International Rice Research Notes

The International Rice Research Notes (IRRN) expedites communication among scientists concerned with the development of improved technology for rice and rice-based systems.

The IRRN is a mechanism to help scientists keep each other informed of current rice research findings. The concise scientific notes are meant to encourage rice scientists to communicate with one another to obtain details on the research reported.

The IRRN is published three times a year in April, August, and December by the International Rice Research Institute.

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Evaluating IRRN and its audiences

In a 1990 study, IRRI found that survey respondents, consisting of individual and institutional subscribers of the International Rice Research Notes (IRRN) as well as IRRI scientists and researchers, considered IRRN to be the most useful among IRRI publications.

Considering this finding and the perceived need to improve the IRRN and make it a more useful publication, IRRI’s Communication and Publications Services (CPS) is conducting a readership survey to get more concrete information about IRRN audiences and their information needs and preferences. The study is intended to identify the factors that make IRRN a successful and useful publication, and also to pinpoint aspects where it can be improved.

Attached is a 3-part questionnaire that covers sociodemographic information, general perceptions about distribution, and perceptions and preferences on content and layout of IRRN. The questionnaire has been distributed to individual and institutional recipients of IRRN on the mailing list. Other readers and individuals not on the mailing list but who are interested in participating in the survey are invited to fill out the questionnaire. Please mail the completed questionnaire no later than 30 December 1998 to IRRN Central, Communication and Publications Services, IRRI, P.O. Box 933, 1099 Manila, Philippines.

If you wish to get an electronic copy (email/pdf file) of the questionnaire, please send an email to kslopez@irri.cgiar.org. And if you want to answer the questionnaire online, please go to the IRRI homepage at http://www.cgiar.org/irri/irrn.htm.

Upcoming changes in the content and format of IRRN are part of a larger effort to improve the quality, usefulness, and accessibility of this valued IRRI publication. Other components of the renewal project include the appointment of an IRRI editorial board of scientists composed of six internationally recruited staff, creation of a position for IRRN Managing Editor, and release of IRRN on the World Wide Web.

IRRN production team

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The International Rice Research Institute (IRRI) was established in 1960 by the Ford and Rockefeller Foundations with the help and approval of the Government of the Philippines. Today IRRI is one of 16 nonprofit international research centers supported by the Consultative Group on International Agricultural Research (CGIAR). The CGIAR is cosponsored by the Food and Agriculture Organization of the United Nations (FAO), the International Bank for Reconstruction and Development (World Bank), the United Nations Development Programme (UNDP), and the United Nations Environment Programme (UNEP). Its membership comprises donor countries, international and regional organizations, and private foundations.

As listed in its most recent Corporate Report, IRRI receives support, through the CGIAR, from a number of donors including UNDP, World Bank, European Union, Asian Development Bank, and Rockefeller Foundation, and the international aid agencies of the following governments: Australia, Belgium, Canada, People’s Republic of China, Denmark, France, Germany, India, Indonesia, Japan, Republic of Korea, The Netherlands, Norway, Philippines, Spain, Sweden, Switzerland, United Kingdom, Thailand and United States.
Germplasm improvement

Genetics

Genetic variability in floral traits of 10 cytosterile lines of rice (Oryza sativa L.)

R. Singh and B. Singh, Genetics and Plant Breeding Department, Institute of Agricultural Sciences, BHU, Varanasi 221005, India

We evaluated 10 cytosterile lines and their respective maintainers for different floral traits such as duration of opening of florets, angle of opened florets, percentage of stigma exsertion, percentage of panicle exsertion, stigma length, anther length, filament length, and stigma surface influencing outcrossing in rice. Results are shown in the table.

Analysis of variance recorded highly significant treatment differences for all traits, indicating the presence of variability for selection. Some of the most important floral traits—duration of opening of florets, angle of opened florets, percentage of stigma exsertion, and percentage of panicle exsertion substantially influencing outcrossing—were predominant in cytosterile lines PMS2A/B, PMS6A/B, PMS7A/B, IR58025A/B, and IR62829A/B.

On the basis of variability studies, cytosterile line IR62829A/B expressed the best values overall for stigma characteristics (stigma exsertion percentage, stigma length, stigma surface) followed by PMS3A/B, PMS10A/B, and PMS2A/B. The most popular CMS line, IR58025A, showed poorer stigma characteristics compared with other cytosterile lines, but it had pronounced anther characteristics. In general, A lines showed better traits that influence outcrossing than their respective B lines.

Analysis of variance and genetic parameters of variation and mean performance for eight floral characters in 10 cytosterile lines (A) and their maintainer lines (B) in rice.

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>DOF (min)</th>
<th>PSE</th>
<th>PPE</th>
<th>AOF (°)</th>
<th>SL (mm)</th>
<th>SS (mm²)</th>
<th>AL (mm)</th>
<th>FL (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A/B</td>
<td>A</td>
<td>B</td>
<td>A</td>
<td>B</td>
<td>A</td>
<td>B</td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>Replication</td>
<td>2</td>
<td>775.61</td>
<td>65.20</td>
<td>13.03</td>
<td>9.85</td>
<td>2.58</td>
<td>10.51</td>
<td>0.008</td>
<td>0.009</td>
</tr>
<tr>
<td>Treatment (G)</td>
<td>9</td>
<td>2,420.98**</td>
<td>378.79**</td>
<td>399.03**</td>
<td>264.83**</td>
<td>70.49**</td>
<td>236.65**</td>
<td>17.86**</td>
<td>0.154**</td>
</tr>
<tr>
<td>Error</td>
<td>18</td>
<td>288.22</td>
<td>76.15</td>
<td>11.75</td>
<td>5.65</td>
<td>2.99</td>
<td>6.37</td>
<td>0.008</td>
<td>0.008</td>
</tr>
<tr>
<td>CD (5%)</td>
<td>-</td>
<td>29.12</td>
<td>14.95</td>
<td>5.86</td>
<td>4.68</td>
<td>2.96</td>
<td>4.33</td>
<td>0.008</td>
<td>0.008</td>
</tr>
</tbody>
</table>

Genetic parameters of variation

Mean | 90.57 | 64.50 | 50.92 | 53.26 | 64.63 | 90.04 | 25.26 | 23.07 | 1.42 | 1.43 |
CV (%) | 18.33 | 13.53 | 7.60 | 8.42 | 3.14 | 3.43 | 6.34 | 6.96 | 6.27 | 6.47 |
Range (minimum) | 61.67 | 47.50 | 7.88 | 29.45 | 58.45 | 77.90 | 22.89 | 19.67 | 1.19 | 1.19 |
Range (maximum) | 146.67 | 84.17 | 66.71 | 75.19 | 69.01 | 100.00 | 32.45 | 27.61 | 1.97 | 2.02 |
Variance (P) | 2,613.13 | 429.56 | 371.60 | 275.26 | 72.48 | 240.89 | 25.00 | 19.58 | 0.16 | 0.18 |
Variance (G) | 2,324.90 | 353.41 | 359.85 | 259.61 | 69.49 | 234.52 | 22.47 | 17.00 | 0.15 | 0.17 |
Coefficient (GCV) | 28.80 | 20.63 | 25.20 | 25.20 | 4.82 | 8.42 | 10.42 | 9.77 | 15.59 | 16.36 |

Mean performance

IR58025A/B | 103.06 | 71.67 | 53.28 | 56.93 | 68.96 | 85.21 | 24.00 | 22.89 | 1.23 | 1.19 |
IR62829A/B | 72.33 | 70.00 | 65.61 | 71.07 | 66.22 | 89.78 | 27.00 | 25.77 | 1.97 | 2.02 |
PMS2A/B | 146.67 | 50.83 | 49.83 | 42.49 | 66.45 | 89.15 | 24.11 | 20.88 | 1.28 | 1.33 |
PMS3A/B | 71.50 | 47.50 | 38.54 | 50.94 | 64.65 | 77.90 | 23.78 | 24.00 | 1.42 | 1.43 |
PMS6A/B | 131.67 | 50.83 | 49.83 | 42.49 | 66.45 | 89.15 | 24.11 | 20.88 | 1.28 | 1.33 |
PMS7A/B | 105.00 | 68.33 | 56.43 | 48.47 | 65.34 | 93.56 | 32.45 | 27.61 | 2.66 | 2.66 |
PMS8A/B | 61.67 | 47.50 | 38.54 | 50.94 | 64.65 | 77.90 | 23.78 | 24.00 | 1.42 | 1.43 |
PMS10A/B | 84.17 | 64.17 | 48.37 | 67.35 | 69.49 | 234.52 | 22.47 | 17.00 | 0.15 | 0.17 |
NMS1A/B | 70.55 | 56.67 | 57.43 | 29.45 | 69.01 | 99.32 | 25.78 | 24.45 | 1.55 | 1.54 |
PMS2A/B | 79.17 | 73.33 | 7.88 | 31.39 | 62.02 | 85.39 | 22.89 | 22.78 | 1.19 | 1.20 |

** = significant at 1% level, * = significant at 5% level, GCV = genotypic coefficient of variation, PCV = phenotypic coefficient of variation, DOF = duration of opening of florets, PSE = percentage of stigma exsertion, PPE = percentage of panicle exsertion, AOF = angle of opened florets, SL = stigma length, SS = stigma surface, AL = anther length, FL = filament length.
Does cross-pollination occur during seed regeneration at the International Rice Genebank?

R. Reaño, IRRI, and J.L. Pham, IRRI, seconded from ORSTOM (Institut français de recherché scientifique pour le développement en coopération), Paris, France

Preserving genetic integrity of accessions through cycles of conservation and regeneration is a major objective of the International Rice Genebank (IRG). The careful management of seed lots at all steps of the conservation-regeneration process contributes to this objective. Although cultivated rice is a self-pollinated crop, cross-pollination between accessions can potentially occur during seed regeneration when numerous accessions usually flower at the same time.

To estimate the outcrossing rate in Oryza sativa and determine whether the plot design currently used at IRG for seed regeneration permits outcrossing between accessions, an experiment was conducted at IRRI during the 1996 dry season.

Five pairs of varieties were used (Table 1). All accessions used as the pollen source (male) had a purple-pigmented basal leaf sheath, whereas pollinated (female) accessions had a green basal leaf sheath. Hybrid seedlings showed purple pigmentation. The pollen-receivers represented a large range of variation for stigma length and stigma exsertion and the pollinators were matched to the other accessions for plant height and flowering date criteria (Table 1).

Four different planting designs or treatments were studied (Fig. 1). All plots were separated from each other by a 1.5-m-wide alley. Two replications were made for all treatments. The experimental plots were laid out such that pollen sources, especially in treatment T3, were oriented across the predominant direction of the wind (Fig. 1).

Seeds from the female plants were collected from about 50-75 panicles per treatment per pair of varieties, from which 600-900 good seeds, depending on availability, were germinated for testing.

Varieties BG 90-2, Secano de Brazil, and Red Rice, with an average outcrossing rate across treatments of 0.40%, 0.27%, and 0.35% (Table 2), respectively, were more subjected to outcrossing than Tojo and CI 8898-2 (0.02%) (Fig. 2). These three varieties have longer and more exerted stigmas.

Table 1. Accessions used in the experiment.

