolla

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P fertilizer is the most critical and costly input for the cultivation of rice and azolla. Most soils used for growing rice in AP are P deficient, which adversely affects the multiplication of azolla. Single superphosphate (SSP) at 8.8 kg P/ha is recommended for growing azolla, but SSP is expensive. We investigated using rock phosphate (RP), which is a less expensive source of P than SSP.

In a greenhouse experiment, we added 4.4, 8.8, and 17 kg P/ha as SSP (16% water-soluble P_2O_5) and RP (21% total P_2O_5) to a Vertisol that had 8.8 kg native P/ha. Combinations of SSP and RP to supply 4.4 + 4.4, 2.9 + 5.9. and 2.2 + 6.6 kg P/ha were also used.

Fronds of *A. caroliniana* and *A. pinnata* (Rajendranagar strain) were inoculated at 10 g fresh weight/pot (45 cm diam, 20-cm-deep, containing 5 kg soil). Each treatment was replicated three times. The fronds were harvested, blotted on absorbent paper, and weighed to get the fresh weight of azolla 30 d after inoculation (see table).

Azolla responded positively to both P sources. Equal biomass was produced using up to 8.8 kg P/ha as SSP and up to 17 kg P/ha as RP. Of all the combinations of SSP + RP tested, 1:1 was best, which was on par with the two treatments above. RP can be used as a total or partial substitute for SSP, thus reducing the cost of inputs for azolla. ■

Efficiency of single superphosphate and phosphate rock as P source for azolla.

P treatment	Azolla biomass production (g fresh wt/0.16 m^2)		Mean[a]
	A caroliniana	*A. pinnata*	
Control	61.8	49.4	51.6
SSP 4.4 kg P/ha	88.7	68.1	78.4
SSP 8.8 kg P/ha	148.1	104.0	126.0
SSP 17 kg P/ha	152.4	111.5	132.0
PR 4.4kg P/ha	78.5	79.1	78.8
PR 8.8kg P/ha	97.7	93.1	95.4
PR 17 kg P/ha	120.7	119.1	123.9
SSP[b] + PR 1.1	154.7	100.1	127.4
SSP[b] + PR 1.2	124.7	100.2	112.5
SSP[b] + PR 1:3	86.9	105.9	96.4
Mean	112.2	93.1	
LSD (P = 0.05)	*Azolla* species	3.8	
	Treatments	8.4	

[a] Mean of 3 replications. [b] At 8 8 kg P/ha

Influences of soybean N fixation on soil N balance in rice - soybean rotation

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Soybean has a significant role in maintaining the soil N fertility in rice - soybean cropping systems. We examined the effects of soybean N fixation on N fertility of the ricefield in a rice - soybean rotation.

The experiment was conducted in a sandy loam San Sai soil with pH 5.7-5.9 and 0.05-0.06% total N from Chiang Mai, Thailand (19° N, 99° E), from Aug 1988 to Apr 1989. Chiang Mai has a definite wet season (WS) and dry season (DS). The nine treatments included a factorial combination of N fertilizer applied to rice

N balance for soybean grown after rice fertilized at 3 N levels, and supplied with 3 levels of starter N. Chiang Mai, Thailand, 1988-89.

Treatment	N (kg/ha)				N balance[b]	
	Total [a]	In seed	In straw + seed	Fixed	Seed only[c]	Seed + straw[d]
R0						
S0	145	122	135	122	0 ab	–13 ab
S25	164	133	152	132	– 1 bc	–20 bc
S50	169	131	155	140	9 a	–15 ab
R100						
S0	164	133	152	138	5 ab	–14 ab
S25	166	134	155	134	0 ab	–21 bc
S50	168	134	155	130	– 4 bc	–25 cd
R300						
S0	169	130	145	139	9 a	– 6 a
S25	170	133	155	136	3 ab	–19 bc
S50	179	138	163	128	–10 c	–35 d

[a] Includes fallen leaves; did not include roots and nodules. [b] Means having a common letter in a column are not significantly different at the 5% level of significance. [c] N fixed = seed N. [d] N fixed = seed N + straw N.

cultivar RD21 at 0 (R0), 100 (R100), and 300 (R300) kg N/ha and to the following soybean cultivar SJ5 at 0 (SO), 25 (S23, and 50 (S50) kg N/ha. The experiment was laid out in a randomized complete block design with six replications. Rice was transplanted in WS. Soybean inoculated with *Bradyrhizobium japonicum* was sown in DS after the rice was harvested. We measured N fixation in soybean using the xylem-sap method.

The amount of N fixed was either simiilar to or exceeded the amount of N removed in the harvested soybean seed. A little N was left after seed harvest in some treatments (ROS50, R 100S0. R300S0. R300S25). If soybean straw was also removed at harvest, a net N loss occurred in all treatments.

When the rice crop was not fertilized with N, net soil N depletion decreased with increasing levels of starter N. But with 100 and 300 kg N/ha, the net depletion of N increased with increasing levels of starter N for soybean. The net soil N depletion was estimated to range from - 1 kg N/ha in R0S25 to -10 kg N/ha in R300S50. The net depletion of soil N ranged from -6 kg N/ha in R300S0 to -35 kg N/ha in R300S50 if straw N removal was also considered (see table).

Soil N balance was significantly different among treatments after seed was harvested. Small amounts of N were left in the soil at moderate N levels; at low N levels, fixed N was equal to removed N. A negative N balance was found at high N levels. When straw was also removed (a normal practice in the Chiang Mai Valley), a negative N balance was found in each treatment, which means the soil N pool was depleted. Thus soybean crops in rice - soybean cropping systems appear to reduce soil N. ■

Sugar beet tops as green manure for rice

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In subtropical northwestern India, farmers have started to cultivate sugar beet as a winter crop followed by rice. Sugar beet tops under these conditions can contain 100 kg N/ha or more.

We conducted an experiment for 2 yr to determine the usefulness of sugar beet tops as green manure on a a sandy loam soil having pH 8.2,0.35% organic C, 0.03% total N, 19.5 kg available N/ha (alkaline potassium permanganate extractable), 13.2 kg available P/ha, and 90 kg available K/ha. The treatments tested in a randomized block design were 0, 60, 90, 120, and 150 kg N/ha as urea alone and 0,60,90, and 120 kg N/ha along with sugar beet tops.

Sugar beet tops amounting to 35 t/ha (av regional yield of variety Ramonskaya-06) containing 89 kg N/ha in the first year and 9 I kg N/ha in the second were chopped at harvest (about 45 d before transplanting of rice) and incorporated into the soil for the treatments. Inorganic N was applied in three equal splits as per treatment. A basal uniform dose of 13 kg P and 25 kg K/ha was applied before PR 106 seedlings were transplanted. The rice crop was irrigated. Data were pooled for the 2 yr.

Incorporation of sugar beet tops increased rice grain yield in both the absence and presence of urea N (Table 1). Statistically, grain yield increased up to 90 kg N/ha in soils amended with tops and up to 120 kg N/ha without tops. Sugar beet tops without urea N increased yield by 52% over control. The yield obtained with 60, 90, and 120 kg N/ha with tops were at par with those obtained at higher N levels of 90, 120, and 150 kg N/ha (Table 1).

The rice grain yield (y), when regressed on the urea N levels (N), gave the following best model, which was significant at 1% level of probability:

Table 1. Rice grain yield without and with sugar beet top incorporation. Punjab, India. [a]

Urea N rate (kg/ha)	Grain yield (t/ha)	
	Without tops	With tops
0	2.2	3.4
60	4.1	5.5
90	5.2	6.2
120	6.3	6.8
150	6.5	–
LSD (0.05)	0.6	0.6

[a] Mean of 2 yr

Table 2. Predicted urea N equivalents and apparent N recovery from sugar beet tops. Punjab, India.

Urea N rate (kg/ha)	Preicted urea N equivalent (kg/ha)	Apparent N recovery (%) from sugar beet tops
0	32	20
60	39	32
90	40	27
120	35	25
Mean	37	26

$$Y = 21.84 + 0.385\ N - 0.006333\ N^2$$

Analysis of this response equation revealed that sugar beet tops (depending upon the rate of inorganic N used) were equivalent to 32-40 kg of urea N, or an average of 37 kg N/ha. The percent utilization of the applied N through tops also varied with urea N rates, with an overall average of 26% (Table 2).

Results suggest that sugar beet tops should be incorporated into the soil rather than be removed from a field before rice is planted. ■

Top pruning of *Sesbania rostrata* to increase rice grain yield

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Seed availability is a major constraint in the use of *S. rostrata* as a green manure (GM) crop for rice. Pruning the top of sesbania at the juvenile stage can promote production of axillary buds and new branches, thus resulting in higher biomass production and higher N accumulation. We studied whether pruning can increase biomass production of prerice sesbania to compensate for a lower seeding rate.

Sesbania seeds were sown at increasing rates (see table) in rows 40 cm apart in well-tilled 3- × 6-m plots. The experiment was laid out in a randomized complete block design with four replications. Two treatments of *A. afraspera* were compared with sesbania. Two fallow weed-free treatments were maintained as controls. The GM crop was irrigated and received no fertilizer.

The top 1/3 of the treated plants were pruned at 25 d after emergence (DE). The pruned tops were weighed, and then returned to the plots. The plants were cut at ground level at 55 DE and soil-incorporated after recording height and fresh weight. All plots received 13 kg P/ha and 25 kg K/ha during soil puddling.

IR72 rice was transplanted at 25- × 25-cm spacing. In one control treatment, 65 kg N/ha was applied basally and 35 kg N/ha was applied at 4 d before panicle initiation. The other control plot received no N. Plots were kept flooded until harvest.

Pruning the tops of the GM plants did not improve their biomass production. The unpruned plants were significantly taller at 55 DE and generally had greater total dry matter than the pruned plants. Plant height and dry matter increased with increasing seeding rate, particularly in the unpruned treatments.

Compared with the zero N control, the application of N and GM significantly increased rice plant height, grain yield, and total dry matter yields (TDMY), but not tiller number. The N-fertilized and green-manured rice yields were comparable. Pruning the GM plants generally had no effect on rice grain yield, TDMY, height, and tiller number. Regardless of the pruning treatment, increasing the seed rate from 10 to 40 kg/ha did not clearly benefit grain yield and other parameters. ■

Effect of pruning[a] and seeding rate of green manures *S. rostrata* and *A. afraspera* on rice performance. IRRI, 1990 wet season.

Sesbania management			Sesbania		Rice (IR72)				
Treatment no.	Seed rate (kg/ha)	Pruning management	Dry matter (t/ha)	Height (cm)	Grain yield (t/ha)	TDMY (t/ha)	Plant height (cm)	Total tillers (no/m^2)	Productive tillers (no./m^2)
1	10	Pruned (P)	0.48	77	2.7	7.3	83	329	300
2	10	Unpruned (UP)	0.38	90	2.7	7.2	83	343	314
3	20	P	0.37	71	2.5	7.9	84	337	309
4	20	UP	1.41	111	2.9	8.6	86	341	310
5	30	P	1.03	89	2.8	7.8	83	319	293
6	30	UP	1.82	123	2.6	7.8	87	366	326
7	40	P	0.88	87	2.8	8.2	85	329	302
8	40	UP	2.04	130	2.6	8.3	85	360	325
9	Fallow	(0 N on rice)	–	–	2.3	5.9	79	310	279
10	Fallow	(100 kg N/ha on rice)	–	–	2.6	6.3	81	306	274
11	20	*A. afraspera* (P)	0.84	60	2.7	7.8	86	345	319
12	20	*A. afraspera* (UP)	1.45	87	2.6	8.3	85	339	311
		CV (%)	51.9	11.5	7.2	10.4	2.7	12.7	13.0
		Comparison[b]							
		T1 × T2	ns	*	ns	ns	ns	ns	ns
		T3 × T4	**	**	**	ns	ns	ns	ns
		T5 × T6	*	**	ns	ns	ns	ns	ns
		T7 × T8	**	**	ns	ns	*	ns	ns
		T1, 2 × T3,4	**	ns	ns	*	ns	ns	ns
		T9 × T10	?	?	*	ns	ns	ns	ns
		T11 × T12	ns	**	ns	ns	ns	ns	ns
		T11, 12 × T3, 4	ns	**	ns	ns	ns	ns	ns
		T9 × T1, 2	ns	**	**	**	**	ns	ns
		T10 × T1, 2	ns	**	ns	ns	ns	ns	ns

[a] The top 1/3 of the GM was pruned at 25 DE. [b] *, ** = significant at 5% and 1% levels, respectively ns= nonsignificant.