<table>
<thead>
<tr>
<th>Accession no.</th>
<th>Variety name</th>
<th>Source</th>
<th>Stigma exsertion (%)</th>
<th>Stigma length (mm)</th>
<th>Plant height (cm)</th>
<th>Days to 50% flowering</th>
</tr>
</thead>
<tbody>
<tr>
<td>36951</td>
<td>BG 90-2</td>
<td>Sri Lanka</td>
<td>70.8</td>
<td>1.21</td>
<td>133</td>
<td>89</td>
</tr>
<tr>
<td>3513</td>
<td>Red Rice</td>
<td>Iran</td>
<td>69.2</td>
<td>1.87</td>
<td>130</td>
<td>80</td>
</tr>
<tr>
<td>3375</td>
<td>Secano de Brazil</td>
<td>El Salvador</td>
<td>68.1</td>
<td>1.88</td>
<td>135</td>
<td>80</td>
</tr>
<tr>
<td>2755</td>
<td>Tojo</td>
<td>Japan</td>
<td>35.8</td>
<td>1.00</td>
<td>139</td>
<td>80</td>
</tr>
<tr>
<td>3432</td>
<td>CI 8898-2</td>
<td>Africa</td>
<td>32.2</td>
<td>1.03</td>
<td>145</td>
<td>80</td>
</tr>
<tr>
<td></td>
<td>Male varieties (purple)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>27334</td>
<td>Padi Kawaluhun</td>
<td>Indonesia</td>
<td>141</td>
<td>89</td>
<td></td>
<td></td>
</tr>
<tr>
<td>46747</td>
<td>Tikanath</td>
<td>India</td>
<td>136</td>
<td>80</td>
<td></td>
<td></td>
</tr>
<tr>
<td>58951</td>
<td>Dhanush Ban</td>
<td>Nepal</td>
<td>138</td>
<td>80</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2325</td>
<td>Duk Zuk Zodo</td>
<td>Korea</td>
<td>142</td>
<td>80</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3441</td>
<td>Mamoriaka</td>
<td>Africa</td>
<td>152</td>
<td>80</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 2. Average outcrossing rates (%) observed, by entry and treatment.a

<table>
<thead>
<tr>
<th>Pollinated accession</th>
<th>T0</th>
<th>T1</th>
<th>T2</th>
<th>T3</th>
<th>Av (by entry)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BG 90-2</td>
<td>0.83</td>
<td>0.50</td>
<td>0.25</td>
<td>0</td>
<td>0.40</td>
</tr>
<tr>
<td>Tojo</td>
<td>0.08</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.02</td>
</tr>
<tr>
<td>CI 8898-2</td>
<td>0.08</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.02</td>
</tr>
<tr>
<td>Secano de Brazil</td>
<td>0.83</td>
<td>0.25</td>
<td>0</td>
<td>0</td>
<td>0.27</td>
</tr>
<tr>
<td>Red Rice</td>
<td>0.92</td>
<td>0.50</td>
<td>0</td>
<td>0</td>
<td>0.35</td>
</tr>
</tbody>
</table>

aSee Fig. 1 for treatment details.

This study also demonstrated that cross-pollination can occur in farmers' fields where intentional or accidental varietal mixtures are grown, and can contribute to the overall evolutionary process of rice genetic resources.

Genetic research

Phylogenetic relationship of genus Oryza as revealed by RAPD analysis

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The agronomically important genus Oryza L. includes some 20 wild and 2 cultivated species and is divided into four complexes based on morphological and cytogenetical studies. New molecular approaches, such as restriction fragment length polymorphism (RFLP), internal transcribed spacer (ITS) sequencing, random amplified polymorphic DNA (RAPD), and chloroplast sympo sequence repeats (cpSSR), have been increasingly employed to assess phylogenetic relationships of the genus, but controversy still exists with regard to species relationships. This study applied RAPD technology to determine the phylogenetic relationships of Oryza and evaluate the value and limitation of this technology in phylogenetic studies.

Total DNA was extracted from fresh or dried leaves of 36 accessions representing 23 Oryza taxa and 1 accession from Porteresia coarctata and Leersia hexandra (see table). Polymerase chain reaction (PCR) RAPD was carried out on a Rapidcycler (ATC) in a volume of 10 µL, containing 1.2 µmol L\(^{-1}\) primer, 5-10 ng µL\(^{-1}\) genomic DNA template, 50 mmol L\(^{-1}\) Tris HCl (pH 8.3), 0.5 µg (L\(^{-1}\) BSA, 2 mmol L\(^{-1}\) MgCl\(_2\), 0.5U Taq DNA polymerase, 200 µmol L\(^{-1}\) dNTP, 1% Ficoll, and 1 mmol L\(^{-1}\) tartrazine. The first program was two cycles of 1 min at

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2. Outcrossing rates (%) observed for the different variety × planting design combinations.

The latter trait appeared to be the key trait for the ability to receive exogenous pollen. Treatment T0 was the only one where outcrossing was observed for all varieties; the outcrossing rate was found to be more correlated to stigma exertion (r = 0.977, P = 0.004) than stigma length (r = 0.650, P = 0.25). Only BG 90-2, the variety with the most exerted stigma, was cross-pollinated in treatment T2. Outcrossing rate was related to the proximity of male and female plants.

The highest outcrossing rates were observed in T0, where panicles were clipped together (0.08-0.92%). All female varieties showed cross-pollination in this design. The second highest frequency of hybrid seeds was observed in T1, where male and female plants were alternated (0-0.5%). Very few hybrid seeds were observed in T2 (alternate rows). No hybrid was observed in T3 (side-by-side plots).

No outcrossing was observed in T3, which mimics the field design used by the IRG to regenerate seeds. The experiment did not show that outcrossing does not occur during seed regeneration, but it strongly suggested that if outcrossing occurs, it occurs at a rate much lower than the 0.9% observed when panicles are clipped together. Moreover, during normal seed regeneration, seeds are harvested only from the four middle rows out of the eight rows of each plot to decrease the risk of outcrossing. Overall, results did not suggest any need to modify the design for the next regeneration cycles.

Results from T1 showed that seed mixtures can be a significant source of outcrossing and must be avoided. Also, multiplication plots must be carefully monitored to discard plants grown from seeds left from previous experiments.
94 °C, 10 s at 35 °C, and 20 s at 72 °C, followed by 45 cycles of 2 s at 94 °C, 10 s at 35 °C, and 1 min at 72 °C. The reaction was held at 72 °C for 4 min at the end of the cycles. The RAPD products were electrophoresed in 1.5% agarose gels and then stained with ethidium bromide.

Of the 30 randomly selected primers, 16 (OPL-01, 02, 03, 05, 07, 08, 10, 11, 13, 14, 16, 18, 19, 20, and OPY-06 and OPY-08) successfully showed amplified interspecific polymorphism. RAPD bands were scored as present (1) or absent (0), each of which was treated as an independent character regardless of its intensity. Inconsistent bands were excluded from the data analysis. Data were compiled in a binary matrix for similarity-based analyses using the program of NTSYS-pc (Version 2.02a). The SIMQUAL program was used to calculate Jaccard’s coefficient, a common estimator of genetic identity, or to estimate interspecific relationships. Cluster analysis using the similarity estimates was performed with the UPGMA method.

The 16 RAPD primers produced a total of 368 fragments, ranging from 200 to 2,000 bp. A high degree of polymorphism was revealed by a large number of fragments, including some species-specific or genome-specific ones, indicating the usefulness of RAPD variation in polygenetic studies of rice species. The dendrogram (see figure) generated from UPGMA agreed well with the current grouping of Oryza species by Vaughan (1989), but with some exceptions. All species with AA genome formed a single group, corresponding to the O. sativa complex. Species with BB, CC, BBCC, and CCDD genomes formed a different group, corresponding to the O. officinalis complex. The O. ridleyi and O. meyeriana complexes were included in the third group. O. brachyantha was grouped with O. schlechteri, and then joined Porteresia coarctata and Leersia hexandra to form another cluster (see figure). The cultivated O. sativa subsp. japonica and subsp. indica were closely related to their putative ancestors, O. nivara and O. rufipogon. One accession of O. nivara showed a higher affinity to O. sativa than to O. rufipogon or other O. nivara accessions. It was difficult to separate O. nivara from O. rufipogon based on the RAPD variation. This supports the results from rDNA ITS sequence analysis (Y. Zhou et al, unpub. data). Two accessions of O. glumaepatula showed clear differentiation from O. rufipogon or O. nivara, suggesting its independent taxonomic status. The African cultigen O. glaberrima closely clustered with its progenitor O. barthii, supporting the hypothesis that the Asian and African cultivated rice were domesticated independently. The subgroup of O. meridionalis and O. longistaminata was relatively separated from the other AA genome species, which agrees with the treatment of O. meridionalis and O. longistaminata as independent species.

In the second largest group with BB, BBCC, CC, and CCDD genome species, two accessions of diploid O. officinalis (CC) from China were clustered with O. minuta (BBCC), whereas another tetraploid accession from the Philippines clustered with O. eichingeri and O. rhizomatis, indicating remarkable differentiation between the diploid and tetraploid O. officinalis. Three South American species with CCDD genomes clustered together with the CC genome species, suggesting close affinity to the CCDD and CC genome species.

Noticeably, the EE genome O. australiensis formed an independent group, strongly indicating its unique origin and differentiation from other

<table>
<thead>
<tr>
<th>Taxon</th>
<th>Accession no.</th>
<th>Genome</th>
<th>Country of origin</th>
</tr>
</thead>
<tbody>
<tr>
<td>O. sativa subsp. indica</td>
<td>951001</td>
<td>AA</td>
<td>China</td>
</tr>
<tr>
<td>O. sativa subsp. japonica</td>
<td>951002</td>
<td>AA</td>
<td>China</td>
</tr>
<tr>
<td>O. nivara (1)</td>
<td>100918*</td>
<td>AA</td>
<td>Cambodia</td>
</tr>
<tr>
<td>O. nivara (2)</td>
<td>100195*</td>
<td>AA</td>
<td>Myanmar</td>
</tr>
<tr>
<td>O. rufipogon (1)</td>
<td>940135</td>
<td>AA</td>
<td>China</td>
</tr>
<tr>
<td>O. rufipogon (2)</td>
<td>940331</td>
<td>AA</td>
<td>China</td>
</tr>
<tr>
<td>O. rufipogon (3)</td>
<td>940332</td>
<td>AA</td>
<td>China</td>
</tr>
<tr>
<td>O. rufipogon (4)</td>
<td>102186a</td>
<td>AA</td>
<td>India</td>
</tr>
<tr>
<td>O. meridionalis (1)</td>
<td>103317a</td>
<td>AA</td>
<td>Australia</td>
</tr>
<tr>
<td>O. meridionalis (2)</td>
<td>103321a</td>
<td>AA</td>
<td>Australia</td>
</tr>
<tr>
<td>O. glumaepatula (1)</td>
<td>103810a</td>
<td>AA</td>
<td>Venezuela</td>
</tr>
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<td>AA</td>
<td>Surinam</td>
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<tr>
<td>O. meyeriana</td>
<td>103056a</td>
<td>AA</td>
<td>Mali</td>
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<td>101257a</td>
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<td>Chad</td>
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<td>104140a</td>
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*Materials obtained from IRRI with International Rice Genebank collection numbers.
Dendrogram produced from UPGMA cluster analysis of 38 accessions of Porteresia, Leersia, and Oryza species based on RAPD variation patterns. Accession number and origin of species followed the arrangement in the table.

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Genetic evaluation

**Identification of an alternate cytoplasmic male sterile source in rice**

T. Vanaja and V.V. Radhakrishnan, Agricultural Research Station, Mannuthy, Kerala 680651, India

Research is in progress in China, at IRRI, and elsewhere to diversify sources of cytoplasmic male sterility (CMS) in rice.

To study gene action in high-yielding rice varieties of diverse origin, 13 genetically distinct parents were selected from nine clusters, comprising 56 rice genotypes of different ecogeographic origin, formed through Mahalanobis D2 statistics. Selected parents were subjected to full diallel crosses and F1 plants were raised. Observations were taken on yield components.

Among 156 F1 progenies, we obtained two highly sterile F1 progenies from the crosses Vytila-3/IR36 and Vytila-3/Hraswa (Vytila-3 is an improved saline-resistant rice variety bred for Kerala conditions and Hraswa is an extra short-duration rice variety—70-75 d—recommended for cultivation in Kerala). The F1 progenies of their reverse crosses—IR36/Vytila-3 and Hraswa/Vytila-3—were fully fertile. This suggested that Vytila-3 possesses sterility-inducing cytoplasm. Percentage of pollen sterility was estimated using iodine potassium iodide solution; 70% pollen sterility was found in both crosses using Vytila as the female parent.

Among the 100 BC1F1 progenies from the cross Vytila-3 × IR36 [(Vytila-3 × IR36) × IR36], 50% pollen sterility in 52% of the plants and 80-82% pollen sterility among the rest was observed. The segregation of F2 progenies of the same cross (Vytila-3 × IR36) was also analyzed for pollen sterility. Of the 78 F2 progenies, 4 plants showed 100% sterility and 74 plants showed sterility ranging from 3% to 92%.

F2 progenies of the cross Vytila-3 × Hraswa were also analyzed for pollen sterility. The plants also exhibited a high range of pollen sterility (from 5% to 80%).

sequences to distinguish one from the other. *O. brachyantha* and *O. schlechteri* were unexpectedly clustered together. This result was different from previous reports. Furthermore, *O. brachyantha* and *O. schlechteri* showed higher affinities to *Porteresia coarctata* and *Leersia hexandra* than to other species in the genus *Oryza*, and the four species unexpectedly joined together.■

Species in the *O. sativa* and *O. officinalis* groups, *O. ridleyi* and *O. longiglumis* were closely related to each other and formed a group. In the *O. meyeriana* complex, one accession of *O. granulata* from China clustered with *O. meyeriana* and another one from India with *O. ridleyi* and *O. longiglumis*, although the *O. ridleyi* and *O. meyeriana* complexes had genome-specific repeated
From the segregation progenies of the cross Vytila-3 × IR36, we were able to isolate four completely CMS lines suitable for warm, humid climatic conditions at Kerala (Figs. 1 and 2).

Virmani et al (1985) reported attaining a highly sterile BC4F1 progeny from the cross ARC13829-26/IR1079-2-3-1.

Reference

Inheritance study of seedling elongation in rice
P. M. Mohapatra, A. R. Panda, and S. N. Ratho, Genetics and Plant Breeding Division, Central Rice Research Institute (CRRI), Cuttack, Orissa, India

The inheritance of seedling elongation in rice was studied in the cross IR42 (dwarf nonelongating)/Jalamagna (tall elongating) for two different ages of seedlings (21 and 30 d old) under deep water conditions during the 1995 wet season at CRRI. Seedlings of F1 and F2 and parental lines raised in small galvanized iron trays (size 50 × 40 cm) were submerged in a water tank. Seedling heights were taken just before submergence. On the first day of submergence, water depth was 40 cm which was raised the following day to 80 cm and 90 cm for 21- and 30-d-old seedlings, respectively. These levels were maintained for 7 d.

Seedling heights were recorded after draining the tank. The mean heights of F1 and the elongating parent (Jalamagna) before submergence with 21- and 30-d-old seedlings were 42 and 43 cm, and 48 and 47 cm, respectively (see figure). The respective values after submergence were 80 and 85 cm, and 122 and 126 cm, respectively, suggesting the dominance of elongation ability. The figure shows the frequency distribution curves for height. The segregation pattern for height observed in the F1 before and after submergence is described below.

For 21 DAS, seedling height before submergence ranged from 20 to 70 cm and plant distribution was distinctly unimodal, with a peak at 55 cm. After submergence, plant height ranged from 30 to 110 cm, separating the population into elongating type (such as Jalamagna) and nonelongating type (such as IR42); distribution was bimodal. Of 235 F2 plants studied, 130 were elongating and 105 were nonelongating, fitting the 9:7 ratio ($\chi^2 = 0.0818, P = 0.75-0.90$).

For 30 DAS, seedling height varied from 20 to 75 cm before submergence. Plant distribution was unimodal. After submergence, distribution was clearly bimodal, with a wider height range of 40-150 cm. Of 244 F2 plants, 148 were elongating types and 96 were nonelongating types, which fitted the 9:7 ratio ($\chi^2 = 1.924, P = 0.10-0.25$).

Results suggested two dominant complementary genes responsible for seedling elongation in rice. The presence of both genes conferred an elongation ability similar to that of Jalamagna, and the absence of either gene or both genes resulted in plants such as IR42, the nonelongating parent.
Studies on combining ability and heterosis in rice

P.V. Satyanarayana, Agricultural Research Station, Maruteru 531422, W.G. District, Andhra Pradesh; I. Kumar, Pro Agro Co., Ltd., Hyderabad; and M.S.S. Reddy, Genetics and Plant Breeding Department, College of Agriculture, APAU, Hyderabad, India

The usefulness of a particular cross in the exploitation of heterosis in rice is judged by analyzing combining ability. An attempt was made to understand the nature of gene action governing grain yield in heterotic F₁ rice combinations at the Directorate of Rice Research in Hyderabad, India.

For this study, we used 33 genotypes as male parents to make 99 crosses with three cytoplasmic male sterile lines—V20A, IR58025A, and IR62829A—in a three replications in the 1992 dry season. Each treatment (plot) consisted of one plant from each plot were randomly measured for yield and yield component analysis.

Analysis of variance indicated that differences among treatments, which included 36 parents and 99 hybrids, were highly significant for all characters studied, implying a high degree of genetic differences in the material.

In general, variance due to specific combining ability (SCA) was greater than that due to general combining ability (GCA) for the characters studied, indicating the predominance of nonadditive gene interaction in governing yield and other related traits. This offers the possibility of exploiting heterosis.

Of the 99 Fₛ, 21 cross combinations exhibited >20% yield advantage over the best check Jaya. The table presents the performance, SCA effects of crosses, GCA effects of parents, and standard heterosis over Jaya. Thirteen of these 21 superior crosses exhibited significant SCA effects. The other eight crosses registered nonsignificant SCA effects. The cross A3/R26 had very high SCA effects but did not rank high in yield. On the other hand, crosses A2/R31 and A3/R15 showed a very high mean yield performance with moderately significant SCA effects. Crosses with nonsignificant SCA effects performed better than some crosses with significant SCA effects (such as A2/R31, A3/R1, A2/R14, A2/R18, etc.).

These results clearly indicated that high-yielding hybrids need not be the ones with high SCA effects and vice versa as reported earlier. Results showed that of 13 crosses with significant SCA effects, 10 crosses involved one parent with high GCA effects and others had either high, average, or low combining ability effects (see table). This indicates additive as well as nonadditive genetic interactions operating in the crosses studied.

<table>
<thead>
<tr>
<th>Code</th>
<th>Cross combination</th>
<th>Yield plant¹ (g)</th>
<th>SCA effect</th>
<th>GCA effect of female</th>
<th>GCA effect of male</th>
<th>Standard heterosis (over Jaya)</th>
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¹, ** = significant at 1 and 5% level, respectively; ns = not significant, H = high GCA effects, A = average, L = low GCA effects.

Breeding methods — tissue culture

Effects of L-tryptophan, L-proline, and activated charcoal on plant regeneration in indica rice (Oryza sativa L.)

A.K. Sahrawat and S. Chand, Plant Tissue Culture and Genetics Research Group, School of Life Sciences, Devi Ahilya University, Khandwa Road Campus, Indore 452001, India

Production and maintenance of embryogenic callus and subsequent plant regeneration in higher frequency are important aspects of tissue culture. A rapid decrease in morphogenetic capacity with age in culture has often been observed. To overcome this problem, several methods have been suggested. We report the promotive effect of L-tryptophan, L-proline, and activated charcoal on plant regeneration in long-term callus cultures of indica rice.

Callus cultures were raised from 4-d-old coleoptile tissue of indica rice (Oryza sativa L. cv Kasturi). Mature
seeds were surface-sterilized and kept for germination on MS0 medium (MS without any growth hormone) for the first 2 d in the dark at 26 ± 2 °C and then transferred to 16 h/8 h light/dark. Coleoptile tissues (1 cm long) were dissected from 4-d-old germinating seeds and cultured on MS medium containing 0.5 mg kine- tin L-1 and 2.5 mg 2,4-D L-1 (MS1).

Cultures were initially incubated in the dark at 24 ± 2 °C for 3 wk and then transferred to a fresh medium and kept under 16 h/8 h light/dark for the next 3 wk. After 6 wk, embryogenic calli were divided into small pieces and transferred to various maintenance media (see table) for 8 mo before they were transferred to the regeneration medium, MS + 0.5 mg IAA L-1 + 4.0 mg BAP L-1.

Callus initiation was observed after 4 d of inoculation. Compact and globular embryogenic calli were clearly visible after 20 d of culture initiation (Fig. 1). The first 45 embryogenic calli clumps were transferred on various maintenance media where they were subcultured at 4-wk intervals for 8 mo. During maintenance, somatic embryoid-like structures (Fig. 2) were observed on a maintenance medium (MS1) containing 100 mg L-tryptophan L-1.

After 8 mo, calli maintained on medium containing L-tryptophan, L-proline, and activated charcoal remained embryogenic. Nearly half of the calli clumps (24 of 45 embryogenic calli clumps) maintained without L-tryptophan, L-proline, and activated charcoal turned blackish and lost their embryogenic potential. When the remaining embryogenic calli clumps (approximate wt 0.29 g) were transferred to the regeneration medium (MS + 0.5 mg IAA L-1 + 4.0 mg BAP L-1), a few calli clumps (23.8%) showed green shoot bud induction after 14 d. Among calli clumps obtained from a medium containing L-tryptophan and activated charcoal, 71.4% showed green shoot bud after 8 d of transfer on a regenera- tion medium. These shoot buds further proliferated into multiple shoots (Fig. 3).

The maximum average number of plantlets (5.3 per calli clump) was recovered from calli clumps maintained on a medium containing 100 mg L-tryptophan L-1 and 1% activated charcoal. A maintenance medium containing L-proline (100 mg L-1) and activated charcoal (1%) was suitable for regenerating green plantlets. Regenerated plantlets were counted after 6 wk of subculture. Calli clumps maintained without L-tryptophan, L-proline, and activated charcoal produced only 1.3 plantlets per calli clump. The regenerated plantlets were rooted on MS medium

Effects of L-tryptophan, L-proline, and activated charcoal (added to MS medium) on plant regeneration from long-term callus cultures of indica rice.

<table>
<thead>
<tr>
<th>Maintenance medium (mg L⁻¹) + (supplements)³</th>
<th>Calli forming shoot buds (no.)</th>
<th>Calli forming shoots (%)</th>
<th>Green plantlets (no.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MS1</td>
<td>5</td>
<td>23.8</td>
<td>7</td>
</tr>
<tr>
<td>MS1 + L-tryptophan (100)</td>
<td>9</td>
<td>42.8</td>
<td>33</td>
</tr>
<tr>
<td>MS1 + L-tryptophan (100) + activated charcoal (1%)</td>
<td>15</td>
<td>71.4</td>
<td>80</td>
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<tr>
<td>MS1 + L-proline (100)</td>
<td>8</td>
<td>39.0</td>
<td>35</td>
</tr>
<tr>
<td>MS1 + L-proline (100) + activated charcoal (1%)</td>
<td>14</td>
<td>66.7</td>
<td>65</td>
</tr>
</tbody>
</table>

³Maintenance media (MS1) = MS + 0.5 mg L⁻¹ 2,4-D + 0.5 mg L⁻¹ kinetin. Regeneration media = MS + 0.5 mg IAA L⁻¹ + 4.0 mg BAP L⁻¹. Data are average of three replications treatment; each treatment consists of seven calli (average weight 0.29 g replicate). In each case, 21 calli were plated. The experiment was repeated two times.

1. Nodular and embryogenic calli after 20 d of culture initiation.

2. Initiation of somatic embryoid-like structures from embryogenic callus on MS1, a maintenance medium containing 0.5 mg 2,4-D L⁻¹ + 0.5 mg kine- tin L⁻¹ + 100 mg L-tryptophan L⁻¹.

3. Multiple shoot proliferation on MS medium containing 0.5 mg IAA L⁻¹ + 4.0 mg BAP L⁻¹ (after 28 d of transfer).
Regenerated plantlets showing rooting on MS medium containing 1.0 mg IBA L^{-1} (Fig. 4) and were transferred to pots.

Results indicated the usefulness of L-tryptophan and activated charcoal in increasing regeneration of green plants from long-term callus cultures of indica rice.

Grain quality

**Modeling water uptake and degree of polish of milled rice**

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This study was undertaken to model the process of water uptake behavior during cooking and to correlate water uptake with degree of polish for two varieties (coarse Jaya and scented fine Basmati) commonly grown in the western part of Uttar Pradesh, India. Rough rice samples were collected from a farmer’s field just after harvest, cleaned, and shade-dried up to milling moisture content (14% dry basis). These were then shelled and polished in a Satake rice sheller and polisher. Milling / polish time varied from 0 s to 60 s to control the degree of bran removal (degree of polish) with an increment of 15 s. The degree of polish of milled samples ranged from 2.7% to 8.4% for Jaya and 2.9% to 8.5% for Basmati at 15 s and 60 s, respectively.

The 1,000-kernel weight of Jaya (28.6 g) was higher than that of Basmati (24.5 g). The length and width-thickness ratio of Jaya were 8.67 mm and 3.04 mm, respectively, and those of Basmati were 11.09 mm and 5.13 mm. The angle of repose of Basmati (32°) was wider than Jaya’s (24.8°). Bulk and true density were determined by measuring the weight of known volumes of samples and by the method of relative density, respectively. Porosity, the index of void space in the bulk, was calculated as follows:

\[
\text{Porosity} = \frac{\text{True density} - \text{bulk density}}{\text{True density}} \times 100 \quad (1)
\]

Table 1 shows the bulk density, true density, and porosity of the two rice varieties.