Fertilizer management

Response of Mukthi (CTH1) ratoon to nutrition in coastal Karnataka, India

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Rice predominates over other crops in coastal Karnataka during the three growing seasons. We studied the possibilities of rice ratooning during 1989-90 rabi season (Sep-Dec). Mukthi was found to be a good ratooner among the five varieties tested. To improve the performance of the ratoon crop, nutritional parameters were imposed on Mukthi ratoon at the Regional Research Station (RRS), Brahmavar, during 1991 rabi. Soils are lateritic, rich in organic C, low in available P and K, and have a pH of 5.1 (air-dried soil).

We applied different amounts of N with farmyard manure (FYM) and Agroplus (a liquid micronutrient fertilizer) on a Mukthi ratoon crop. The experiment was laid out in a strip-plot design, replicated three times.

Results showed that fertilizer levels up to 50 kg N/ha increased grain yield (see table). FYM and Agroplus had a marginal effect on the crop at all N levels. Tillers per hill, grain number, and weight per panicle showed a trend similar to that of grain yield. The ratoon crop matured in 70 d; the preceding main crop took 102 d and yielded 3.9 t grain/ha.

Mukthi can be ratoon-cropped successfully by applying 50 kg N/ha; it can be harvested about a month earlier than the main crop. ■

Effect of nutrition on Mukthi (CTH1) ratoon rice. RRS, Brahmavar, India, 1991 rabi.

Treatment[a]	Tillers/hill (no.) at 21 DAR[b]	Grains/ panicle (no.)	Gram wt/panicle (g)	Grain yield (t/ha)
$F_1$0	7.0	46.1	0.67	1.6
F_1AP	6.4	48.6	0.73	1.7
F_1FYM	7.2	50.6	0.75	1.9
$F_2$0	11.0	57.4	0.88	2.3
F_2AP	11.6	59.4	0.93	2.5
F_2FYM	12.2	56.7	0.87	2.3
$F_3$0	14.4	61.2	0.95	2.7
F_3AP	15.2	65.2	1.04	3.0
F_3FYM	15.6	62.1	0.98	2.8
$F_4$0	13.4	56.5	0.88	2.7
F_4AP	14.2	56.2	0.89	2.8
F_4FYM	14.0	55.4	0.87	2.7
For fertilizer levels				
S.Em±	0.2	0.7	0.02	0.1
LSD (0.05)	0.8	2.3	0.07	0.2
CV(%)	6.0	4.0	7.00	9.0
For AP and FYM				
SEm±	0.1	0.9	0.01	0.02
LSD (0.05)	0.2	ns	ns	0.1
CV (%)	1.0	5.0	5.0	2.0
For interaction				
For comparing two nutrition means at the same level of fertilizer	–	–	–	–
S.Em ±	–	–	–	0.1
LSD (0.05)	–	–	–	0.3
For comparing two fertilizer means at the same level of nutrition	–	–	–	–
S.Em±	–	–	–	0.1
LSD (0.05)	–	–	–	0.2
CV (%)	6.0	4.0	5.0	5.0

[a]F_1 = 0-25-25 kg NPK/ha, F_2 = 25-25-25 kg NPK/ha, F_3 = 50-25-25 kg NPK/ha, F_4 = 75-25-25 kg NPK/ha, AP = Agroplus 2 ml/liter at 15 DAR, FYM = 2.5 t/ha on ratooning day, 0 = control. [b]Days after ratooning.

Influence of green manures on P use efficiency in rice

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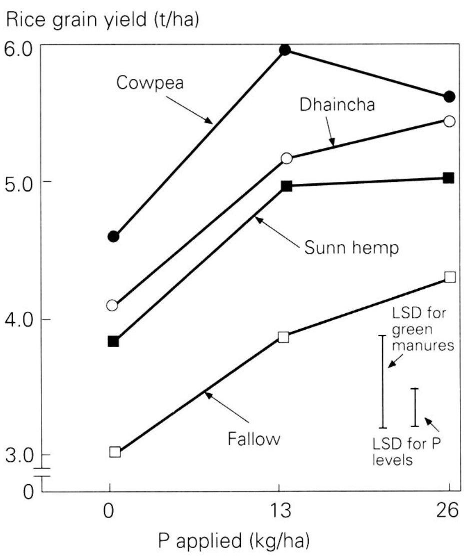
We studied the effect of green manure crops cowpea *Vigna unguiculata.* dhaincha *Sesbania aculeata.* and sunn hemp *Crotalaria juncea* on P use efficiency in rice cultivar PR 106 compared with a fallow field over 2 yr. We incorporated 60-d-old unfertilized green manure into soil 1 d before transplanting rice. Rice received 0, 13, or 26 kg P/ha as single superphosphate along with a basal dose of 120 kg N/ha as urea and 50 kg K/ha as muriate of potash. Each treatment was replicated three times.

Results were based on total dry matter accumulation and total P uptake by green manures. Sunn hemp produced the most dry matter and contained relatively higher amounts of P (see table).

Rice grain yield was significantly higher in cowpea-manured plots and lowest in fallow plots (see figure). The rice crop responded significantly to 13 kg P/ha in green-manured plots and to 26 kg P/ha in fallow plots, showing the beneficial effects of green manures as substitutes for fertilizer P in rice (see figure).

Cowpea-manured plots produced the highest yield at 6 t grain/ha with 13 kg P/ha, perhaps because cowpea decomposes



Effect of green manure and applied P on rice grain yield (av of 2 yr). Ludhiana, India.

Dry matter accumulation, total P uptake by various green manurecrops, and fertilizer P use efficiency of rice as affected by various green manures. Ludhiana, India.

Green manure crop	Dry matter produced (t/ha)		Total P uptake (kg/ha)		Fertilizer P use efficiency of rice[a] (kg grain/kg applied P)	
	1st yr	2d yr	1st	2d yr	13 kg applied P/ha	25 kg applied P/ha
Cowpea	4.25	3.92	12.3	11.1	108 (41)	41 (21)
Dhaincha	3.99	3.04	11.4	8.7	85 (18)	54 (34)
Sunn hemp	5.00	4.52	12.2	11.2	89 (22)	49 (29)
Fallow	–	–	–	–	67	20
LSD (0.05)	0.57	0.59	ns	2.6		

[a] Av of 2 yr Values in parentheses show Increase in P use efficiency over fallow plots.

relatively fast compared with sunn hemp and dhaincha. Every kilogram of P applied at 13 kg/ha produced 108 kg grain in cowpea, 85 in dhaincha, 89 in sunn hemp, and 67 in fallow plots, showing an increase of 18-41 kg grain/kg P over fallow plots (see table).

Green manuring saved about 13 kg P/ha and contributed to extra grain yield. Cowpea was the best green manure crop for rice. ■

Crop management

Effect of tillage on physical properties of soil and yield of peanut in a rice-based cropping system

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Farmers in southern India, particularly in Andhra Pradesh, grow peanut after wet season puddled rice. In the rhizosphere, peanut requires a physical environment entirely different from that of rice. Inadequate peanut seedbed preparation in puddled soils results in poor germination, plant stand, growth, and yield.

We studied the effect of five tillage methods (see table) for irrigated peanut after puddled rice during 1988-89 and 1989-90 wet seasons. The experiment was laid out in a randomized block design with four replications in a sandy loam soil with 0.11% organic C.

Plowing was deeper in the tractor-drawn treatment. Mean weight diameter (MWD) of seed zone aggregates varied among the tillage treatments. MWD, with many clods, was highest with the country plow. The rototiller treatment had small and relatively uniform aggregates.

Tillage affected germination. It was highest with the rototiller, where aggregate sizes favored good seed-soil contact and the highest soil moisture content. Soil penetration resistance recorded at pegging stage was least in the rototiller treatment. Haulm and pod yields were highest in the tractor-drawn treatment, closely followed by those with the rototiller.

The higher yields obtained with tractor tillage compared with bullock-drawn treatments might be due to the deeper plowing, which resulted in breaking of the subsoil hardpan layer and smaller aggregates. Higher yields with rototillage were due to uniform aggregate size and low soil strength (penetration resistance).

We suggest that farmers use rototillage when growing peanut after puddled rice in light-textured soils because of the relative ease of operation, low cost, and higher yields. ■

Effect of tillage on physical properties of soil and yield of peanut. Hyderabad, India, 1988 and 1989.

Treatment	Plowing depth (cm)	Mean weight diameter (cm)	Soil moisture[a] (% wt/wt)	Germination (%)	Penetration resistance at pegging stage (kg/cm^2)	Yield (t/ha)	
						Haulm	Pod
T1 Plowing twice with bullock-drawn, country plow	7.0	4.5	7.4	47	35	2.39	1.44
T1 + disc harrow twice, bullock drawn	7.1	3.0	7.9	51	33	2.52	1.45
T1 + disc harrow 4 times, bullock drawn	7.8	2.3	7.2	52	35	2.54	1.70
T1 + rototiller twice, power tiller drawn	7.6	1.6	11.3	57	29	3.13	1.90
T5 Disc plow once + disc harrow once, tractor drawn	12.9	3.0	10.7	55	31	3.20	1.96
LSD (0.05)	–	–	1.3	6	1	0.35	0.11

[a] Soil moisture at 20 d after sowing.

Evaluation of rice planting methods for rainfed lowlands of Karnataka

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Rice is normally sown with a seed drill in the rainfed lowlands of interior Karnataka. Sowing dry seed on most soil with the onset of the monsoon (DSR-moist) is the common practice, with dry sowing on dry soil (DSR-dry) seen in some areas. Wet sowing can be difficult

Grain yield and net profit as influenced by planting methods of rice in rainfed lowlands of Karnataka, India, 1990 and 1991 kharifs. [a]

Treatment	Grain yield (t/ha)		Net profit ($/ha)	
	1990	1991	1990	1991
Wet sown without fertilizer	4.3	F	10.7	F
Wet sown with fertilizer	5.6	F	13.6	F
Dry sown without fertilizer	N	4.5	N	14.5
Dry sown with fertilizer	5.2	6.1	12.4	21.2
Line transplanted with fertilizer	5.0	5.6	10.8	17.2
Broadcast pre-germinated seeds with fertilizer	1.8	F	0.9	F
LSD (0.05)	1.2	1.3		

[a] N = treatment not included, F = failed treatment.

in years when the monsoon comes early and the rain is heavy.

We evaluated different planting methods for establishing rice in rainfed lowlands during 1990 and 1991 kharif. Treatments included DSR-moist and DSR-dry with and without fertilizer on puddled soil, line transplanting (TPR), and broadcasting pregerminated seeds (WSR) under puddled conditions. The trial was laid out in randomized block design with four replications on a clay soil with pH 7.4, 0.74% organic C, 36 kg available P/ha, and 228 kg available K/ha.

For the fertilized treatments, 100-22-41 kg NPK/ha was applied. P and K were broadcast before sowing or transplanting, and N was applied in three equal splits at 20 and 40 d after sowing and just before panicle initiation. Abhilash was the test variety.

DSR-dry was done on 18 May 1990 and 13 May 1991; DSR-moist on 29 May 1990 and 4 Jun 1991; TPR on 19 Jul 1990 and 16 Jul 1991; WSR on 19 Jul 1990 and 14 Jun 1991.

The monsoon started on 26 May 1990 and 30 May 1991 with total rainfall of 1,038 mm in 1990 and 1.265 mm in 1991. Rainfall of 1990 was closer to average for the area (950 mm) than that of 1991, which was 33% more than the average. Excessive rains after sowing led to failure of DSR-moist and WSR because seeds were submerged and subjected to anoxic conditions.

Dry sowing in dry soil produced higher, more stable grain yields and higher net profit than the other planting methods (see table). With the clay soils of the region, however, methods of dry soil preparation are needed to facilitate early establishment of DSR. ■

Integrated pest management — diseases

Maintenance of *Rhizoctonia solani* Kuhn, the causal agent of rice sheath blight (ShB), in gum flakes

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Fungal cultures have been maintained for several years in sterile distilled water, soil, liquid nitrogen, by freeze drying, and by deep freezing. We developed a simple method that allows workers to maintain large numbers of fungal cultures under limited resources and space.