<table>
<thead>
<tr>
<th>Property</th>
<th>Jaya</th>
<th>Basmati</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size (mm)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Length</td>
<td>8.7</td>
<td>11.1</td>
</tr>
<tr>
<td>Width</td>
<td>2.8</td>
<td>2.0</td>
</tr>
<tr>
<td>Thickness</td>
<td>2.0</td>
<td>1.8</td>
</tr>
<tr>
<td>1,000-kernel weight (g)</td>
<td>28.6</td>
<td>24.5</td>
</tr>
<tr>
<td>Bulk density (g cc^{-1})</td>
<td>0.6</td>
<td>0.5</td>
</tr>
<tr>
<td>True density (g cc^{-1})</td>
<td>1.3</td>
<td>1.0</td>
</tr>
<tr>
<td>Porosity (%)</td>
<td>51.2</td>
<td>51.4</td>
</tr>
<tr>
<td>Angle of repose(°)</td>
<td>24.8</td>
<td>32.6</td>
</tr>
</tbody>
</table>

Water uptake and kernel elongation after cooking were also determined (Table 2). Kernel elongation was 35% more in Basmati than in Jaya for 6% degree of polish. A similar observation was recorded for different samples of milled rice. Water uptake was found to be more for the same degree of polish for Basmati than for Jaya. Water uptake behavior for Jaya and Basmati can be described by the following equation:

\[
W_{\text{up}} = A \times e^{B D_p} \quad (2)
\]

where \(A = 1.71\) and \(B = 0.91\).

This mathematical expression describes the kinetics of water uptake (mL) and its relation with degree of polish (%) satisfactorily under obtainable conditions. The correlation coefficient and standard error of estimate for the above equation were 0.987 and 0.089, respectively.

**Breeding of Gan wan nuo 5, a new high-quality glutinous indica variety**

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Gan wan nuo 5, released in 1993 by the Jiangxi Provincial Seed Board, is a new glutinous indica rice variety with high quality. It was derived from the cross MY82166/Ma ba xian nuo. MY82166 is an indica rice with high resistance to blast, whereas Ma ba xian nuo is an aromatic glutinous indica variety. Gan wan nuo 5 is suitable for later season planting in the double-cropped area of southern China and single-cropped area of central China. Yield of this variety averaged 6.8 t ha^{-1} in double-cropped areas; it was 7.5 t ha^{-1} in single-cropped areas. This yield was 7% more than that of Jing Nuo 6, a glutinous check, and nearly the same as that of Shan you 63, a check hybrid. Because of its high quality and other good traits (see table), the award-winning Gan wan nuo 5 is replacing Jing Nuo 6 in many areas.
Gan wan nuo 5 has a strong, 120-cm-long stem. It has a growth duration of 135-140 d in single-cropped areas. The variety has high yield potential with good irrigation and good management.

Gan wan nuo 5 has a 1,000-grain weight of 25.3 g, panicle length of 24.9 cm, and 141 filled grains panicle⁻¹. The variety is used for making stuffed dumplings, cakes, and sweet wines.

Gan wan nuo 5 is widely planted and is spreading quickly in southern and central China. A total area of 70,000 ha was devoted to the crop from 1992 to 1998.

**Pest resistance — diseases**

**Inheritance of resistance to bacterial leaf blight in different rice variety Asominori**

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Asominori is one of the international differentials used for testing the pathogenicity of the bacterial leaf blight (BLB) pathogen, *Xanthomonas oryzae pv. oryzae*. It has been one of the varieties most resistant to BLB in Japan since its release in 1973. Extensive testing under the JIRCAS and YAAS collaborative research project on rice genetic resources between 1994 and 1996 showed that Asominori has stable resistance to BLB in both indica and japonica rice-growing areas in Yunnan, China. Hence, Asominori is considered a useful source of durable resistance to BLB. We found that Asominori has an allele of the *Xa1* locus on chromosome 4 for BLB resistance, although it has been reported to harbor *Xa17* independent from *Xa1*.

First, we found that Asominori grain showed a positive reaction to phenol solution, even though almost all japonica varieties in Japan have been reported to show negative reactions. The trait was inherited as a monogenic character in $F_2$ plants between Asominori and varieties Kogyoku and ST No. 1, which showed a negative reaction to phenol. No segregant had a negative reaction to phenol in the $F_2$ seeds of each $F_1$ plant ($n = 240$) between Asominori and a near-isogenic line of *Taihung* 65 with a marker *Ph*, suggesting that Asominori had the *Ph* gene on chromosome 4.

To further test the association between phenol reaction of grains and resistance to BLB, we screened 16 varieties or breeding lines in the pedigree of Asominori. Only Saikai 85 displayed a positive phenol reaction and resistance to BLB isolates. None of the other 15 varieties/lines (Tadukan, Senbonasahi, Pi No. 2, Saikai 97, Jikkoku, Zensho 26, Benisengoku, Chukyoasahi, Ojo, Saikai 59, Chujo 2, Norin 22, Tozan 38, Shinyamabuki, and Sachikaze) showed either of the two traits.

Second, BLB resistance of the varieties and their hybrids was evaluated by the clipping inoculation method around the heading stage in a rice field. Table 1 shows the reaction of parental varieties, $F_1$, and $F_2$ plants. All the $F_1$ plants were resistant to BLB isolates T7174 (race 1), H9153 (race 2–2), and H75304 (race V), which were collected in Japan. The segregation ratios in the $F_2$ populations were 3 (resistant): 1 (susceptible), suggesting that BLB resistance in Asominori was controlled by a single dominant gene. The BLB resistance gene of Asominori and *Ph* was closely linked with a recombination value of 2.4% in the coupling phase; all the segregation ratios were consistent with the genetic model (Table 2). This value was also consistent with the 2.8% recombination between *Ph* and *Xa1* reported earlier.

### Table 1. Segregation for reaction to BLB isolates in $F_2$ populations between Asominori, Kogyoku, and ST No. 1.

<table>
<thead>
<tr>
<th>Variety or cross combination</th>
<th>Number of plants for each reaction to T7174, H9153, and H75304*</th>
<th>Goodness of fit to 3:1</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>RRR</td>
<td>RSR</td>
</tr>
<tr>
<td>Asominori</td>
<td>15</td>
<td>0</td>
</tr>
<tr>
<td>Kogyoku</td>
<td>15</td>
<td>0</td>
</tr>
<tr>
<td>ST No. 1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Asominori/ Kogyoku (F₁)</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Asominori/ ST No. 1 (F₁)</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>Asominori/ Kogyoku (F₂)</td>
<td>296</td>
<td>94</td>
</tr>
<tr>
<td>Asominori/ ST No. 1 (F₂)</td>
<td>50</td>
<td>0</td>
</tr>
<tr>
<td>Asominori/ ST No. 1 (F₂)</td>
<td>265</td>
<td>0</td>
</tr>
</tbody>
</table>

* \( R = \) resistant, \( S = \) susceptible, \( RRR \) stands for resistant reaction to three BLB isolates used, respectively. *Inoculated by isolates T7174 and H75304 only.

### Table 2. Linkage relationship between BLB resistance and a genetic marker *Ph* in $F_2$ populations between Asominori, Kogyoku, and ST No. 1.

<table>
<thead>
<tr>
<th>Cross combination (F₁)</th>
<th>Segregation mode*</th>
<th>Recombination value ± SE (%)</th>
<th>Goodness of fit</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>AB</td>
<td>ab</td>
<td>ab</td>
</tr>
<tr>
<td>Asominori/ Kogyoku</td>
<td>292</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Asominori/ ST No. 1</td>
<td>49</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

* \( A = \) a dominant gene for BLB resistance in Asominori; \( B = \) *Ph* gene for phenol reaction. *Weighted mean of recombination values is 2.4% in a coupling phase.
using Japanese and IRRI varieties. Furthermore, we did not observe a segregant susceptible to isolates T7174 and H75304 in the F₁ plants (n = 390) and to isolate T7174 in the F₂ (n = 880) from Asominori / Kogyoku harboring the resistance gene Xa1. Thus, we concluded that Asominori had an allele at the Xa1 locus controlling resistance to the three BLB isolates.

Another allele at the Xa1 locus, Xa1-h, was previously reported in IRRI varieties IR28, IR29, and IR30. The Xa1-h allele differs from the Xa1 of Kogyoku in that Xa1-h shows high resistance to BLB race I at both the seedling and adult stages, whereas Xa1 shows unstable resistance at the seedling stage and high resistance at the adult stage. The resistance of IR28, IR29, IR30, and Kogyoku to BLB race V was controlled not by the alleles of Xa1, but by those of Xa12 closely linked with Xa1. The allele of Asominori on the Xa1 locus, however, displayed high resistance to races I and V at both the seedling and adult stages. Therefore, we tentatively designated the Xa1 allele responsible for the high resistance in Asominori as Xa1-as(t).

Asominori with Xa1-as(t) has been highly resistant to BLB for more than 20 yr whereas Kogyoku and Asakaze with Xa1 showed a breakdown in resistance. We are developing near-isogenic lines on Xa1-as(t) to clarify the relationship between the durability of Asominori’s resistance and the pleiotropic effects of Xa1-as(t).

<table>
<thead>
<tr>
<th>Accession no.</th>
<th>Wild rice species</th>
<th>Origin</th>
<th>Biotype</th>
<th>ELISA</th>
</tr>
</thead>
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<tr>
<td>100115</td>
<td>O. brachyantha</td>
<td>Guinea</td>
<td>BPH 1: 22</td>
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<tr>
<td>100139</td>
<td>O. glaberrima</td>
<td>Africa</td>
<td>BPH 2: 19</td>
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<tr>
<td>100153</td>
<td>O. glaberrima</td>
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<td>BPH 3: 34</td>
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</tbody>
</table>

Table 1. Mass screening of wild rice species for resistance to RGSV-2.

Potential sources of resistance against RGSV-2 in wild rice germplasm

E. Coloquio, R.C. Cabunagan, and O. Azzam, IRRI

IRRI varieties released after IR28 possess a source of resistance from *Oryza nivara* against rice grassy stunt virus, RGSV-1 strain. Although the resistance seems to be durable, the presence of a resistance-breaking strain, RGSV-2 (Hibino et al 1985), raises concerns about possible outbreaks if no new sources of resistance are found. Since 1985, about 12,000 accessions have been screened against the two strains, but no suitable resistance sources have been identified (Koganezawa 1994). Thus, during 1996-97, a collection of wild rice species was screened for RGSV-2 using the standard mass-screening cage method (Ling et al 1970) and some accessions, which showed low visual scores, were evaluated further using the enzyme-linked immunosorbent assay (ELISA).

Based on ELISA scores, several *O. officinalis* accessions from the Philippines, Indonesia, Malaysia, Brunei, and Thailand, *O. minutata* from the Philippines, and *O. punctata* from Nigeria showed 0% infection (Table 1). Because all these species are also resistant to the three brown planthopper (BPH) biotypes, however, it is difficult to predict whether the resistance is targeted against the virus or the vector. Two *O. nivara* accessions
Table 2. Mass screening of *O. nivara* germplasm collection for resistance to RGSV-2.

<table>
<thead>
<tr>
<th>Accession no.</th>
<th>Wild rice species</th>
<th>Origin</th>
<th>Biotype</th>
<th>Visual score</th>
<th>ELISA score</th>
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<td></td>
<td>BPH 1</td>
<td>n</td>
<td>% infection</td>
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</table>

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from Bangladesh (IRGC 103835 and IRGC 105316) and a cross between O. sativa and O. nivara (IRGC 105316), which showed less than 30% infection (Table 2) based on visual scores and ELISA, could be considered as potential resistance donor lines. Because O. nivara is susceptible to BPH, the resistance could be against the virus.

References

Green leafhopper-susceptible advanced lines resistant to rice tungro viruses

Eight rice varieties and lines susceptible to green leafhoppers were tested in field plots in Muñoz, Nueva Ecija, and Midsayap, North Cotabato, for their reactions to tungro viruses. IR26, TKM6, Utri Merah, IR69705-1-1-3-2-1, IR69706-1-4-2-5-2-2, IR73889-5-1-1-1-1-2, IR1561-228-3-3, and TN1 (control) were tested during the 1996 wet season (WS), 1997 dry season (DS), and 1997 WS cropping. They were planted in 4 x 4-m plots laid out in a randomized complete block design with four replications. All rice hills were scored visually for disease incidence at 30 and 60 d after transplanting (DAT).

Leaf samples of each entry from five quadrats in an x pattern with nine hills each were also taken in all replicates in the same period for enzyme-linked immunosorbent assay (ELISA) to determine the presence of rice tungro bacilliform virus (RTBV) and rice tungro spherical virus (RTSV). Each leaf sample was crushed in a leaf and bud press (Eijkelkamp Agrisearch Equipment, The Netherlands) and leaf sap was extracted with 1 mL of 0.1 M phosphate buffer (pH 7) containing 0.15 M NaCl and 0.05% Tween 20. For ELISA, the microtiter plate (Costar, Cambridge, MA) was coated by immunoglobulin (courtesy of IRRI) at 0.5 µg mL⁻¹ for RTBV and 1 µg mL⁻¹ for RTSV. The immunoglobulin-alkaline phosphate conjugate was diluted 1,000 times for RTBV and 500 times for RTSV. For each plate, four wells were set aside for the extracts of healthy TN1 leaves, along with one well for extracts of RTBV + RTSV-infected TN1 leaves and one well with the extraction buffer for the control. The presence of tungro viruses in the extracts was determined by measuring the absorbance at 405 nm in a MicroELISA reader (Bio-Rad 3550). Absorbance of more than twice the mean of four healthy control readings was considered positive.

At the Nueva Ecija site, very low tungro incidence based on symptoms was recorded at 30 DAT during the three seasons (data not shown). Because of the very low disease incidence observed and the limited supply of antiserum, the 1996 WS and 1997 DS samples, taken at 30 DAT at this site, were not tested by ELISA.

The ELISA results of the 1997 WS samples taken at 30 DAT also showed low rates of RTBV + RTSV and RTBV infection. During this period, more infection by RTSV alone than by RTBV + RTSV and RTBV alone was recorded in most entries and was significantly high in TN1. Increased infection by either RTSV and RTBV or both was observed in all entries at 60 DAT. IR26, TKM6, Utri Merah, IR69705-1-1-3-2-1, and IR69706-1-4-2-5-2-2 showed significantly lower infection by RTBV + RTSV compared with other entries. The 1996 and 1997 WS trials had higher rates of RTBV + RTSV infection at 60 DAT than the 1997 DS trial where infection by mostly RTSV alone was obtained (see table). This confirmed previous observations of low tungro incidence in the DS and at the early stage of crop growth, especially in areas with a low level of disease pressure.

In North Cotabato during the 1996 and 1997 WS trials, significantly higher RTBV + RTSV infection on TN1 was obtained as early as 30 DAT. More single infections of RTSV or RTBV, rather than dual infection, were obtained at 30 DAT in the 1997 DS trial, with significantly higher infection by RTSV alone observed on TN1 than on other test entries. This again showed the prevalence of dual infection during the WS crop. Although higher tungro infection occurred at 30 DAT in North Cotabato than in Nueva Ecija, Utri Merah and its derivatives, IR69705-1-1-3-2-1 and IR69706-1-4-2-5-2-2, maintained their low infection even at 60 DAT regardless of season (see table). IR26 and TKM6 recorded high RTBV + RTSV infection at 60 DAT during the 1997 DS and 1997 WS trials, in contrast to their low infection in Nueva Ecija during the same period, indicating that these varieties succumbed to tungro under high disease pressure or presence of a virus strain that can infect these varieties. During the trials, visual scoring of the plants was difficult at 60 DAT due to the effects of rice black bug (Scotinophara coarctata F.) infestation, which severely damaged the plants, especially in the 1996 WS trial, in which most plants died.

The average yield of 3.6 t ha⁻¹ of IR69705-1-1-3-2-1 during the 1996 WS trial in Nueva Ecija was not significantly different from the 4.0 t ha⁻¹ yield of IR26 (a high-yielding variety). Similarly, IR69706-1-4-2-5-2-2 yielded 4.0 t ha⁻¹ in the 1997 DS trial at the same location. These results showed that the yield of test varieties is on a par with that of a high-yielding variety when...
grown in an area with low tungro pressure. The yield of all test entries in North Cotabato was drastically reduced by rice black bug infestation. In the 1997 DS trial, IR69705-1-1-3-2-1 yielded an average of 1.9 and 0.9 t ha\(^{-1}\), respectively. The latter was significantly higher than the 0.7 t ha\(^{-1}\) yield of IR26. The low tungro virus infection and the relatively high yield of these advanced lines showed their potential use as stop-gap planting materials for tungro disease management.

### Stress tolerance — excess water

#### Inheritance of submergence tolerance at the early seedling stage in rainfed lowland rices

B. Swain, B. Acharya, K. Pande, and R.N. De, Central Rainfed Lowland Rice Research Station, IIT Campus, Kharagpur 721302, West Bengal, India

In the early seedling stage, mostly under direct-seeded conditions, lowland rice varieties are subjected to submergence because of erratic rainfall distribution and prolonged water stagnation. As a result, crop establishment is poor and productivity is low. Tolerance for submergence is therefore a highly desired trait of rainfed lowland varieties.

We studied the inheritance of submergence tolerance in four crosses involving two tolerant (T) varieties—FR43B and Rahaspanjar—and two susceptible (S) varieties—IR42 and Pankaj. Seeds of parents, \(F_1\) s, and \(F_2\) s of each cross were raised in galvanized-iron trays (70×60×15 cm) filled with clay soil on polythene sheet. Twenty lines with 15 seedlings line\(^{-1}\) were grown in each tray. Both parents and their \(F_1\) s were grown in a single line each, whereas the rest of the populations were raised in RCBD with three replications. Thirty-five-day-old seedlings were completely submerged in an artificial

<table>
<thead>
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<th>Cross</th>
<th>Submergence score</th>
<th>Seedlings in (F_2) (no.)</th>
<th>(\chi^2)</th>
<th>Ratio</th>
<th>Probability</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Parents (F_1)</td>
<td>(T)</td>
<td>(S)</td>
<td></td>
<td></td>
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<tr>
<td>FR43B (T)/IR42(S)</td>
<td>2.6 (T)</td>
<td>8.5 (S)</td>
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*\(T\) = tolerant, \(S\) = susceptible.
Ten rice lines with different responses to Zn deficiency were grown in a Zn-deficient soil with 0 (Zn0) or 10 (Zn10) mg Zn kg⁻¹ soil. The soil was a fine montmorillonitic calcareous Typic Hydramoll from Tiaong, Quezon, Philippines (DTPA-extractable Zn 0.04 mg kg⁻¹, pH 7.8). Portions (3 kg) of the soil were placed in plastic pots and flooded with water for 3 wk. Pre-germinated seeds were then sown and the plants were grown for 3 wk in a glasshouse under typical humid tropical wet-season conditions. The following measurements were made: Zn deficiency score by the IRRI Standard evaluation system for rice, number of leaves with Zn deficiency symptoms, number of tillers, plant height, shoot dry weight, and shoot Zn content.

ANOVA revealed significant differences among the populations in reaction to submergence. Submergence scores in the F₁s of four crosses-FR43B(T)/IR42(S), FR43B(T)/Pankaj(S), Rahaspanjar(T)/IR42(S), and Rahaspanjar(T)/Pankaj(S)—tended toward those of the tolerant parents.

In the F₂ generation, the segregation ratio was 9:7 (T:S) (see table). This ratio indicated that submergence tolerance can be explained by the complementary action of at least two genes. 

Stress tolerance — adverse soils

Performance of different rice lines in Zn-deficient soil

P. Thongbai, G.J.D. Kirk, C. Quijano, and D. Senadhira, IRRI

Nine indices of performance were calculated from the results and ranked (Table 1). These indices are all quantitative and Zn-specific, and could therefore be used for quantitative trait loci (QTL) analysis. The indices were used to distinguish different performance characteristics (Table 2).

Results showed that lines IR26, IR58, CSR10, and IR65 were intolerant of Zn deficiency, with IR26, CSR10, and IR65 tending to accumulate Zn without an increase in growth. Lines IR8192, Madhukar, FR13A, Ketumbar, and to a

Table 1. Performance indices for growth under Zn deficiency.

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<th>Performance index</th>
<th>Scoring</th>
<th>Ranking*</th>
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<td>Visual score in Zn0</td>
<td>IR26 IR58 IR65 CSR10 Ketumbar KDM105 IR9764 Mahsuri FR13A IR8192 Kuatik Madhukar</td>
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<td>Number of leaves with deficiency symptoms in Zn0</td>
<td>a: least, d: most</td>
<td>c b b a c a c a c a</td>
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<tr>
<td>Shoot dry wt/ shoot Zn concentration in Zn0</td>
<td>a: highest, c: lowest</td>
<td>c b c b b b b c a d</td>
</tr>
<tr>
<td>Shoot dry wt/ quantity of Zn in shoot in Zn0</td>
<td>a: highest, g: lowest</td>
<td>f b g e b b c f b a d</td>
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<tr>
<td>Shoot Zn concentration in Zn0</td>
<td>a: highest, e: lowest</td>
<td>a e a b e c b a e b d</td>
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<tr>
<td>Quantity of Zn in shoot in Zn0</td>
<td>a: highest, c: lowest</td>
<td>c c c c c b c a c a a</td>
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<tr>
<td>Av % growth (dry wt, tiller no.) reduction</td>
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<td>c d d c b b b b a a a</td>
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<tr>
<td>(Dry wt Zn0 / dry wt Zn10)%</td>
<td>a: highest, d: lowest</td>
<td>c a b d c a b d a d a</td>
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<tr>
<td>(Dry wt Zn0 - dry wt Zn10) / quantity of Zn supplied</td>
<td>a: highest, g: lowest</td>
<td>f e g b d f c a b a b b</td>
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</tbody>
</table>

Table 2. Performance characteristics based on indices in Table 1.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Index rankings required</th>
<th>IR26</th>
<th>IR58</th>
<th>IR65</th>
<th>CSR10</th>
<th>Ketumbar</th>
<th>KDM105</th>
<th>IR9764</th>
<th>Mahsuri</th>
<th>FR13A</th>
<th>IR8192</th>
<th>Kuatik</th>
<th>Madhukar</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tolerance deficiency</td>
<td>Low 1, 2, 7</td>
<td>L</td>
<td>L</td>
<td>ML</td>
<td>ML</td>
<td>H</td>
<td>MH</td>
<td>H</td>
<td>MH</td>
<td>MH</td>
<td>MH</td>
<td>H</td>
<td></td>
</tr>
<tr>
<td>Internal efficiency (transport and use within plant)</td>
<td>High 3, 4, 6; low 5</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>H</td>
<td>M</td>
<td>L</td>
<td>L</td>
<td>H</td>
<td>H</td>
<td>L</td>
<td></td>
</tr>
<tr>
<td>External efficiency (mobilization in rhizosphere, absorption)</td>
<td>High 3, 4, 6;</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>L</td>
<td>M</td>
<td>H</td>
<td>H</td>
<td>L</td>
<td>L</td>
<td>H</td>
<td></td>
</tr>
<tr>
<td>Responsiveness</td>
<td>High 8, 9</td>
<td>L</td>
<td>M</td>
<td>L</td>
<td>MH</td>
<td>M</td>
<td>L</td>
<td>M</td>
<td>MH</td>
<td>H</td>
<td>HH</td>
<td>MH</td>
<td>H</td>
</tr>
<tr>
<td>High accumulation (high shoot Zn with poor growth)</td>
<td>High 5, low 6</td>
<td>H</td>
<td>L</td>
<td>H</td>
<td>H</td>
<td>L</td>
<td>M</td>
<td>H</td>
<td>H</td>
<td>L</td>
<td>L</td>
<td>H</td>
<td></td>
</tr>
<tr>
<td>Low accumulation (low shoot Zn with good growth)</td>
<td>Low 5, high 6</td>
<td>L</td>
<td>MH</td>
<td>L</td>
<td>L</td>
<td>M</td>
<td>M</td>
<td>ML</td>
<td>L</td>
<td>HH</td>
<td>HH</td>
<td>L</td>
<td>H</td>
</tr>
</tbody>
</table>

*H = high, M = moderate, L = low.
lesser extent, KDML 105 were efficient in internal transport and use of Zn; IR9764, Mahsuri, Kuatik Putih, and to a lesser extent, KDML 105 were efficient in Zn acquisition from the soil. Lines IR8192, FR13A, and Madhukar were responsive to Zn addition as well as efficient in internal use.

Genetic variability and path analysis in rice grown in saline soil

O.M. Gonzales and R. Ramírez, Nuclear Laboratory of the Agricultural Research Institute "Jorge Dimitrov", Gaveta Postal 2140, Bayamo 85100, Granma, Cuba

Our study aimed to examine genetic variability, heritability, and correlation coefficients among different characters when rice varieties were grown under saline conditions. We estimated the genetic parameters of seven quantitative characters in 20 rice genotypes grown under saline conditions. The experiment was laid out in a randomized block design and replicated three times during 1995-96 on saline soils (4-5 dS m\(^{-1}\)) at the Rice Research Station “Jucarito,” Granma Province, Cuba. Hills were spaced 20 × 10 cm, with a single seedling hill\(^{1}\). Observations were recorded on five randomly selected plants replication–1.

The mean, standard deviation, phenotypic coefficient of variation (PCV), genotypic coefficient of variation (GCV), broad-sense heritability (\(h^2\)), and genetic advance as a percentage of mean (GA%) were calculated for seven traits. Path coefficient analysis was used to partition the genotypic correlation coefficient into direct and indirect effects.