In the method, 3- × 1 -inch glass slides were cleaned to make them grease-free, rinsed in ethanol, and air-dried. Two to three drops of 1% dextrose were put in the middle of the slide. Either a sclerotium or a fungal bit taken from an actively growing culture was placed in the dextrose solution. The slides were placed in sterile petri dishes lined with moist filter papers and then incubated at 25 ± 1ºC for 96 h for sclerotial germination or ramification of mycelium.

A few drops of Camel Adhelin (a synthetic gum manufactured by Camlin Pvt. Ltd., Bombay 400059, India) that had been autoclaved at 15 lb pressure for 15 min were poured over the mycelium on the slides. When the slides were dried at 25ºC. thin flakes formed with the fungus firmly embedded in them. We eased these flakes off the slides with a sterile blade and stored them in small sterile vials. Gum-free slides with fungal growth served as control. The fungus was also maintained on potato dextrose agar (PDA) (5 ml/test tube. 120 × 15 mm). Each treatment was replicated 10 times.

The viability of *R. solani* was tested monthly after 6 mo of storage by transferring it to PDA. A culture was recorded as nonviable if it did not grow after repeated transfers.

R. solani had 5-99% viability in the three substrates (see table). Subcultures obtained from the gum flake grew slowly at first compared with those maintained in other substrates and periodically transferred. This slow growth may be due to the time required for the gum flake to soften and for dormant mycelium to be activated by the moisture present in the medium. ■

Viability of *R. solani* maintained in various substrates.

Substrate	Duration of survival (mo)	Duration of survival (%)
Gum flake	38	99
Gum-free slide with fungal growth	7	10
Potato dextrose agar slant	18	5

A new assessment key for leaf blast (Bl)

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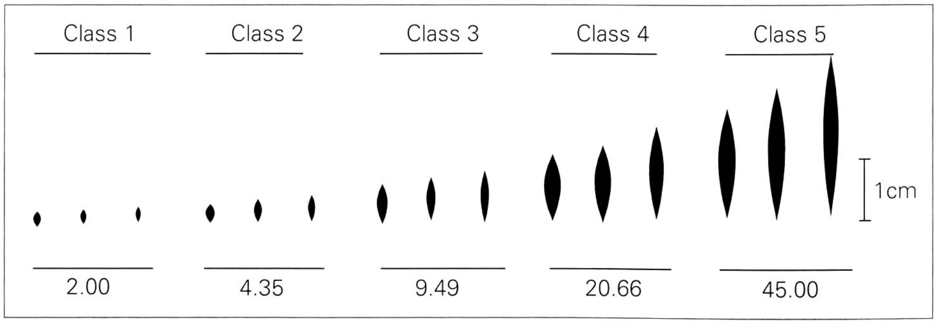
A flexible key for leaf B1 assessment has been designed for quantitative epidemiological and host-pathogen interaction studies. The key takes into account leaf B1 severity and the stratification of lesion type. It uses lesion size and appearance as criteria to characterize the lesions.

Typical lesions are spindle-shaped, with varying length, width, and 1ength:width ratio. Lesion area can be approximated by the formula

$$F = \frac{W}{15}(6L + 8\sqrt{((W^2 + L^2)/4)})$$

where F = lesion area (mm^2), L = lesion length (mm), and W = lesion width (mm). From this equation, we developed a diagram that divides susceptible type lesions into five size classes on an exponential scale. The L:W ratio of lesions varied within each class while the lesion area remained the same (see figure). Resistant type lesions (not shown in figure) were assumed to cover an area of 0.25 mm^2.



Exponential assessment key for susceptible type leaf Bl lesions. Numbers indicate the mean lesion size (mm^2) of the respective classes.

Susceptible lesions were further classified into four types (see table). Unpublished data showed that this classification scheme captures the reaction type, the ontogenetic stage, and the presumable sporulation intensity (no. spores/unit of lesion area per unit of time) of lesions. Depending on the research objective, criteria for lesion size and lesion type can be combined or used independently to classify leaf lesions into respective categories by counting.

An example of a record sheet where both lesion criteria are combined and leaf area measurements included is in the table. This scheme provides the basis to determine any of the following parameters on a per sample or per leaf area basis: a) lesion number or lesion area, b) lesion number or lesion area, stratified by lesion type, c) leaf B1 severity, d) leaf B1 severity, stratified by lesion type, e) relative prevalence of lesion types in terms of lesion number and/or lesion area, f) mean lesion type in terms of lesion number and/or lesion area, and g) sporulation potential of leaf B1 populations. For the last item. the relationship between lesion type and sporulation has to be established experimentally for specific varieties and pathogen races.

This key thus combines most of the features of assessment schemes published earlier while offering higher accuracy, more flexibility, and wider applicability. ■

Example of a record sheet for assessing leaf Bl, based on a key that combines criteria to characterize lesion size and lesion type. [a]

Sample number	Lesion size class	Lesion size (mm^2)	Lesion type	Lesions (no.)	Leaf area (cm^2)
	0 (resistant type)	ca. 0.25	A		
	1	2.00	B		
			C		
			D		
	2	4.35	B		
			C		
			D		
	3	9.49			
	4	20.66	C		
			D		
	5	45.00	C		
			D		

[a] Description of lesion types (based on unpublished data of the relationship among type, age, and sporulation of lesions): A = hypersensitive reaction type lesion that does not sporulate: brown, pinhead-sized spot: B = susceptible reaction type lesion of young physiological age with very high to maximum sporulation intensity: center dark-green, water-soaked to greyish green, no margin or margin purplish green to purplish, C = susceptible reaction or type lesion of intermediate physiological age with very high to intermediate sporulation intensity center greyish green to grey, margin purplish to purplish brown, D = susceptible reaction type lesion of old physiological age with intermediate to very low sporulation intensity: center grey and brittle, margin brown to necrotic brown.

Determining mating type of *Magnaporthe grisea* population in Bangladesh

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Rice blast (B1), caused by *Magnaporthe grisea* (anamorph *Pyricularia grisea* Cav.), is a destructive rice disease. Modern varieties react differently in recurrent B1 epidemics. This suggests the occurrence of different races over time.

New *P. grisea* races can appear through mutation or sexual reproduction, but the latter is unknown in nature. The B1 pathogen is heterothallic and mates with isolates from other hosts.

It has been reported that two mating types, Mat 1-1 and Mat 1-2, exist and that they are male, female, or hermaphrodite. Perithecia are produced only when isolates of opposite mating types are crossed. Progeny of such crosses produce the two mating types in equal proportions. Therefore. the potential for sexual reproduction to occur in a population can be obtained from the mating type ratio within the *M. grisea* population.

The mating ability of 73 *M. grisea* isolates obtained from the BRRI B1 nursery and from infected fields in the endemic areas of Bangladesh was tested using two Mat 1-1 and two Mat 1-2 standard testers. Three testers were obtained from Dr. J. L. Notteghem of the Institute for Research in Tropical Agriculture, France, and one from Dr. Hei Leung of Washington State University, USA. All the standard testers are fertile, hermaphroditic, and nonpathogenic to rice.

Petri dishes containing oatmeal agar were inoculated with two standard isolates of the same mating type and one of the rice isolates. After 3-5 d of growth, they were placed under fluorescent light at 20 ± 1 °C. After 3-4 wk, plates were observed for perithecia formation. Among the 73 isolates tested, 46.6% are Mat 1-1 and 20.5% are Mat 1-2. Nearly 33% of the isolates mated with neither Mat 1-1 nor Mat 1–2.

The results show that both mating-type isolates are prevalent in Bangladesh. Mat 1-1, however, appears to predominate. We are studying the distribution of the mating types by region and identifying isolates that do not mate with either type. ■

Forecasting rice tungro disease (RTD) occurrence in asynchronous rice planting areas on an empirical basis

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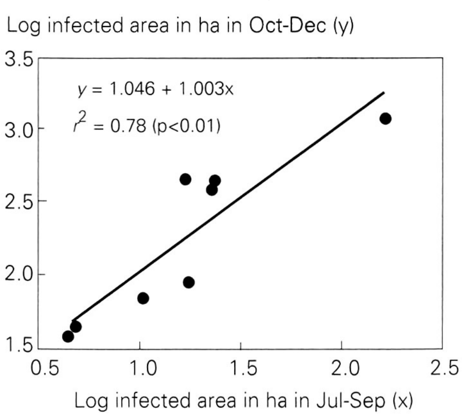
The most frequent and serious outbreaks of RTD during the past decade in Indonesia have occurred in Bali Province, where rice is cultivated asynchronously throughout the year. RTD occurrence fluctuates seasonally in Bali and in the country's other asynchronous rice planting areas. The infected area increases around the start of the wet season (WS), reaches its peak in the mid-wet to early dry season (DS), and shrinks toward the late DS. We studied empirical rules of RTD occurrence in WS in Badung, Tabanan, and Gianyar, the major RTD-endemic regencies of Bali.

Analyses were made with data from Apr 1983 to Mar 1991. Data on monthly rainfall and RTD-infected area were obtained from pest observers' reports. The Bali Provincial Agriculture Service provided relevant agriculture statistics. In Badung, Tabanan, and Gianyar, rice was cultivated in WS on an average of 19,300, 29,800, and 16,000 ha, respectively, and in DS on 16,700, 21,900, and 16,600 ha, during the 8-yr period.

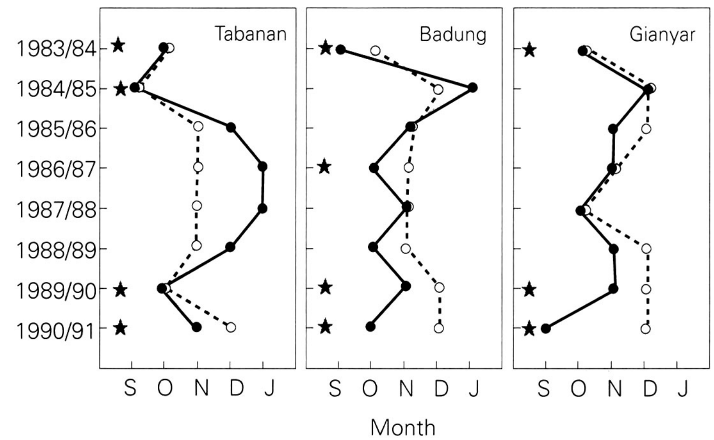
The RTD-infected area in Oct-Dec (transition to early WS) is positively related with that in Jul-Sep (second half of the DS) when RTD incidence is lowest in a year (Fig. 1). Rainfall, mean temperature, and the area planted with vector-susceptible cultivars failed to account for significant additional variance in the infected area in Oct-Dec.

The RTD onset month (defined as the month when the newly infected area was greater than twice that of the previous month and increased more than 1 ha) tended to precede the start of WS (monthly rainfall > 200 mm) in years of severe occurrence where infected area in WS was 100 ha. In ordinary years, RTD onset month often came after the beginning of WS (Fig. 2). The difference in RTD onset month relative to that of the WS between the two categories of years is significant (Mann-Whitney U-test, $p < 0.05$.

RTD occurrence in Bali in the 1990-91 WS was successfully forecast using these empirical rules. ■



1. Regression of RTD-infected area in Oct-Dec on that in Jul-Sep in 3 regencies of Bali, Indonesia, 1983-91. Total area planted to rice in Oct-Dec averaged 24,400 ha.



2. Relationship in the starting months between RTD onset (solid circles) and WS (open circles) in 3 regencies of Bali. Stars denote WS of severe RTD occurrence.

A procedure for miniscale preparation of *Pyricularia grisea* DNA

R. P. Scott, R. S. Zeigler, and R. J. Nelson, IRRI

DNA from the blast (B1) pathogen *Pyicularia grisea* can be prepared inexpensively in 1.5-ml microcentrifuge tubes in sufficient quantities for several Southern hybridizations and polymerase chain reaction experiments. We found that the potassium acetate extraction method can be successfully applied to ground mycelia. The isolated DNA is sufficiently pure to allow digestion with restriction enzymes, making organic solvent extraction optional. Using the following method, DNA can be conveniently extracted from 100 samples of ground mycelia within a day. The procedure is outlined below.

Grow hyphal cultures in 50 ml of Fries medium in 125-ml flasks at 30°C with shaking. After 5-10 d, harvest the mycelia by suction and lyophilize them. Grind the dried mycelia finely using a mortar and pestle with liquid N or, alternatively, with a few grains of sterile acid-washed sand. If stored at -20°C with a desiccant, the mycelial powder will keep for several months.