Significant differences were observed for all traits, indicating great variability between genotypes. PCV was usually higher than GCV, but the difference was very low, indicating less environmental influence on the expression of different traits. The higher GCV and PCV for grain yield plant\(^{-1}\), panicle weight, and plant height provided better scope for improvement through selection for saline conditions (Table 1).

A moderate amount of variability (11-12%) was observed for panicles plant\(^{-1}\) and filled grains panicle\(^{-1}\), whereas a low GCV and low GA% were observed for panicle length and 1,000-grain weight. These indicated that the characters were under high environmental influence, and that selection based on these characters would be ineffective under saline conditions.

The high value of GCV, \(h^2\), and GA% estimated for grain yield plant\(^{-1}\), plant height, and panicle weight indicated the predominance of additive gene action, and that direct phenotypic selection based on these traits would be effective for varietal improvement on saline soils.

Grain yield plant\(^{-1}\) was positively and significantly correlated with panicle weight, filled grains panicle\(^{-1}\), 1,000-grain weight, and plant height, but negatively and significantly correlated with panicles plant\(^{-1}\). Panicle length did not show any correlation with yield (Table 2).

The path coefficient analyses also indicated that panicle weight, filled grains panicle\(^{-1}\), and plant height had the largest direct effect on yield. Thus, these three characters emerged as the main components of rice grain yield under saline conditions. Other characters, such as panicles plant\(^{-1}\), panicle length, and 1,000-grain weight, did not show any direct effect on yield, but they influenced yield via plant height. Panicle weight, filled grains panicle\(^{-1}\), and plant height appeared to be the most reliable indices for selection under Cuba’s saline conditions.

<table>
<thead>
<tr>
<th>Trait</th>
<th>Mean</th>
<th>Standard deviation</th>
<th>PCV(^a)</th>
<th>GCV</th>
<th>(h^2)</th>
<th>GA%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plant height (cm)</td>
<td>100.5</td>
<td>1.82</td>
<td>28.18</td>
<td>28.16</td>
<td>90.6</td>
<td>30.2</td>
</tr>
<tr>
<td>Panicles plant(^1) (no.)</td>
<td>9.6</td>
<td>0.80</td>
<td>11.52</td>
<td>11.48</td>
<td>94.8</td>
<td>21.4</td>
</tr>
<tr>
<td>Panicle length (cm)</td>
<td>24.8</td>
<td>2.24</td>
<td>3.00</td>
<td>2.97</td>
<td>37.2</td>
<td>12.9</td>
</tr>
<tr>
<td>Panicle weight (g)</td>
<td>4.3</td>
<td>0.52</td>
<td>22.84</td>
<td>22.80</td>
<td>89.4</td>
<td>22.8</td>
</tr>
<tr>
<td>Filled grains panicle(^1) (no.)</td>
<td>92.8</td>
<td>9.60</td>
<td>12.65</td>
<td>12.63</td>
<td>42.5</td>
<td>22.6</td>
</tr>
<tr>
<td>1,000-grain weight (g)</td>
<td>29.3</td>
<td>0.80</td>
<td>6.05</td>
<td>6.02</td>
<td>97.0</td>
<td>10.6</td>
</tr>
<tr>
<td>Grain yield plant(^1) (g)</td>
<td>12.6</td>
<td>2.62</td>
<td>39.86</td>
<td>39.84</td>
<td>97.2</td>
<td>34.5</td>
</tr>
</tbody>
</table>

\(^a\)PCV = phenotypic coefficient of variation, GCV = genotypic coefficient of variation, \(h^2\) = heritability, GA% = genetic advance as % of mean.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Plant height</th>
<th>Panicles plant(^1)</th>
<th>Panicle length</th>
<th>Panicle weight</th>
<th>Filled grains panicle(^1)</th>
<th>1,000-grain weight</th>
<th>Total genotypic correlation with yield</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.437</td>
<td>0.145</td>
<td>-0.043</td>
<td>0.078</td>
<td>0.027</td>
<td>-0.088</td>
<td>0.557**</td>
</tr>
<tr>
<td>2</td>
<td>-0.148</td>
<td>-0.026</td>
<td>0.040</td>
<td>-0.069</td>
<td>-0.011</td>
<td>0.066</td>
<td>-0.549**</td>
</tr>
<tr>
<td>3</td>
<td>0.118</td>
<td>0.107</td>
<td>-0.161</td>
<td>0.055</td>
<td>0.033</td>
<td>-0.082</td>
<td>0.270</td>
</tr>
<tr>
<td>4</td>
<td>0.249</td>
<td>0.213</td>
<td>-0.065</td>
<td>1.138</td>
<td>0.017</td>
<td>-0.062</td>
<td>0.691**</td>
</tr>
<tr>
<td>5</td>
<td>0.160</td>
<td>0.066</td>
<td>-0.073</td>
<td>0.033</td>
<td>0.575</td>
<td>-0.046</td>
<td>0.875***</td>
</tr>
<tr>
<td>6</td>
<td>0.170</td>
<td>0.124</td>
<td>-0.059</td>
<td>0.038</td>
<td>0.015</td>
<td>0.226</td>
<td>0.564**</td>
</tr>
</tbody>
</table>

*Residual effect = 0.082 direct effects. All others are indirect effects. ** = significant at 5% level, *** = significant at 1% level.
Satyam and Kishori, two high-yielding varieties developed for the rainfed lowlands of Bihar, India

R. Thakur, A.K. Singh, R.S. Singh, S.B. Mishra, N.K. Singh, and J.N. Rai, Rice Research Unit, Rajendra Agricultural University (RAU), Bihar, Pusa (Samastipur) 848125, India

Rainfed lowlands constitute nearly half of the total rice area in Bihar (2.7 million ha). The rice crop depends on the monsoon. When the monsoon is delayed, rice planting is also delayed. No high-yielding varieties (HYVs) are suitable for delayed conditions mainly because they flower at the end of October when low temperature sets in, causing nonuniform flowering and poor seed setting. Farmers therefore rely on traditional photoperiod-sensitive, tall cultivars that are tolerant of cold at flowering. HYVs are consequently grown under favorable conditions only.

To develop HYVs adapted to delayed monsoon conditions, crosses involving traditional cultivars (as one of the parents) were made in the early 1980s. Several cultures derived from IR8/Barogar and RD19/Desaria were tested under both normal and delayed monsoon conditions against standard checks in a regional trial. Based on average performance, many cultures were promoted to state multilocational variety trials with three replications in 1993. From 1993 to 1996, RAU1119-13-3-1 (Kishori) derived from IR8/Barogar and RAU3025-2-1B-2-1 (Satyam) derived from RD19/Desaria were superior to Radha and Pankaj (Table 1), the standard checks recommended earlier for normal planting conditions. Satyam had a 10.8% and 13.8% yield advantage over Radha and Pankaj, respectively, whereas Kishori yielded 13.5% and 16.6% more than the checks. These varieties were also tested in the multilocational Indian Council of Agricultural Research (ICAR)-IRRI collaborative shuttle breeding trial in eastern India, under both normal (30-d-old seedlings) and delayed planting (60-d-old seedlings) against checks adapted to rainfed lowland conditions, including Sabita, a photoperiod-

Table 1. Performance of Satyam and Kishori in state multilocational varietal trials conducted under normal planting conditions, 1993-96.

<table>
<thead>
<tr>
<th>Year</th>
<th>Site</th>
<th>Yield (t ha⁻¹)</th>
<th>LSD (at 5%)</th>
<th>CV (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Satyam</td>
<td>Kishori</td>
<td>Radha</td>
</tr>
<tr>
<td>1993</td>
<td>Patna</td>
<td>3.3</td>
<td>3.5</td>
<td>3.6</td>
</tr>
<tr>
<td></td>
<td>Pusa</td>
<td>5.6</td>
<td>3.8</td>
<td>4.6</td>
</tr>
<tr>
<td></td>
<td>Sabour</td>
<td>4.9</td>
<td>4.5</td>
<td>5.2</td>
</tr>
<tr>
<td></td>
<td>Bikramganj</td>
<td>6.0</td>
<td>2.7</td>
<td>6.1</td>
</tr>
<tr>
<td>1994</td>
<td>Patna</td>
<td>5.6</td>
<td>4.8</td>
<td>3.7</td>
</tr>
<tr>
<td></td>
<td>Sabour</td>
<td>3.4</td>
<td>3.8</td>
<td>2.3</td>
</tr>
<tr>
<td></td>
<td>Bikramganj</td>
<td>4.3</td>
<td>4.6</td>
<td>2.7</td>
</tr>
<tr>
<td>1995</td>
<td>Patna</td>
<td>2.0</td>
<td>3.9</td>
<td>2.0</td>
</tr>
<tr>
<td></td>
<td>Jhanjharpur</td>
<td>3.7</td>
<td>4.6</td>
<td>2.9</td>
</tr>
<tr>
<td></td>
<td>Pusa</td>
<td>3.1</td>
<td>4.1</td>
<td>1.6</td>
</tr>
<tr>
<td></td>
<td>Sabour</td>
<td>3.9</td>
<td>-</td>
<td>4.0</td>
</tr>
<tr>
<td></td>
<td>Bikramganj</td>
<td>3.6</td>
<td>-</td>
<td>4.8</td>
</tr>
<tr>
<td>1996</td>
<td>Pusa</td>
<td>4.3</td>
<td>4.3</td>
<td>4.1</td>
</tr>
<tr>
<td></td>
<td>Patna</td>
<td>3.4</td>
<td>4.0</td>
<td>3.0</td>
</tr>
<tr>
<td></td>
<td>Dhangain</td>
<td>5.5</td>
<td>5.7</td>
<td>5.8</td>
</tr>
<tr>
<td></td>
<td>Jhanjharpur</td>
<td>4.6</td>
<td>4.5</td>
<td>3.6</td>
</tr>
<tr>
<td></td>
<td>Pooled mean</td>
<td>4.1</td>
<td>4.2</td>
<td>3.7</td>
</tr>
<tr>
<td></td>
<td>Pooled LSD (5%)</td>
<td>1.3</td>
<td>1.1</td>
<td>1.5</td>
</tr>
</tbody>
</table>

*Mean of three replicates.

Table 2. Yield performance (t ha⁻¹) of Kishori and Satyam in ICAR-IRRI collaborative shuttle breeding trial in eastern India, 1994-96.

<table>
<thead>
<tr>
<th>Year</th>
<th>Site</th>
<th>Yield (t ha⁻¹)</th>
<th>LSD (at 5%)</th>
<th>CV (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Satyam</td>
<td>Kishori</td>
<td>Rajshree</td>
</tr>
<tr>
<td>1994</td>
<td>Masodha</td>
<td>-</td>
<td>5.6</td>
<td>7.0</td>
</tr>
<tr>
<td></td>
<td>Patna</td>
<td>5.9</td>
<td>2.1</td>
<td>4.3</td>
</tr>
<tr>
<td></td>
<td>Pusa</td>
<td>4.5</td>
<td>3.8</td>
<td>6.1</td>
</tr>
<tr>
<td></td>
<td>Titabar</td>
<td>5.1</td>
<td>4.4</td>
<td>4.3</td>
</tr>
<tr>
<td>1995</td>
<td>Patna</td>
<td>2.8</td>
<td>5.8</td>
<td>1.7</td>
</tr>
<tr>
<td></td>
<td>Pusa</td>
<td>6.3</td>
<td>3.2</td>
<td>5.6</td>
</tr>
<tr>
<td></td>
<td>Raipur</td>
<td>2.1</td>
<td>1.9</td>
<td>2.3</td>
</tr>
<tr>
<td>1996</td>
<td>Patna</td>
<td>5.3</td>
<td>2.3</td>
<td>5.1</td>
</tr>
<tr>
<td></td>
<td>Pusa</td>
<td>4.2</td>
<td>3.1</td>
<td>4.4</td>
</tr>
<tr>
<td></td>
<td>Masodha</td>
<td>6.2</td>
<td>3.8</td>
<td>5.3</td>
</tr>
<tr>
<td></td>
<td>Titabar</td>
<td>5.3</td>
<td>3.1</td>
<td>4.9</td>
</tr>
<tr>
<td></td>
<td>Pooled mean</td>
<td>5.0</td>
<td>3.6</td>
<td>4.6</td>
</tr>
<tr>
<td></td>
<td>Pooled LSD (5%)</td>
<td>1.5</td>
<td>1.3</td>
<td>1.8</td>
</tr>
</tbody>
</table>

*Transplanted at 30 d after sowing. Transplanted at 60 d after sowing. Direct seeding vs transplanting.
sensitive variety. They outyielded checks under normal and delayed planting conditions (Table 2). Because of their superior performance in numerous on-farm trials, Satyam and Kishori were released for general cultivation in rainfed lowlands for normal and delayed monsoon conditions.