For a single extraction, suspend 50-75 mg of pulverized mycelia in 750 µl extraction buffer (1 00 mM Tris-HCl, pH 8; 100 mM EDTA; and 250 mM NaCl) by light vortexing in a 1.5-ml microcentrifuge tube. The needed amount of mycelia powder will fill about a quarter of the tube. Add 75 µl 10% (wt/vol) SDS; mix the contents gently and incubate for at least 30 min at 65°C. Then add 300 µl potassium acetate solution (3 M potassium acetate-2 M acetic acid, pH 4.8), mix gently by inversion, and incubate the tube on ice for 15 min. Spin down precipitate (proteins and detergent) and debris at 13,000 rpm for 15 min.

Carefully transfer 750 µl of supernatant to a fresh tube containing 750 µl 2-propanol. (If a cleaner preparation is needed, the supernatant may be extracted with an equal volume of 24: 1 (vol/vol) chloroform-isoamyl alcohol prior to alcohol precipitation.) Invert the tube to mix. Keep the tube on ice for 10 min, or longer if precipitation of nucleic acids is not satisfactory. Pellet down the nucleic acid (13,000 rpm for 5 min), wash with 70% ethanol, air-dry, and resuspend in 40 µl of TE buffer (10 mM Tris-HCI, pH 7.5-8; and 1 mM EDTA). This procedure will yield about 15 µg of DNA.

For a single Southern hybridization, use 1-3 µg of DNA per lane. DNA stored at 4°C or lower will remain stable in TE buffer for several months. Contaminating RNA can be eliminated with RNAse A (20 µg/pl final concentration) either during or after DNA restriction digestion. ■

Sclerotia of false smut (FSm) of rice from Assam, India

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Sclerotia of FSm *Claviceps oryzae sativae* Hashioka were found in Assam for the first time in late Nov 1991.

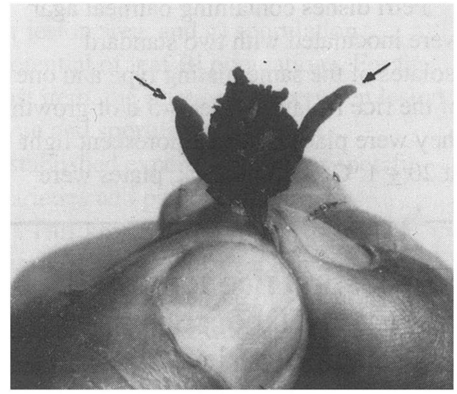
Less than 1% of the FSm spore balls in a rainfed lowland winter rice (Jul-Dec) crop had the sclerotia. They were borne as peelings from the surface of some spore balls and looked like petals of a flower bud (Fig. 1). Two sclerotia usually developed on a spore ball. They were never formed inside the spore balls.

Sclerotia were shed easily and were collected from the ground near rice hills. The largest sclerotium measured 14 × 7 mm, the smallest was 5 × 3 mm (Fig. 2).

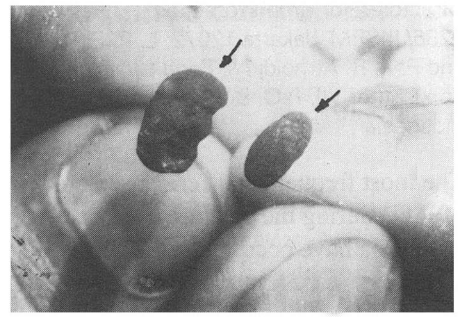
The maximum and minimum temperatures during the week in which sclerotia developed ranged from 20 to 26°C and from 11 to 15°C, respectively. The relatively low temperatures during late Nov to early Dec induced sclerotia formation.

The sclerotia germinated after 3 mo when buried in sterile moist sand. They produced stalked stroma with plenty of ascospores.

FSm sclerotia were earlier reported in India at altitudes of 1,200 m and above in the hilly regions of the north where temperate climate prevails. The sclerotia recently observed are in the plains region (Jorhat) at an altitude of 91 m. Sclerotia, through ascospores, can cause primary infection of rice. ■



1. Sclerotia of FSm borne on spore ball.



2. Sclerotia of FSm detrached from spore ball.

A rapid method for DNA fingerprinting of the rice blast fungus *Pyricularia grisea*

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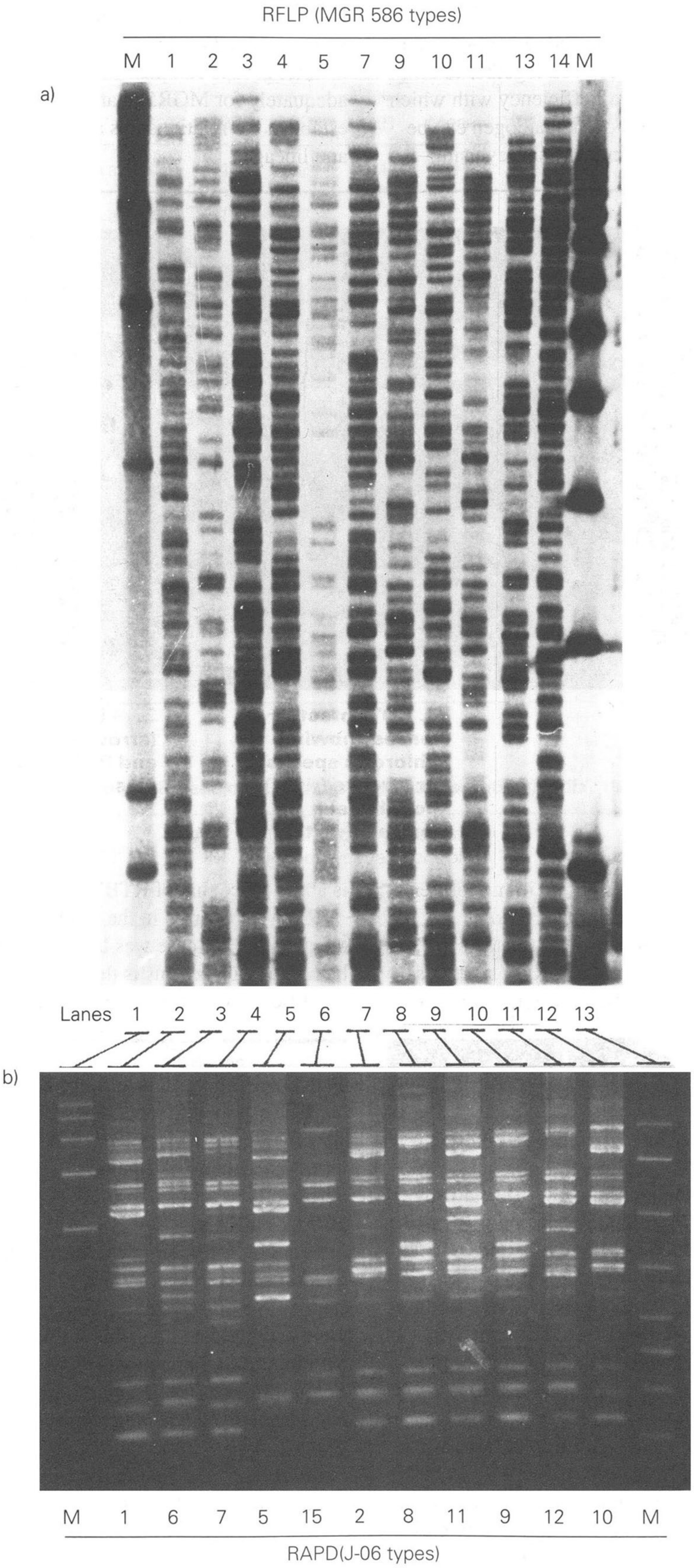
DNA fingerprinting and phylogenetic analysis based on the repetitive DNA probe MGR586 (Dupont) have been useful in studying the population structure of the rice blast fungus *P. grisea.* The DNA fingerprints are used to group isolates according to genetic similarity. The inference is that the groups share a common ancestor and,

Association between groups of isolates defined by RAPD (primer J-06) and RFLP (probe MGR586).[a]

RFLP (MGR586)	RAPD (J-06)	Isolates (no.)
1, 1c, 1d, 1e	1	24
7, 7a	2	12
4, 4a. 4b, 4c	3, 4, 5	69
2	6	1
3	7	5
9	8	1
11	9	1
14	10	5
10	11	1
13	12	1

[a]MGR586 designations with the same number and different letters are very similar but not identical (80% of bands in common). Each distinct profile produced by RAPD (J-06) was given a different number. Designations for groups of isolates are arbitrary.



DNA profiles generated by a) RFLP MGR 586 and b) RAPD (J-06). M = DNA molecular weight markers.

given the asexual propagation of the pathogen, therefore belong to one lineage.

The restriction fragment length polymorphism (RFLP) technique, however, is time-consuming and expensive, involving restriction endonuclease digestion, agarose gel electrophoresis, Southern blotting, DNA hybridization, and detection. A simplified DNA technique could allow greater efficiency in characterizing pathogen populations.

We tried a polymerase chain reaction (PCR)-based technique termed randomly amplified polymorphic DNA (RAPD). It is faster and simpler than RFLP and allows in vitro synthesis or amplification of random DNA segments that are determined by single primers of arbitrary nucleotide sequence. The amplified products are then electrophoresced in 2% agarose and DNA polymorphism can be detected by examining the ethidium bromide-stained gel under UV light.

When twenty-seven 10-base primers (Operon Technologies) were randomly selected and screened; 17 showed polymorphism among five diverse strains of *P. grisea.* Primer 5-06 (5’TCGTTCCGCA 3’) generated clear DNA profiles and defined groups of isolates that corresponded well with the groupings generated by repetitive DNA probe MGR586 for 120 isolates collected from Cavinti, Laguna, Philippines, and from IRRI-blast nursery upland screening sites (see table). Each distinct MGR lineage corresponded to one or a few RAPD (J-06) types. The DNA fingerprints generated by the two methods are shown in the figure.

RAPD (J-06) is faster than RFLP (MGR586) analysis, but it is less informative for phylogenetic analysis because fewer bands are produced for each isolate. Because corresponding groups of isolates are defined with MGR586 and RAPD (J-06) for the Philippine isolates tested, we propose that the two methods be used together to improve the overall efficiency with which field populations of the pathogen can be analyzed. A preliminary survey using RAPD can be used to group similar strains and reduce redundancy. All distinct groups can then be sampled adequately for MGR586 analysis to establish the relationships among strains and lineages. ■

Rice dwarf (RD), a new virus disease in the Philippines

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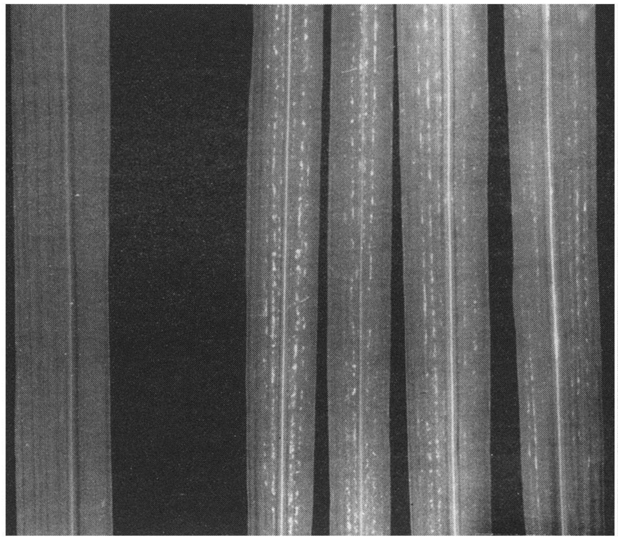
R. C. Cabunagan, and F. C. Sta. Cruz, IRRI

RD is a destructive virus disease that was known to occur only in temperate regions such as Japan, Korea, China, and Nepal.

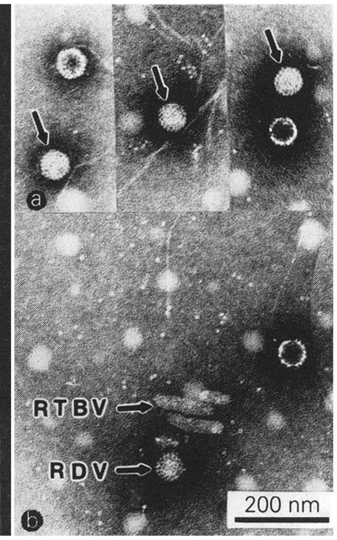
RD disease symptoms were recently observed in ricefields in Midsayap, North Cotabato, Philippines. Infected plants showed stunting and fine chlorotic specks or streaks on leaf blades (Fig. 1). Most of the plants showing the chlorotic specks were also infected with tungro disease, which obscures the symptoms of RD. However, RD leaf symptoms were clearly visible in plants infected with rice tungro bacilliform virus (RTBV) only.

Serological tests and electron microscopy confirmed RD infection in plant samples collected from Midsayap. Leaf extracts from symptomatic leaves diluted up to a thousand times gave a strong positive reaction to RD virus (RDV) antiserum in rapid immunofilter paper assay. Electron microscopic observations of clarified infected sap revealed the presence of RDV particles (Fig. 2a), the diameter of which (65 nm) is about twice that of RTBV (Fig. 2b).

RD was reported in the Philippines in the past, but the case was later proven to be tungro. Hence, this is the first true identification of RD in the Philippines. ■



1. RDV-infected leaves showing chlorotic specks or streaks (right); healthy leaf (extreme left).



2. a) RDV particles (arrows); b) RDV and RTBV particles.

Integrated pest management—weeds

Weed control in upland ricefields of Karnataka

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Weeds are a big constraint to raising the average upland rice yield in Karnataka from the current low of about 1 t/ha. Hand weeding is very effective but requires a lot of labor, thus making it costly for the upland farmer. Suitable herbicides have not yet been found.

To determine effective and economical weed control practices, we experimented during 1989-91 kharif by combining herbicides or using them with cultural practices. Butachlor and pendimethalin were applied alone or in combination with 2.4-D or hand weeding (Table 1). A weed-free treatment, two hand weedings at 20 and 40 d after rice emergence (DE), and nonweeded treatment were used for comparison. Plots were hand weeded in the weed-free check.

The trial was laid out in a randomized complete block design. Soil is silty clay loam with pH 7.0. 0.84% organic C, and an average 0.6 kg P/ha and 114.1 kg K/ha. Avinash in 1989 and 1990 and IETS6S6 in 1991 were seeded at 100 kg/ha with a spacing of 20 cm between rows. Fertilizer was applied 100-10.9-20.7 kg NPK/ha.

We took weed samples from a 1-m^2 quadrat and weighed them at the heading stage of the grassy weeds. We recorded yield and yield components from a 5-m^2 net plot area. Common weeds were *Echinochloa colona, Panicum* spp., *Digitaria* sp., *Ischaemum rugosum. Cyperus iria, C. rotundus, C. difformis, Cyanotis* spp., *Commelina benghalensis, Spilanthes punicdata, Ageratum conyzoides,* and *Eclipta prostata.*

Table 1. Effect of weed control treatments on weed dry weight and grain yields in upland rice. Karnataka, India, 1989-91 kharif.

Treatment [a]	Weed dry weight (g/m^2)				Grain yield (t/ha)			
	1989	1990	1991	Mean	1989	1990	1991	Mean
Butachlor 2.0 kg ai/ha at 4-6 DE	413	429	111	318	2.1	0.7	2.0	1.6
Butachlor 1.5 kg ai/ha at 4-6 DE + 2.4-D 0.6 kg ai/ha at 25-30 DE	177	425	–	301	2.6	1.3	–	2.0
Butachlor 1.5 kg ai/ha at 4-6 DE + 1 hand weeding at 25-30 DE	22	–	22	22	4.1	–	2.5	3.3
Pendimethalin 1.5 kg ai/ha at 4-6 DE	312	328	89	243	1.9	0.7	1.6	1.4
Pendimethalin 1.0 kg ai/ha at 4-6 DE + 2,4-D 0.6 kg ai/ha at 25-30 DE	155	176	96	142	3.0	2.3	1.9	2.4
Pendimethalin 1.0 kg ai/ha at 4-6 DE + 1 hand weeding at 25-30 DE	47	–	24	36	4.1	–	2.2	3.2
Weed-free check	5	7	5	6	4.4	5.9	2.6	4.3
Two hand weedings at 20 and 40 DE	28	42	24	31	4.1	3.6	2.3	3.3
Nonweeded control	972	610	201	594	0.1	0.1	0.5	0.2
LSD (0.05)	78	164	24		0.7	0.5	0.4	

[a] DE = days after emergence.

Neither butachor nor pendimethalin, whether alone or combined with 2,4-D, effectively controlled weeds. However, when combined with one hand weeding at 25-30 DE, they controlled weeds as effectively as two hand weedings at 20 and 40 DE. When butachlor or pendimethalin were combined with one hand weeding, grain yields were on par with those of two hand weedings and greater than the treatments with no hand weeding (Table 1).

The cost of additional production over the nonweeded control was highest with the weed-free check, followed by butachlor + hand weeding, pendimethalin + hand weeding, and two hand weedings. The marginal benefit-to-cost ratio, however, was higher with herbicides combined with one hand weeding than with two hand weedings or in the weed-free check because of the higher weed control costs of the weedings (Table 2). ■

Table 2. Economics of weed control in upland rice. Karnataka, India, 1989-91 kharif.

Treatment [a]	Value of additional output [b] over nonweeded control				Cost of weed control [c]				Marginal benefit-to-cost ratio [d]			
	1989	1990	1991	Mean	1989	1990	1991	Mean	1989	1990	1991	Mean
Butachlor 2.0 kg ai/ha at 4-6 DE	189	50	198	146	22	15	15	17	8.5	3.4	13.5	8.5
Butachlor 1.5 kg ai/ha at 4-6 DE + 2,4-D 0.6 kg ai/ha at 25-30 DE	240	100	–	170	22	17	–	20	10.9	5.7	–	8.3
Butachlor 1.5 kg ai/ha at 4-6 DE + 1 hand weeding at 25-30 DE	380	–	279	329	52	47	49	50	7.3	–	5.7	6.5
Pendimethalin 1.5 kg ai/ha at 4-6 DE	177	54	146	126	33	28	33	31	5.3	1.9	4.4	3.9
Pendimethalin 1.0 kg ai/ha at 4-6 DE + 2,4-D 0.6 kg ai/ha at 25-30 DE	276	180	185	214	28	25	28	27	10.0	7.3	6.7	8.0
Pendimethalin 1.0 kg ai/ha at 4-6 DE + 1 hand weeding at 25-30 DE	385	–	237	311	58	–	57	57	6.7	–	4.1	5.4
Weed-free check	413	475	294	394	142	143	145	144	2.9	3.3	2.0	2.7
Two hand weedings at 20 and 40 DE	381	291	252	308	96	99	102	99	4.0	2.9	2.5	3.1

[a] DE = days after emergence.
[b] Production cost = $111.54/t rough rice. [c] Cost of inputs ($): butachlor = 4.04/liter, pendimethalin = 6.15/liter, 2,4-D = 3.35/liter, "A" class labor = 0.48/d, 'B' class labor = 0.46/d.
[d] $\text{Marginal B:C} = \frac{\text{Value of additional output over nonweeded control}}{\text{Cost of weed control treatment}}$

Weed species in irrigated ricefields in Northeast Thailand

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We identified weed species growing in farmers' irrigated ricefields in the Lam Dom Noi Irrigation Project Area (Ubon Province, Northeast Thailand) during the 1987 dry season (Jan-Apr). Some ecological traits of the weeds are included in the table. ■

Weed species in farmers' irrigated ricefields. Ubon Province, Northeast Thailand, 1987 dry season.

Scientific name	Family	Water depth (cm) at which species is most common[a]	Importance[b]	Flowering during study[c]
Grasses				
A. Emersed, rooting				
Leersia hexandra (L.) Sw.	Poaceae	2	2	+
Panicum repens L.	Poaceae	2	2	+
Paspalurn scrobiculatum L.	Poaceae	1	1	+
B. Littoral				
Cynodon dactylon (L.) Pers.	Poaceae	0	2	–
Digitaria spp.	Poaceae	0	2	–
Echinochloa crus-galli (L.) P. Beauv.	Poaceae	1	1	+
Eragrostis inamoena K. Schuhm.	Poaceae	0	3	+
Ischaemum sp.	Poaceae	0	1	+
Rottboellia cochinchinensis (Lour.) W. D. Clayton	Poaceae	0	2	+
Sacciolepis indica (L.) A. Chase	Poaceae	0	1	+
Cyperaceae				
A. Emersed, rooting				
Cyperus difformis L.	Cyperaceae	1	3	+
Cyperus halpan L.	Cyperaceae	1	3	+
Cyperus pulcherrimus Willd. ex Kunth.	Cyperaceae	1	3	+
Eleocharis spp.	Cyperaceae	3	2	–
Eriocaulon spp.	Eriocaulaceae	1	2	+
Fimbristylis acuminata (L.) Vahl	Cyperaceae	1	1	+
Fimbristylls miliacea (L.) Vahl	Cyperaceae	1	3	+
Fuirena ciliaris (L.) Roxb.	Cyperaceae	1	2	+
Scirpus juncoides Roxb.	Cyperaceae	1	1	+
Scirpus sp.	Cyperaceae	1	1	+
B. Littoral				
Cyperus iria L.	Cyperaceae	0	1	+
Cyperus rotundus L.	Cyperaceae	0	2	–
Fimbristylis cymosa R. Br.	Cyperaceae	0	1	+
FImbristylis dichotoma (L.) Vahl	Cyperaceae	0	1	+
Broad-leaved weeds				
A. Floating				
Eichhornia crassipes (Mart.) Solms	Pontederiaceae	3	1	–
Neptunia oleracea Lour.	Fabaceae	3	1	+
B. Creeping				
Ipomoea aquatica Forssk.	Convolvulaceae	3	2	+
Ludwigia adscendens (L.) Hara	Onagraceae	3	3	+
C. Emersed, rooting				
Ammannia baccifera L.	Lythraceae	2	3	+
Hydrolea zeylanica (L.) Vahl	Hydrophyllaceae	2	2	–
Linnophila aromatica (Lam.) Merr.	Scrophulariaceae	2	1	–
Limnophila geoffrayi Bonati	Scrophulariaceae	2	1	–
Limnophila heterophylla (Roxb) Benth.	Scrophulariaceae	2	1	–
Lindernia antipoda (L.) Alston	Scrophulariaceae	1	3	+
Lindernia crustacea (L.) F. Muell.	Scrophulariaceae	1	3	+

continued on next page

Table continued.

Scientific name	Family	Water depth (cm) at which species is most common[a]	Importance[b]	Flowering during study[c]
Ludwigia hyssopifolia (G. Don) Exell	Onagraceae	1	3	+
Monochoria vaginalis (Burm. f.) Presl.	Pontederiaceae	3	3	+
Rotala indica (Willd) Koehne	Lythraceae	2	3	-
D. Littoral				
Alternanthera sessilis (L.) R. Br. ex Roem. & Schult.	Amaranthaceae	1	1	+
Hedyotis racemosa Lam.	Rublaceae	1	2	+
Hygrophila phlomoides Nees	Acanthaceae	0	2	–
Limnocharis flava (L.) Buch.	Butomaceae	3	1	+
Lindernia pusilla (Willd.) Bold.	Scrophulariaceae	0	3	+
Miscellaneous weeds				
A. Floating				
Azolla pinnata R. Br.	Azollaceae	3	1	?
Lemna minor L.	Lemnaceae	3	1	?
Pistia stratiotes L.	Araceae	3	1	?
Salvinia cucullata Roxb. ex Bory	Salvinlaceae	3	1	?
Wolffia arrhiza (L.) Wimm.	Lemnaceae	3	1	?
B. Submerged				
Chara zeylanica Kl. ex Willd.	Characeae	3	1	?
Nitella sp.	Characeae	3	1	?
Nitellopsis sp.	Characeae	3	1	?
Oscillatoria spp.	Oscillatorlaceae	3	1	?
Spirogyra spp.	Zygnemataceae	3	1	?
Urticularia aurea Lour.	Lentibunaceae	3	1	+
C. Emersed, rooted				
Marsilea minuta L.	Marsileaceae	2	3	?
Urticularia bifida L.	Lentiburiaceae	1	1	+
Xyris indica L.	Xyridaceae	1	3	+

[a] 3 = deep (>10 cm), 2 = medium (5-10 cm), 1 = shallow (0-5 cm), and 0 = dry. [b] 3 = primary weed species, 2 = secondary weed species, 1 = incidental weed species. [c] + = flowering observed, – = flowering not observed, ? = not detected on a macroscopic scale.