Both have intermediate heights (120-125 cm), compact erect habit, and 145-150-d maturity. Satyam has long fine grains and Kishori has long bold grains. They are resistant to bacterial blight and tolerant of brown spot and Zn and Fe deficiencies.

**Integrated germplasm improvement — upland**

**On-farm characterization of upland rice varieties in north Thailand**

K. Van Keer, Laboratory for Soil Fertility and Soil Biology, KU Leuven tout court, 3001 Leuven, Belgium; G. Trebil and B. Courtois, IRRI, seconded from CIRAD-CA; C. Vejpas, IRRI

An on-farm diagnostic survey on the extent and causes of variability of upland rice yields was carried out during 1993-96 in Mae Haeng, Chiang Mai Province, in upper northern Thailand (600-700 masl).

Farmers’ varieties were characterized from physiological, agronomic, and genetic points of view. Data were obtained over four successive wet seasons from a total of 423 small squares (1 m²) from 63 farmers’ fields representing an extensive range of upland rice-cropping conditions under a predominant swidden cultivation system. Plots were monitored every 2 wk to quantify key physiological and agronomic parameters needed to understand yield buildup patterns of various types of cultivars. Isozyme analysis was carried out to assess the genetic variability of farmers’ upland rice varieties.

All upland rice cultivars were found to belong to group 6 (tropical japonicas) of Glaszmann’s classification. Heterogeneity was sometimes detected between samples of the same variety coming from different farms. The rare allele 3 at locus *Amp-1* typical of varieties from the Himalayan foothills was observed in some cultivars. Only two late-maturing varieties were found to be glutinous, a type of rice used to prepare rice cakes during traditional festivals.

Two main types of cultivars, early (95-115 d) and late maturing (138-177 d), were distinguished and played different roles on the farms. Late-maturing varieties clearly constituted the most important type in terms of production volume, whereas early maturing varieties were planted to improve food security before the main harvesting period. Early and late cultivars were found to be weakly and strongly photoperiod-sensitive, respectively. When expressed in degree days, crop duration cycle was evenly split between the vegetative and reproductive phases for early cultivars.

<table>
<thead>
<tr>
<th>Variety</th>
<th>Importance</th>
<th>Varietal group</th>
<th>Photoperiodism</th>
<th>Grain type</th>
<th>DD to PP</th>
<th>DD to harvest</th>
</tr>
</thead>
<tbody>
<tr>
<td>Early maturing types</td>
<td>Chaloina</td>
<td>Rare</td>
<td>Tropical japonica</td>
<td>Weakly sensitive</td>
<td>Nonglutinous</td>
<td>650</td>
</tr>
<tr>
<td></td>
<td>Kochokai</td>
<td>Rare</td>
<td></td>
<td></td>
<td></td>
<td>800</td>
</tr>
<tr>
<td></td>
<td>Chaloioe</td>
<td>Dominant</td>
<td></td>
<td></td>
<td></td>
<td>670</td>
</tr>
<tr>
<td></td>
<td>Kochole</td>
<td>Rare</td>
<td></td>
<td></td>
<td></td>
<td>590</td>
</tr>
<tr>
<td>Late maturing types</td>
<td>Chaae</td>
<td>Rare</td>
<td>Tropical japonica</td>
<td>Strongly sensitive</td>
<td>Nonglutinous</td>
<td>1060</td>
</tr>
<tr>
<td></td>
<td>Chanoko</td>
<td>Common</td>
<td></td>
<td>Glutinous</td>
<td></td>
<td>1060</td>
</tr>
<tr>
<td></td>
<td>Chafuma</td>
<td>Common</td>
<td></td>
<td>Nonglutinous</td>
<td></td>
<td>1000</td>
</tr>
<tr>
<td></td>
<td>Chazu</td>
<td>Rare</td>
<td></td>
<td>Nonglutinous</td>
<td></td>
<td>1230</td>
</tr>
<tr>
<td></td>
<td>Komu</td>
<td>Rare</td>
<td></td>
<td>Nonglutinous</td>
<td></td>
<td>1150</td>
</tr>
<tr>
<td></td>
<td>Chanona</td>
<td>Rare</td>
<td></td>
<td>Glutinous</td>
<td></td>
<td>860</td>
</tr>
</tbody>
</table>

*Based on isozyme analysis. *DD = degree-days (13 °C threshold temperature), PI = panicle initiation.

<table>
<thead>
<tr>
<th>Variety</th>
<th>Chaloina</th>
<th>Chaae</th>
</tr>
</thead>
<tbody>
<tr>
<td>Duration</td>
<td>Early</td>
<td>Late</td>
</tr>
<tr>
<td>Observations (no.)</td>
<td>75</td>
<td>234</td>
</tr>
<tr>
<td>Maximum grain yield (g m² at 0% H₂O)</td>
<td>308</td>
<td>438</td>
</tr>
<tr>
<td>Maximum 100-grain weight (g at 0% H₂O)</td>
<td>23.2</td>
<td>25.0</td>
</tr>
<tr>
<td>Threshold value for filled spikelets m⁻² (no.)</td>
<td>13,300</td>
<td>17,500</td>
</tr>
<tr>
<td>Maximum value for filled spikelets m⁻² (no.)</td>
<td>16,200</td>
<td>20,600</td>
</tr>
<tr>
<td>Maximum grain filling (%)</td>
<td>81</td>
<td>98</td>
</tr>
<tr>
<td>Threshold value for spikelets m⁻² (no.)</td>
<td>20,100</td>
<td>21,500</td>
</tr>
<tr>
<td>Maximum value for spikelets m⁻² (no.)</td>
<td>20,000</td>
<td>26,700</td>
</tr>
<tr>
<td>Maximum value for spikelets panicle⁻¹ (no.)</td>
<td>144</td>
<td>183</td>
</tr>
<tr>
<td>Threshold value for panicles m⁻² (no.)</td>
<td>155</td>
<td>146</td>
</tr>
<tr>
<td>Maximum value for panicles m⁻² (no.)</td>
<td>228</td>
<td>237</td>
</tr>
<tr>
<td>Maximum value for panicles plant⁻¹ (no.)</td>
<td>2.8</td>
<td>3.6</td>
</tr>
<tr>
<td>Threshold value for plants m⁻² (no.)</td>
<td>81</td>
<td>66</td>
</tr>
</tbody>
</table>

*Threshold value = value required to achieve the maximum for a particular yield component.*
whereas for late-maturing ones, the reproductive phase tended to be longer (Table 1).

For the two dominant varieties, Chaloina (early) and Chaae (late), maximum grain yields were measured in fields with no inputs applied but where environmental constraints were minimal. Yields for Chaloina and Chaae reached 308 and 438 g m⁻² at 0% H₂O, respectively (Table 2). These relatively high yields can thus be considered the maximum yield potential in the subsequent analyses of yield buildup processes and agronomic diagnosis of limiting factors and conditions.

Table 2 shows the maximum values of yield components unit area⁻¹ characterizing the classic four successive phases of the yield buildup processes. Threshold values corresponding to the minimum level of the previous yield components required to achieve the potential level of the following one are also provided.

The maximum number of panicles unit area⁻¹ was found to be similar for both varieties but was reached differently. Because of Chaloina’s lower maximum number of panicles plant⁻¹, it required a higher threshold of plants m⁻² to achieve a number of panicles (230 m⁻²) similar to the potential achieved by Chaae.

The differentiation in potential yields between Chaloina and Chaae started at spikelet formation and continued in the following phases. A higher maximum number of spikelets panicle⁻¹ was recorded for the late-maturing cultivar as well as a better rate of grain filling (possibly due to more favorable climatic conditions rather than genetic differences) and higher maximum grain weight.

These maxima and the associated threshold values for yield components can be used to construct an empirical model of upland rice yield buildup processes. Such a model can be used for either agronomic diagnoses of limiting factors of yield and for designing and evaluating improved sequences of cultivation practices.

### Crop resource management

#### Fertilizer management

### Evaluation of P sources in a rice - wheat cropping system in northwestern India

B. Singh, Y. Singh, T.S. Khera, C.S. Khind, and Rachna Nayyar, Soils Department, Punjab Agricultural University, Ludhiana 141004, India

Increasing costs have resulted in reduced applications of P fertilizers to rice - wheat systems in the Indo-Gangetic plains of India. Partly to address this issue, nitrophosphate P sources have been developed by acidulation of rock phosphate with nitric acid rather than imported and expensive sulfuric acid. These are cheaper than the traditional superphosphate and diammonium phosphate.

We evaluated three nitrophosphate P sources along with superphosphate and diammonium phosphate on wheat (1996-97) and rice (1997) grown in rotation at Ludhiana in northwestern India. The nitrophosphates contained 80% (Narmadaphos), 60% (ammonium nitrophosphate), and 30% (Suphala) of their total P in water-soluble form. Soil in the experimental field was a Fatehpur loamy sand with 9% clay, 83% sand, 0.33% organic C, pH 7.4, and 11.2 kg P ha⁻¹ (Olsen P). All P sources were applied at 17.6, 26.4, and 35.2 kg P ha⁻¹ in a randomized complete block design. No P was applied to rice. Nonetheless, the residual effect of the P sources in the following crop of rice was tested. Both wheat and rice were supplied with 120 kg N ha⁻¹ and 25 kg K ha⁻¹.

The table shows grain yield and P uptake for both rice and wheat. A significant response of wheat to application of P as superphosphate or diammonium phosphate was observed up to 17.6 kg P ha⁻¹. Nitrophosphate fertilizers possessing 60% and 80% P in water-soluble form were as efficient as wholly water-soluble sources in increasing grain yield and P uptake by wheat. The source with only 30% water-soluble P was significantly inferior to other sources even when applied at higher P levels. No residual effect of any of the five sources was observed on the yield and P uptake of rice.

**Effect of different applied phosphatic fertilizers on grain yield and P uptake by wheat following a crop of rice. Ludhiana, India, 1996-97.**

<table>
<thead>
<tr>
<th>P source</th>
<th>P level (kg ha⁻¹)</th>
<th>Wheat (t ha⁻¹)</th>
<th>P uptake (kg ha⁻¹)</th>
<th>Rice (t ha⁻¹)</th>
<th>P uptake (kg ha⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No P (control)</td>
<td>0</td>
<td>2.4</td>
<td>7.7</td>
<td>5.2</td>
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</tr>
<tr>
<td>Single superphosphate</td>
<td>17.6</td>
<td>3.8</td>
<td>12.3</td>
<td>5.4</td>
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</tr>
<tr>
<td></td>
<td>26.4</td>
<td>4.0</td>
<td>14.1</td>
<td>5.2</td>
<td>16.5</td>
</tr>
<tr>
<td></td>
<td>35.2</td>
<td>4.2</td>
<td>16.0</td>
<td>5.1</td>
<td>17.5</td>
</tr>
<tr>
<td>Diammonium phosphate</td>
<td>17.6</td>
<td>4.0</td>
<td>15.9</td>
<td>5.4</td>
<td>15.9</td>
</tr>
<tr>
<td></td>
<td>26.4</td>
<td>4.3</td>
<td>16.8</td>
<td>5.7</td>
<td>17.1</td>
</tr>
<tr>
<td></td>
<td>35.2</td>
<td>4.7</td>
<td>16.1</td>
<td>5.9</td>
<td>17.2</td>
</tr>
<tr>
<td>Narmadaphos (80% water-soluble P)</td>
<td>26.4</td>
<td>4.2</td>
<td>15.8</td>
<td>5.6</td>
<td>16.2</td>
</tr>
<tr>
<td></td>
<td>35.2</td>
<td>4.2</td>
<td>16.4</td>
<td>5.8</td>
<td>16.9</td>
</tr>
<tr>
<td>Ammonium nitrophosphate</td>
<td>17.6</td>
<td>4.2</td>
<td>15.4</td>
<td>5.2</td>
<td>16.3</td>
</tr>
<tr>
<td>(60% water-soluble P)</td>
<td>26.4</td>
<td>4.2</td>
<td>14.8</td>
<td>5.4</td>
<td>15.7</td>
</tr>
<tr>
<td></td>
<td>35.2</td>
<td>4.2</td>
<td>15.4</td>
<td>5.5</td>
<td>16.3</td>
</tr>
<tr>
<td>Suphala (30% water-soluble P)</td>
<td>26.4</td>
<td>3.6</td>
<td>13.6</td>
<td>5.7</td>
<td>17.0</td>
</tr>
<tr>
<td></td>
<td>35.2</td>
<td>3.7</td>
<td>13.6</td>
<td>5.2</td>
<td>16.6</td>
</tr>
<tr>
<td>LSD (P = 0.05)</td>
<td>0.3</td>
<td>0.7</td>
<td>ns</td>
<td>ns</td>
<td></td>
</tr>
</tbody>
</table>

*ns = not significantly different.*
Growth and yield response of improved and traditional rice varieties to N fertilization at various growth stages

S. Singh, Central Agricultural Research Institute, Port Blair 744101, India

Growth and yield response of rice varieties to N fertilization depend to a great extent on growth duration, plant type, and growth stage when N is applied. To determine the most responsive growth stage to N fertilization in both improved and traditional rice varieties, we conducted a pot experiment during the wet season with two distinct rice varieties—Mansarover (semitall, high-yielding, improved) and C14-8 (tall, lodging-susceptible, low-yielding, traditional).