Weeds in rice in Madagascar

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We surveyed several rice areas of Madagascar to determine the most important weed species associated with rice. Field visits and farmer interviews were conducted in the Middle West (Kianjasoa, Mahasolo, and Tsiroanomandidy) in Nov 1990, and in the Central Highland (Manjakandriana, Sambaina, Ambanitsena, and Miarina) and the North West (Tsararano, Mampikony, and Port Berge) in May 1992.

Approximately 50 ricefields in the Middle West, 30 in the North West, and 20 in the Central Highland were examined and major weeds were identified and collected for a herbarium. Where possible, we visited fields in the company of farmers. Otherwise, weeds were collected and brought to farmers for them to identify with their local names and to rank according to importance. Final ranking was determined by the number of times each species was mentioned as most important, second most important, and so on. Unidentified weeds that farmers considered important were taken to the Departement Flore du Parc Botanique et Zoologique de Tsambazaza in Antananarivo for identification.

In the Middle West, all farmers ranked *Strip asiatica* as the most troublesome weed because it is difficult to control and causes serious crop damage even before emergence (see table). Farmers estimated that it caused 60-100% yield loss. *Rorttboellia cochinchinensis* was considered the second most important weed species because of its abundance and high seed production.

Sedges, particularly *Cyprus difformis, Cyprus iria, Fimbristylis miliacea,* and *Eleocharis* spp., were considered the most problematic weed species in Tsararano, Marovoay, because of their abundance. Farmers also considered *Cynodon dactylon* to be a problem, but only on bunds.

Farmers in Mampikony ranked *Aeschynomene indica* as the worst weed because of its abundance and vigorous growth. The weed residues left in the

Major weed species in several rice areas as ranked in importance by farmers. Madagascar, Nov 1990 and May 1992.

Weed species	Local name
Middle West[a] (Upland rice ecosystem)	
Striga asiatica	Arema
Rottboellia cochinchinensis	Tsaganday
Acanthospermum hispidum	Bakakely
Urena lobata	Kerijy
Tridax procumbens	Angamay Mahapady
Digitaria setigera	Marorantsana Fandrodahy
North West (Rainfed lowland rice ecosystem)	
Tsararano, Marovoay	
Cyperus difformis	Somotrosy
Cyperus iria	Chipisoka
Fimbristylis miliacea	Sombengy
Ludwigia adscendens	Volondrano
Paspalum distichum	Menavavy
Cynodon dactylon	Fandotrarana
Mampikony	
Aeschynomene indica	Renaud
Ludwigia octovalvis	Ranjamena
Brachiaria distachya	Tergal
Ischaemum rugosum	Tsikalabanga Tainbiriky
Port Berge	
Sphenoclea zeylanica	Bomata
Fimbristylis miliacea	Sombengy
Aeschynomene indica	Renaud
Paspalum distichum	Menavavy
Cyperus difformis	Somotrosy
Cyperus rotundus	Tsimitamita
Echinochloa colona	Tsivakimpanoto Ampody Tsifaryfary
Ischaemum rugosum	Tsikalabanga Tainbiriky
Central Highland[b] (Rainfed lowland rice ecosystem)	
Potamogeton fluitans	Valatendro
Scirpus juncoides	Ahidratsy
Leersia hexandra	Tsiriry
Echinochloa colona[c]	Tsivakimpanoto Ampody Tsifaryfary
Echinochloa crus-galli[d]	Karangimena

[a] Villages of Kianjasoa, Mahasolo, and Tsiroanomandidy. [b] Villages of Manjakandriana, Sambaina, Ambanitsena, and Miarina. [c] Ranked fourth in Miarina, Central Highland. [d] Ranked fourth in Sambaina, Central Highland, and fifth in Miarina, Central Highland.

field after rice harvest were a problem during land preparation.

In Port Berge, *Sphenochlea zeylanica* was the major weed problem. Farmers considered it the most difficult to control because of its abundant growth.

Farmers in three villages of the Central Highland considered *Potamogeton fluitans* to be their worst weed. Control of *P. fluitans* requires large amounts of hand weeding. Few farmers thought that the weed could be controlled by plowing and harrowing after rice harvest and subsequent drying during the dry season.

It was observed that farmers considered a weed important based on abundance in the field and difficulty of control. ■

Weed - fish interactions at different water levels in irrigated ricefields in Northeast Thailand

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We conducted a field trial on eight farms in the Lam Dom Noi irrigated area in Ubon Province, Northeast Thailand, in the 1987 dry season. Each farmer provided two rice - fish fields and two control fields that were 0.1-0.5 ha. Rice crops were transplanted within a 14-d period. Management was left to the farmers.

Fish were stocked at densities of 60-200/ha. A mixture of *Cypirinus carpio* L. (common carp), *Tilapia nilotica* L. (× *mossambica*) (Nile tilapia), and *Puntius gonionotus* Bleeker (Thai silver barb) was used. The fish weighed 10-100 g.

The water depth was read at 2-d intervals from transplanting until weed density measurements at 40 d after transplanting (DT). We studied 6- or 12-m^2 sample plots, depending on field size, in each field. Plot area was reduced to 0.25 m^2 where plots had more than 1,000 plants/m^2. Weed plots were grouped according to average water depth. Weeds/plot were averaged for each weed group,

Number of weeds (+ SE) in different weed groups at 6 water depths. Ubon Province, Northeast Thailand, 1987 dry season.

Item	Weeds (no.) + SE					
	3 cm	5 cm	7 cm	9 cm	11 cm	13 cm
Sedges						
Rice-fish	138 + 44.2	106 + 28.1	81 +59.6	60 +19.6	20 +6.5	15 +12.5
Control	184 + 47.9	146 + 36.8	63 +19.5	28 + 8.6	7 +3.0	3 + 2.2
Broad-leaved weeds (excluding *M. vaginalis* and *M. crenata*)						
Rice-fish	176 + 49.6	60 + 20.9	25 +11.0	170 +29.2	65 +42.3	3 + 2.3
Control	170 + 94.6	124 + 23.5	100 +32.6	79 +40.9	9 +4.2	5 + 2.1
Grasses						
Rice-fish	3.9 + 1.92	2.7 + 0.68	2.5+ 0.87	1.4+ 0.60	0.6 +0.60	0.0+ 0.0
Control	2.1 + 0.79	1.2 + 0.46	0.6+ 0.38	0.8+ 0.22	0.2 +0.20	1.8+ 0.47
Monochoria vaginalis						
Rice-fish	10.5 + 4.37	14.6 + 4.12	11.9+ 6.19	16.3 + 4.88	18.1 + 6.50	14.6 + 12.3
Control	9.8 + 5.65	7.4 + 1.74	10.8+ 3.10	12.9 + 3.86	3.8 + 1.28	2.0 + 1.41
Marsilea crenata						
Rice-fish	0.0 + 0.00	0.0 + 0.00	3.4+ 1.93	20.7 + 7.09	6.2 +5.55	11.4+ 7.28
Control	29.6 + 14.3	11.8 + 5.87	5.7+ 2.76	11.5 + 3.85	11.8 + 7.71	0.0+ 0.00
Area (%) covered by non-algae weeds						
Rice-fish	7.0 + 1.60	3.3 + 0.68	3.4+ 0.67	5.9 + 1.41	3.3 + 1.19	2.4+ 1.27
Control	5.0 + 2.64	4.3 + 2.45	3.1+ 0.92	2.2 + 0.88	0.4 + 0.24	0.0 + 0.00
Plots (no.)						
Rice-fish	13	26	10	21	10	8
Control	11	20	19	20	5	4

treatment, and water depth class.

In control fields, sedges, broad-leaved weeds, and grasses were markedly reduced as water level increased (see table). Fish modified this general pattern by reducing sedges and broad-leaved weeds at low water depth (about 5 cm) when compared with the control. In contrast, fish enhanced weed growth at higher water depths. Similar results were obtained for *Marsilea crenata* and the percentage of area covered by non-algae weeds. Results for grasses and *Monochoria vaginalis* are less conclusive, but show the same trend. Algae were reduced at 2. 6. 10, and 14 cm of water.

At 3 cm, the average number of uprooted sedges and broad-leaved weeds was 7.3/m^2 in rice - fish fields compared with 0.5/m^2 in controls; at 5 cm, it was 2.6/m^2 for rice - fish fields compared with 0.3/m^2 in controls. The results indicate that fish prefer shallow areas in ricefields as a feeding place, possibly because food is more abundant there.

Fish affect ricefields in two major ways: their feeding activities reduce weed growth, and the accelerated turnover of organic matter enhances weed development. These feeding and fertilizing effects counteract each other. Water regime markedly influences the degree to which each effect operates. ■

Farming systems

Rice - wheat yields as affected by tillage and planting date

N. R. Das, N. N. Mukherjee, and S. Sen, Agronomy Department, Faculty of Agriculture, Bidhan Chandra Krishi Viswavidyalaya, Kalyani 741235, West Bengal, India

We studied wheat yield productivity after the main crop of transplanted wet season (TWS) rice in West Bengal. Wheat was planted under irrigated conditions using different planting dates and numbers of tillages at the Agricultural University Farm during 1988-89 and 1989-90.

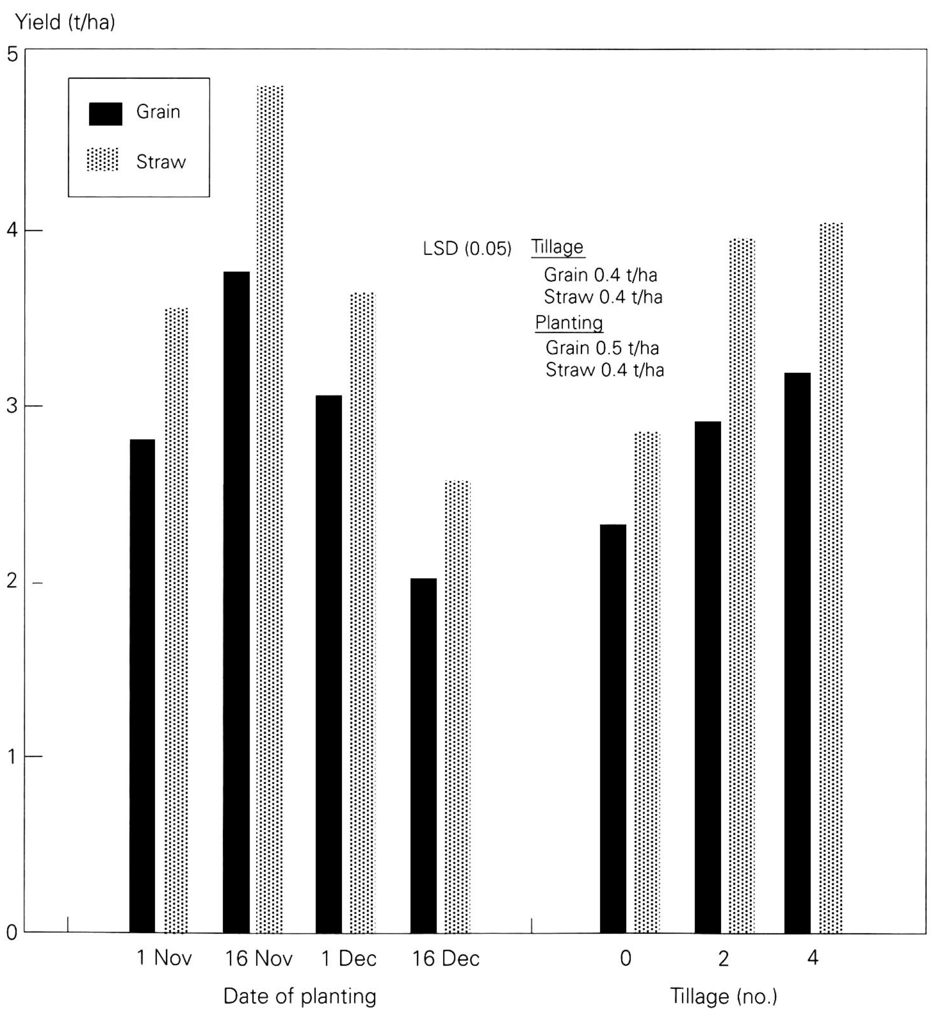
The rice - wheat rotation was laid out in a split-plot design with four replications, with tillage in main plots and planting date in 7.5- × 2.5-m subplots. Soil is medium fertile with pH 6.8,0.061% total N, 7.4 kg available P/ha, and 141 kg available K/ha.

After the harvest of TWS IR36 rice, which yielded an average of 4.1 t grain/ha, fields were fertilized with 100-22-41.5 kg NPK/ha at the end of Oct. UP262 wheat was sown at 100 kg seed/ha in lines spaced at 25 cm on 1 Nov, 16 Nov, 1 Dec, and 16 Dec. Three tillage levels were used: zero - without plowing, but furrows for planting seed were made with hand tine; minimal - two plowings; and conventional - four plowings by bullock. Fertilizer was broadcast at sowing: 100 kg N, 22 kg P, and 4 1.5 kg K/ha from urea, single superphosphate, and muriate of potash, respectively. The wheat crops were harvested during the 1 st, 2d, and 3d wk of Mar for lst, 2d, and 3d and 4th planting dates, respectively.

The maximum grain yield of wheat was obtained from the 16 Nov planting and the least from the 16 Dec planting. Wheat straw yields followed a similar trend (see figure).

Both wheat grain and Straw yield increased with increased tillages, though yields under minimal tillage did not vary much compared with those under conventional tillage (see figure). Mid-Nov planting with either minimal or conventional tillage gave the maximum wheat grain and straw yields after TWS rice (see figure). ■

Grain and straw yield of wheat as affected by planting date and number of tillages after transplanted wet rice. West Bengal, India, 1988-89, 1989-90 winter.



Socioeconomic impact

Price difference of rice grades: case of parboiled and raw rice

M. Wileratne and T. L. L. Chandrakumara, Agricultural Economics Department, Faculty of Agriculture, University of Ruhuna, Kamburupitiya, Sri Lanka

We investigated the price differences between two major grades of rice: parboiled and raw. We collected retail rice prices during 1990 in the important rice-producing districts in Sri Lanka of Hambantota and Polonnaruwa. Monthly average prices were computed (see table).

Prices of parboiled rice were comparatively higher in Hambantota whereas prices of raw rice were higher in Polonnaruwa. Hambantota consumers prefer raw rice to parboiled rice. Producers are disinclined to use parboiling techniques. Although this district is regarded as a surplus area, parboiled rice is not supplied through the marketing system.

Consumers in Polonnaruwa district prefer parboiled rice, so producers tend to use parboiling techniques. Raw rice production is minimal. This district is also regarded as a surplus area. Even though the demand is less, the comparative price of raw rice is higher than that of parboiled rice.

The study reveals that the rice marketing system in each district is geared to purchase the surplus of the main rice grade produced there, but is not concerned about the supply of the other grades preferred by district consumers. ■

Price difference between parboiled and raw rice, Hambantota and Polonnaruwa districts, Sri Lanka, 1990.

Month	Difference ($/1 000 kg)			
	Hambantota		Polonnaruwa	
	Parboiled	Raw	Parboiled	Raw
Jan	305.47	259.28	228.09	254.04
Feb	294.52	227.61	230.09	273.80
Mar	270.71	210.23	234.04	263.80
Apr	259.76	221.66	220.23	241.90
May	255.95	219.04	226.42	230.47
Jun	286.71	283.80	217.14	240.00
Jul	289.52	279.76	219.04	252.38
Aug	289.61	284.52	273.80	273.80
Sep	293.00	290.46	283.09	286.09
Oct	299.61	297.61	297.61	309.52
Nov	328.57	318.33	306.42	313.57
Dec	349.28	343.33	321.42	345.23

Announcements

Rice dateline[a]

15-17 Mar	France-IRRI Workplan Meeting. IRRI. Contact K. Lampe. IRRI.
1-2 Apr	ICAR-IRRI Workplan Meeting. New Delhi, India. Contact G.L. Denning/F.A. Bernardo, IRRI.
5-6 Apr	BRRI-IRRI Collaborative Research and Training Workplan Review. Bangladesh. Contact J.L. McIntosh/G.L. Denning/F.A. Bernardo, IRRI.
8-13 Apr	Bhutan-IRRI Project Planning Meeting. Bhutan. Contact G.L. Denning, IRRI.
12-16 Apr	Second Workshop on Rice Supply and Demand Project. IRRI. Contact M. Hossain, IRRI.
18-20 May	Upland Rice Consortium Steering Committee Meeting. IRRI. Contact M. Arraudeau, IRRI.
31 May-25 Jun	Management of Training Centers Training Course. Bangkok, Thailand. Contact Asian Institute of Technology. GPO Box 2754, Bangkok 10501, Thailand.
1-6 Jun	International Network on Soil Fertility and Sustainable Rice Farming (INSURF) Site Visit and Planning Meeting. China. Contact E.L. Aragon, IRRI.

[a]Address for all IRRI contacts: International Rice Research Institute, P.O. Box 933, Manila 1099, Philippines. Fax: 632-2-8 18-2087

CIAT releases video

The International Center for Tropical Agriculture (CIAT) announces the release of a new video, *A fragile paradise: environmental challenge of tropical America.* Two sections of the video focus on rice research in Latin America. The 27 min 45 s video is available in English and Spanish.

Individuals may order VHS or Beta copies, in NTSC or PAL, for US$21 (includes air mail postage) from the Communications Unit, CIAT, A.A. 6713, Cali, Colombia. Fax: 57-23-647243. The video is also available for television broadcast. ■

Call for news

Individuals, institutions, and organizations are invited to tell readers about upcoming events in rice research or related fields for the Rice Dateline. Send announcements to the Editor, IRRN, International Rice Research Institute. P.O. Box 933, Manila 1099. Philippines. ■

IRRI announces group training courses for 1993

The IRRI Training Center is offering a variety of courses on rice-related subjects in 1993. Courses are held at IRRI headquarters unless otherwise noted. For information about a course, contact the Head, Training Center, International Rice Research Institute, P.O. Box 933, Manila 1099, Philippines. Fax: 63-2-818-2087. Space is available for trainees in the following courses:

Date	Course	Trainees
26 Apr-4 Jun	Engineering for Rice Agriculture	39
7 Jun-30 Jul	Weed Control (Direct Seeded Rice)	9
19 Jul-10 Sep	Integrated Pest Management	25
23 Aug-1 Oct	Irrigation and Water Management	25
4 Oct-26 Nov	Rice Production Research, Thailand	25
4 Oct-26 Nov	Rice Biotechnology[a]	15
4 Oct-5 Nov	Rice Seed Health	8
15-26 Nov	Gender Analysis[a]	25
15-26 Nov	Research Management[a]	15

[a] Special project-funded courses.

Effective irrigation management course

Effective Irrigation Management course will be held at the University of Southampton, 27 Sep-15 Oct 1993. The intensive course is for professionals involved in management and performance assessment of irrigation and related water resources schemes in developing countries. The Institute of Irrigation Studies at the University of Southampton and HR Wallingford are sponsoring the course. Applications must be received by 25 Jun.

For information, contact the Course Administrator, Effective Irrigation Management Short Course, Institute of Irrigation Studies, The University, Southampton SO9 5NH, United Kingdom. Tel: 0703-593728, Telex: 47661 (a/b sotonu g), Fax: 0703-677519. ■

First Asian conference of agricultural economists

The Asian Society of Agricultural Economists (ASAE), a newly created academic forum that focuses on agricultural and rural issues in Asia, will hold the First Asian Conference of Agricultural Economists in Seoul, Korea, 9- 13 Aug 1993. The conference theme is agricultural trade reform and the future of Asian agriculture and agribusiness.

Economists are invited to join the organization and to participate in the conference. Write Dr. Yang Boo Choe, Chairman, Executive Committee, ASAE, c/o Korea Rural Economic Institute, 4-102 Hoegi-dong, Dongdaemun-ku, Seoul 130-050, Korea. ■

Irrigation and drainage congress

The 15th Congress of the International Commission on Irrigation and Drainage (ICID) will be held in The Hague, The Netherlands, 30 Aug - 11 Sep 1993. Water management in the next century is the theme. The 7th International Exhibition on Irrigation, Drainage, and Flood Control takes place during the congress.

For information contact Congress Secretariat, Holland Organizing Centre, 16 Lange Voorhout, 2514EE The Hague, The Netherlands. Tel: 31 70 3657850, Telex: 20010, Fax: 31 70 3614846. ■

AIT course for training managers

The Asian Institute of Technology (AIT) in Bangkok, Thailand, will sponsor the 7th Management of Training Centers course from 3 1 May to 25 Jun 1993. The course will focus on strategic planning; organization, staffing, and administration of the training function; and the role of training in organizational development. For more information, write the Admissions Officer, AIT, GPO Box 2754, Bangkok 10501, Thailand. ■

New IRRI publications

Sharing responsibilities, IRRI 1991 -1992
1991 program report
A farmer's primer on growing rice (rev. ed.), by B. S. Vergara
Insect pests of rice, by M. Pathak and Z. Khan
Nodulation and nitrogen fixation in rice: potential and prospects, ed. by G. S. Khush and J. Bennett
Consumer demand for rice grain quality, ed. by L. J. Unnevehr, B. Duff, and B.O. Juliano

For ordering information, write to Division PR, Information Center, IRRI, P.O. Box 933, Manila 1099, Philippines. ■

New publication

The grass genera of the world. L. Watson and M. J. Dallwitz.

Modern taxonomic treatments of the grass family (Poaceae, Gramineae) recognize about 10,000 species and as many as 778 genera. This book provides detailed descriptions of these genera and is considered to be a definitive reference.

To order, contact CAB International Wallingford, Oxon OX10 8DE, UK. Fax: 0491 33508. ■

New series: *The literature of the agricultural sciences*

Cornell University Press announces the initiation of *The literature of the agricultura1 sciences* series. The seven-volume series explores in depth the literature of the primary fields of the agricultural sciences.

The series uses citation analysis and other bibliometric techniques to identify primary journals, report series, and monographs of current importance to both industrial countries and developing countries.

A set of compact disks with the full texts of the monographs and the last 5 yr of the journals is planned for use in developing countries.

Agricultura1 economics and rural sociology is the first in the series. W. C. Olsen is editor, M. A. Bellamy and B. F. Stanton are contributors. The book analyzes the trends in the published literature of agricultural economics and rural sociology during the past 50 yr.

The literature of agricultural engineering is the second in the series. C. W. Hall and W. C. Olsen are the editors. It analyzes the trends in published literature of agricultural engineering during the past century, with emphasis on the past 40 yr.

To order, or for more information, contact Cornell University Press, 124 Roberts Place, P.O. Box 250, Ithaca, NY 14851-0250, USA. ■

Tropical pest management becomes *International journal of pest management*

During the last decade, *Tropical pest management* has focused on the field of pest management in the tropics. But as the distinction between pest management in tropical and temperate areas becomes blurred and common techniques and approaches are employed in both areas, there are no longer grounds for continuing this separation. Therefore, the journal became the *International journal of pest management* (IJPM) in Jan 1993. It will deal with pest management, research and practice worldwide.

For more information, write to Drs. Neil Kidd and Mark Jervis, School of Pure and Applied Biology, University of Wales College of Cardiff, P.O. Box 915, Cardiff CF1 3TL, UK. Tel: +44 (0)222 874000. Fax: +44 (0)222 874305.

Genetic evaluation and utilization training course

INGER-Africa will hold a training course on genetic evaluation and utilization of rainfed lowland rice from 3 May to 4 Jun 1993 at the Sokoine University of Agriculture, Morogoro, Tanzania. The course is designed for research technicians or junior research officers of Eastern, Central, and Southern Africa (ECSA) who are involved in rice improvement research. The German Agency for Technical Cooperation is funding the course.

To obtain application forms and details, contact

Dr. Krishna Alluri
IRRI liaison scientist and INGER-Africa coordinator
IITA, Ibadan
Nigeria

Rice literature update reprint service

Photocopies of items listed in the Rice literature update are available from the IRRI Library and Documentation Service. Reprints of original documents (not to exceed 50 pages) are supplied free to rice scientists of developing countries. Rice scientists elsewhere are charged US$0.20 for each page or part of a page copied, plus postage. Payment should be in check or money order, payable to Library and Documentation Service, IRRI.

Address requests to Library and Documentation Service, IRRI, P.O. Box 933, Manila 1099, Philippines. Fax: (63-2) 817-8470, electronic mail: IN%" postmaster@IRRI.CGNET.COM"
■

News about research collaboration

IRRI, CIMMYT, NARS investigate yield decline in rice - wheat systems

The yields of rice - wheat systems in South Asia have been steadily declining for 15 yr. The cumulative drop ranges from 10 to 20%, says T. Woodhead, IRRI international coordinator for rice - wheat research.

Rice - wheat cropping in Bangladesh, India, Nepal, and Pakistan increased tenfold in the past 30 yr as new varieties produced higher yields and incomes for farmers. Almost a billion people in South Asia rely on rice and wheat for most of their daily energy.

"In recent years, the rate of yield increase was smaller despite larger inputs of fertilizer, pesticide, and water," says Woodhead.

Scientists of IRRI, the International Center for Maize and Wheat Improvement (CIMMYT) in Mexico, and the national agricultural research systems (NARS) of South Asian countries are studying the yield decline problem. From their work, they expect that farmers can learn how to sustain the productivity and profitability of their rice - wheat rotation. ■

Most of the world's improved rices carry IRRI germplasm

"National rice breeding programs are doing a remarkable amount of borrowing of germplasm," said R. E. Evenson, professor of' economics at the Economic Growth Center in Yale University, USA. "In many cases, IRRI supplied the parents, grandparents, ancestors, and even varieties for their programs."

Evenson and D. Gollin, a graduate student, studied the impact of IRRI's International Network for the Genetic Evaluation of Rice (INGER) on the worldwide exchange and evaluation of promising rice germplasm.

Researchers often take promising lines bred by other programs and use these as parents. Nearly three-quarters of all modern rice varieties have at least one borrowed parent.

INGER is the primary source of germplasm borrowings. "Since 1981, more than half of the globally released varieties have been borrowed through INGER or bred from parents borrowed from the network." Evenson said.

"Of 1,709 modern varieties released by rice breeders since the mid-1960s, 390 are varieties that were borrowed from a different country or breeding program," Evenson reported. IRRI was the largest source of borrowed varieties. The share of nationally released varieties with IRRI ancestors has increased from 54% in 1965-74 to 72% in 1981-90. ■

Boro rice gains popularity in Bangladesh

"Bangladesh farmers are tripling and quadrupling their yields by switching to boro rice from the floating varieties that their ancestors have grown for centuries," reports T. Kupkanchanakul of the Huntra Rice Experiment Station in Thailand. About 800,000 ha have been planted to the irrigated winter rice crop.

Successful boro cropping in Bangladesh results from the availability of short-duration, cold-tolerant varieties and the implementation of major infrastructure modifications, including land leveling, construction of bunds and ditches, and installation of shallow- and deep-well pumps.

The move to boro promises to increase local productivity, but Kupkanchanakul adds a warning. "The rate of change away from floating rice will depend on the availability of irrigation water, soil structure, management of the soil and the ecology in the areas, marketing demands, and on how effectively deepwater rice research can boost floating rice yields."

Thai scientists lead the program to improve rice yields in the deepwater rice ecosystem. ■

IRRI in FAO Inter-Regional Cooperative Research Network on Rice

IRRI was accepted as a permanent observer in the FAO Inter-Regional Cooperative Research Network on Rice during the Oct 1992 meeting in Giza, Egypt. IRRI will be actively involved in the crop production working group and in the network's consultation meetings.

It was proposed at the meeting that Egypt provide japonica indica hybridization service to the network. Other items discussed included INGER assembling a nontropical nursery consisting of lines of early-maturing japonica, indica/japonica, and early indicas with a demonstrated japonica crossing potential; investigating sprinkler-irrigated rice; and leaving out indica lines in materials being distributed within the network because the lines do not readily flower or mature in the area. ■

Maximizing resource allocation: CIAT, IRRI set joint research

IRRI and the International Center for Tropical Agriculture (CIAT) in Colombia are reinforcing their collaboration. Scientists of both centers met in Nov 1992 to plan rice research that maximizes their resources by minimizing duplication of rice research efforts in areas of common interest.

"There is a vast difference between Latin American and Asian farmers," says R. S. Zeigler, IRRI Rainfed Lowland Rice Research Program leader. "Latin American farmers typically own large land holdings, grow rice to sell, and have a range of technical resources and alternatives to apply to their crops. The typical Asian fanners served by IRRI have small land holdings, grow rice to eat, and are resource-poor."

The two centers will collaborate to improve upland rice varieties, primarily through the exchange of breeding lines. They will also develop plant types that tolerate stress, use fertilizer efficiently, and compete effectively with weeds. IRRI will support CIAT to define research on the role of rice in tropical forest margin ecosystem. "This marks a shift as centers are collaborating in research that addresses strategic issues of global relevance, thus capitalizing on the uniqueness of their regions and the strengths of their staff," Zeigler observed. ■

ADB funds IRRI-proposed biotechnology network

The Asian Development Bank (ADB) has granted US$900,000 for IRRI to train Asian rice biotechnologists. The grant is for the first three years of operation of an Asian Rice Biotechnology Network that will build the capability of developing countries to use biotechnology to improve rice. IRRI's active biotechnology program and research links in Asia make it the most suitable institution to launch this effort.

The network will start with India. Indonesia, and the Philippines. "These countries have strong rice breeding programs, some facilities and staff that are already using biotechnology, and are committed to developing biotechnology capabilities for rice improvement," says J. Bennett, IRRI's senior molecular biologist. Other developing countries will be added at the appropriate times.

IRRI is coordinating the network, establishing a biotechnology training laboratory, and supporting national agricultural research systems with equipment, supplies, and on-site technical assistance. Initially, the network will concentrate on training teams of scientists from each participating country. It will undertake collaborative research to develop rices with resistance to three of the major rice diseases: rice blast, tungro, and bacterial blight. ■

Erratum

A *method to synthesize the aroma of certain varieties of fragrant Indian rice,* by M. P. Sarkar et al, 17 (5) (Oct 1992), 9.

M. P. Sarkar and N. D. Sarkar should read: M. Poddar Sarkar and N. De Sarkar. In line 4 of paragraph 4, replace thus with then. ■

RICE PRODUCTION TRAINING MODULE

Weed Identification in Lowland Rice (RP4-14)

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1990 edition. 80 colored slides, one cassette tape, and two self-learning and self-test booklets (10.5 x 21.3 cm). Paperback. HDC US$50.00, LDC US$40.00 airmail postage included.

Weed identification in lowland rice describes some common weeds in lowland areas. Weeds are classified into 3 categories and also according to growth duration.

The lesson lasts for 18 minutes. It will enable the user to

- define a weed and describe how it affects crop growth;
- classify weeds into grasses, sedges, and broadleaf weeds;
- classify weeds according to their growth duration; and
- identify and describe the most common weeds in lowland rice.

Knowledge of the common weed species in lowland rice areas is essential in rice production. Accurate weed identification is necessary for weed control because weeds differ in their response to control practices.

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ISBN 071-22-0005-1

DEEPWATER AND FLOOD TOLERANCE

Rice in Deepwater

DAVID CATLING

1993. 542 pages. 17.78 x 25.40 cm. Paperback. HDC send orders to The Macmillan Press Ltd., 4 Little Essex Street, London WC2R 3LF, England; LDC US$29.25 plus airmail (US$18.00) or surface (US$2.50) postage.

Deepwater rice sustains millions of subsistence farmers in South and Southeast Asia and West Africa. During the monsoon, only deepwater rice can be grown on the fertile plains and deltas of several of the world's great rivers. But the crop was largely overlooked in the first effort to expand production of high-yielding varieties in the favorable environments.

The importance of deepwater rice began to merge in the 1970s. Now the pace of research has quickened. Dr. David Catling, author of this basic text, has been one of the leaders in this development.

The emphasis in the book on all aspects of the deepwater rice agroecosystem — including the human environment, and the preference given to results of field studies over laboratory and greenhouse work — will be especially appreciated by current and future researchers, and by agricultural administrators and planners.

This book is published by Macmillan Press Ltd. with IRRI cooperation. IRRI took a limited stock to distribute to developing countries.

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RICE PRODUCTION TRAINING MODULE

Morphology of the Rice Plant (RP4-01)

INTERNATIONAL RICE RESEARCH INSTITUTE

1987 edition. 79 colored slides, one cassette tape, and two self-learning and self-test booklets (10.5 x 21.3 cm). Paperback. HDC US$50.00, LDC US$40.00 airmail postage included.

Morphology of the rice plant introduces the terms associated with the different parts of the rice plant.

The lesson lasts for about 20 minutes. It will enable the user to identify and describe the morphological characters or parts of the following:

- the germinating rice seed and seedling;
- a rice tiller — roots, culm and leaves;
- the rice inflorescence or panicle.

Understanding of standard terms describing rice morphology is important to effectively communicate with other scientists about the rice plant.

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Growth Stages of the Rice Plant (RP4-02)

INTERNATIONAL RICE RESEARCH INSTITUTE

1988 edition. 80 colored slides, one cassette tape, and two self-learning and self-test booklets (10.5 x 21.3 cm). Paperback. HDC US$50.00, LDC US$40.00 airmail postage included.

Growth stages of the rice plant relates and describes the various stages of growth of the rice plant from seed to maturity.

The lesson lasts for about 26 minutes. It will enable the user to

- recognize the 3 basic growth phases of the rice plant and the stages of development in each phase;
- identify the growth stages of a rice plant according to a 0-9 numerical scale (Each number in the scale corresponds to a specific growth stage.); and
- explain the specific physical changes in a growing rice plant.

It is essential to know the stages of the growth cycle of rice so that appropriate management practices can be employed at the right time. The effectiveness of management practices, such as fertilization and irrigation, and weed, pathogen, and insect control, largely depends on correct timing.

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RICE PRODUCTION TRAINING MODULE

Land Preparation (RP4-06)

INTERNATIONAL RICE RESEARCH INSTITUTE

1989 edition. 78 colored slides, one cassette tape, and two self-learning and self-test booklets (10.5 x 21.3 cm). Paperback. HDC US$50.00, LDC US$40.00 airmail postage included.

Land preparation explains the process, purpose, and the operations involved in land preparation in rice.

The lesson lasts for about 27 minutes. It will enable the user to

- explain the reasons for land preparation and tillage;
- describe the operations involved in primary and secondary tillage and the implements used in each operation;
- describe 2 tillage methods of preparing ricelands; and
- compare the advantages and disadvantages of animal and tractor power.

Land preparation and the associated tillage practices influence growth and yield of rice. A well-prepared field provides favorable soil environment for plant growth.

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RICE PRODUCTION TRAINING MODULE

Methods of Growing Rice (RP4-07)

INTERNATIONAL RICE RESEARCH INSTITUTE

1989 edition. 80 colored slides, one cassette tape, and two self-learning and self-test booklets (10.5 x 21.3 cm). Paperback. HDC US$50.00, LDC US$40.00 airmail postage included.

Methods of growing rice discusses the 2 primary methods of growing rice: direct seeding and transplanting.

The lesson lasts for about 30 minutes. It will enable the user to

- describe the 2 general methods of growing rice and the techniques used for each method;
- discuss requirements, advantages, and disadvantages of each method;
- describe 3 methods of raising seedlings for transplanting and list the advantages and disadvantages of each; and
- explain the importance of and the factors affecting proper spacing in transplanted rice.

Methods of growing rice and the associated cultural practices influence equipment, input and labor requirements, management practices, and, ultimately, increases in grain yield.

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RICE PRODUCTION TRAINING MODULE

Soil Fertility (RP4-10)

INTERNATIONAL RICE RESEARCH INSTITUTE

1988 edition. 78 colored slides, one cassette tape, and two self-learning and self-test booklets (10.5 x 21.3 cm). Paperback. HDC US$50.00, LDC US$40.00 airmail postage included.

Soil fertility deals with essential nutrient elements, ways of nutrient loss, and methods of evaluating soil fertility.

The lesson lasts for about 25 minutes. It will enable the user to

- define soil fertility and relate it to soil productivity;
- recognize the 16 essential nutrient elements and classify them into macroelements or microelements;
- discuss the fate of the essential elements in the soil with emphasis on N, P, and K; and
- discuss 4 methods of evaluating soil fertility.

Soil fertility is one of the many factors that contribute to soil productivity. An adequate evaluation of soil fertility and a properly formulated fertilizer management program can improve productivity of the soil.

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