Thirty-day-old seedlings of both varieties were transplanted in cement pots (30 × 30 × 30 cm) prefertilized with a full dose of P and K (40 kg ha⁻¹ each). The planted pots of both varieties were divided into seven treatments each: (T1) control (no N applied), (T2) low N (100 kg ha⁻¹) at active tillering (15 d after planting [DAP]), (T3) high N (200 kg ha⁻¹) at active tillering, (T4) low N at panicle initiation (PI), (T5) high N at PI, (T6) low N at 50% flowering, and (T7) high N at flowering. All treatments had five replications. A full dose of N (100 and 200 kg ha⁻¹) was applied only once at the respective growth stages. Plants were sampled at 50% flowering to record growth parameters such as leaf area per plant and specific leaf weight; growth and yield attributes were recorded at maturity.

Mansarover showed maximum growth and yield response to N applied at the vegetative growth stage (active tillering), followed by N applied at PI, but did not respond to N applied at flowering. C14-8, however, recorded the highest growth and yield responses to N applied at PI followed by N applied at flowering, but showed a nonsignificant response to N applied at active tillering (see table).

Irrespective of variety and growth stage, application of a high N level brought about greater leaf area expansion and lower specific leaf weight than a low N level. The high grain yield of rice varieties recorded under different treatments was mainly attributed to a greater leaf surface and more panicles plant⁻¹ and grains panicle⁻¹. The growth and yield responses of both rice varieties were invariably higher under high N level than under low N level. N application reduced harvest index in C14-8, which had a lower harvest index and produced more dry matter than Mansarover (see table).

The differential growth and yield responses of modern and traditional rice varieties to N fertilization in stages may perhaps be due to their distinct growth and phenological characteristics. The greater response of traditional tall late-duration variety C14-8 to late N fertilization was mainly due to the significant increase in panicle-bearing nodal tillers, whereas Mansarover failed to retain its panicle number with late N application.

Nitrogen fertilization at various growth stages did not show much

<table>
<thead>
<tr>
<th>Treatment/variety</th>
<th>Plant height (cm)</th>
<th>Leaf area plant⁻¹ (cm²)</th>
<th>Leaf area tiller⁻¹ (cm²)</th>
<th>Specific leaf weight (mg cm⁻²)</th>
<th>Days to maturity</th>
<th>Panicles pot⁻¹ (no.)</th>
<th>Grains panicle⁻¹ (no.)</th>
<th>1,000-grain weight (g)</th>
<th>Spikelet sterility (%)</th>
<th>Economic yield (g pot⁻¹)</th>
<th>Biological yield (g pot⁻¹)</th>
<th>Harvest index (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mansarover</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T1 - Control (no N)</td>
<td>98</td>
<td>13.9</td>
<td>107</td>
<td>5.6</td>
<td>140</td>
<td>11</td>
<td>86</td>
<td>25.7</td>
<td>21.8</td>
<td>20.5</td>
<td>44.1</td>
<td>46.0</td>
</tr>
<tr>
<td>T2 - N1 at T</td>
<td>114</td>
<td>40.6</td>
<td>150</td>
<td>6.0</td>
<td>145</td>
<td>23</td>
<td>101</td>
<td>25.2</td>
<td>13.3</td>
<td>56.5</td>
<td>124.5</td>
<td>47.0</td>
</tr>
<tr>
<td>T3 - N2 at T</td>
<td>115</td>
<td>45.3</td>
<td>181</td>
<td>5.9</td>
<td>147</td>
<td>28</td>
<td>89</td>
<td>24.6</td>
<td>27.0</td>
<td>61.3</td>
<td>138.0</td>
<td>44.0</td>
</tr>
<tr>
<td>T4 - N1 at PI</td>
<td>100</td>
<td>29.1</td>
<td>145</td>
<td>6.1</td>
<td>140</td>
<td>24</td>
<td>69</td>
<td>23.2</td>
<td>23.5</td>
<td>37.0</td>
<td>74.0</td>
<td>50.0</td>
</tr>
<tr>
<td>T5 - N2 at PI</td>
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<td>39.0</td>
<td>152</td>
<td>5.5</td>
<td>140</td>
<td>31</td>
<td>64</td>
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<td>45.6</td>
<td>95.0</td>
<td>48.0</td>
</tr>
<tr>
<td>T6 - N1 at F</td>
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<td>118</td>
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<td>87</td>
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<td>21.0</td>
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<td>T7 - N2 at F</td>
<td>98</td>
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<td>140</td>
<td>13</td>
<td>88</td>
<td>21.0</td>
<td>16.0</td>
<td>24.0</td>
<td>52.0</td>
<td>46.0</td>
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<td>Mean</td>
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<td>142</td>
<td>20</td>
<td>83</td>
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<td>23.3</td>
<td>38.4</td>
<td>81.4</td>
<td>47.0</td>
</tr>
<tr>
<td>C14-8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T1 - Control (no N)</td>
<td>140</td>
<td>12.7</td>
<td>115</td>
<td>6.7</td>
<td>175</td>
<td>10</td>
<td>91</td>
<td>25.0</td>
<td>17.5</td>
<td>20.8</td>
<td>52.3</td>
<td>40.0</td>
</tr>
<tr>
<td>T2 - N1 at T</td>
<td>155</td>
<td>24.8</td>
<td>146</td>
<td>6.1</td>
<td>175</td>
<td>20</td>
<td>64</td>
<td>27.2</td>
<td>13.5</td>
<td>34.7</td>
<td>126.0</td>
<td>28.0</td>
</tr>
<tr>
<td>T3 - N2 at T</td>
<td>159</td>
<td>39.0</td>
<td>150</td>
<td>5.7</td>
<td>174</td>
<td>23</td>
<td>97</td>
<td>25.4</td>
<td>24.5</td>
<td>53.5</td>
<td>189.6</td>
<td>28.0</td>
</tr>
<tr>
<td>T4 - N1 at PI</td>
<td>148</td>
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<td>144</td>
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<td>106</td>
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<td>41.7</td>
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<td>32.0</td>
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<tr>
<td>T5 - N2 at PI</td>
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<td>46.4</td>
<td>186</td>
<td>5.6</td>
<td>195</td>
<td>31</td>
<td>83</td>
<td>25.0</td>
<td>19.8</td>
<td>61.5</td>
<td>182.6</td>
<td>34.0</td>
</tr>
<tr>
<td>T6 - N1 at F</td>
<td>143</td>
<td>31.2</td>
<td>142</td>
<td>6.9</td>
<td>185</td>
<td>21</td>
<td>94</td>
<td>25.8</td>
<td>26.5</td>
<td>47.2</td>
<td>145.1</td>
<td>33.0</td>
</tr>
<tr>
<td>T7 - N2 at F</td>
<td>142</td>
<td>58.8</td>
<td>195</td>
<td>5.9</td>
<td>185</td>
<td>30</td>
<td>82</td>
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<td>20.8</td>
<td>55.0</td>
<td>170.5</td>
<td>32.0</td>
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<tr>
<td>Mean</td>
<td>148</td>
<td>34.5</td>
<td>159</td>
<td>6.1</td>
<td>183</td>
<td>21</td>
<td>88</td>
<td>25.5</td>
<td>20.2</td>
<td>45.0</td>
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</tr>
</tbody>
</table>

LSD (5%)

<table>
<thead>
<tr>
<th>Variety</th>
<th>Plant height (cm)</th>
<th>Leaf area plant⁻¹ (cm²)</th>
<th>Leaf area tiller⁻¹ (cm²)</th>
<th>Specific leaf weight (mg cm⁻²)</th>
<th>Days to maturity</th>
<th>Panicles pot⁻¹ (no.)</th>
<th>Grains panicle⁻¹ (no.)</th>
<th>1,000-grain weight (g)</th>
<th>Spikelet sterility (%)</th>
<th>Economic yield (g pot⁻¹)</th>
<th>Biological yield (g pot⁻¹)</th>
<th>Harvest index (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Man</td>
<td>4.3</td>
<td>0.6</td>
<td>8</td>
<td>ns</td>
<td>7</td>
<td>2.0</td>
<td>7.0</td>
<td>ns</td>
<td>ns</td>
<td>4.4</td>
<td>8.4</td>
<td>2.7</td>
</tr>
<tr>
<td>Treatm</td>
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<td>10</td>
<td>ns</td>
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<td>13.0</td>
<td>ns</td>
<td>ns</td>
<td>6.0</td>
<td>8.2</td>
<td>5.0</td>
</tr>
</tbody>
</table>

*N1 = low N (100 kg ha⁻¹); N2 = high N (200 kg ha⁻¹); T = tillering, PI = panicle initiation, F = flowering.
impact on days to maturity in Mansarover, but showed a marked effect on maturity period in C14-8 when applied at later growth stages, mainly because of a delay in maturity of nodal panicles. It is clear from the results that active tillering was the most N-responsive growth stage in high-yielding Mansarover, whereas the reproductive and flowering stages were found to be the most N-effective growth stages in traditional variety C14-8.

Crop management

Lock-lodge technology for rice ratooning

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Ratooning of rice could be an important crop establishment alternative in many agroecosystems. But low yield potential and asynchronous grain ripening constrain the widespread use of ratooning in the tropics. Braiding and lodging (lock-lodge method) the stubbles after harvest of the main crop can overcome these limitations considerably.

We tested the ratoon performance of varieties IR20, ADT38, CO 43, and Ponni in an experiment conducted at Tamil Nadu Agricultural University in Coimbatore in 1993-94 using both conventional and lock-lodge methods of ratooning. Results showed that lock-lodge ratooning consistently out-yielded the conventional method irrespective of variety. All the traits of the ratoon crop measured were significantly better in the lock-lodge ratoon crop. Grain yield of lock-lodge ratoon crop increased by 41.2% for Ponni to 82.7% for IR20 compared with their respective main crop (see table). Growth duration of lock-lodge ratoon ranged from 95 to 105 d, whereas that of conventional ratoon ranged from 62 to 97 d depending on variety.

### Grain yield and duration of main and ratoon rice varieties.

<table>
<thead>
<tr>
<th>Variety</th>
<th>Grain yield (t ha⁻¹)</th>
<th>Duration (d)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Conventional ratoon</td>
<td>Lock-lodge ratoon</td>
</tr>
<tr>
<td>IR20</td>
<td>1.4 (41.1)</td>
<td>2.9 (82.7)</td>
</tr>
<tr>
<td>CO 43</td>
<td>1.7 (38.9)</td>
<td>3.1 (70.8)</td>
</tr>
<tr>
<td>ADT38</td>
<td>1.3 (23.7)</td>
<td>3.0 (55.2)</td>
</tr>
<tr>
<td>Ponni</td>
<td>1.5 (26.1)</td>
<td>2.4 (41.2)</td>
</tr>
</tbody>
</table>

Numbers in parentheses indicate the percentage grain yield when compared with the respective main crop.

Disease management

Soil-borne and seed-borne pathogens of rice in rice - wheat system-based farmers' fields in Uttar Pradesh

A. Kumar, G.B. Pant University of Agriculture and Technology (GBPvAT), Pantnagar 263145, Uttar Pradesh, India; L. Willocquet and S. Savary, IRRI-ORSTOM Project on Rice Pest Characterization, IRRI; and U.S. Singh, GBPvAT

Pests (insects, weeds, pathogens) are an important component for sustaining rice - wheat systems. Among them, soil- and seed-borne pathogens may play a specific role. Cropping practices may affect the dynamics of these pathogens, both in their survival and epidemic phases. More specifically, the carryover role of other crops in rotation with rice may be critical for these diseases. Pathogen interactions may also alter disease patterns in a field. These interactions remain largely unknown, and we report here some preliminary results on this topic.

Disease incidence due to a few soil- and seed-borne pathogens was quantified in farmers’ fields for sheath blight (ShB, *Rhizoctonia solani*), stem rot (SR, *Sclerotium oryzae*), brown spot (BS, *Cochliobolus miyabeanus*), sheath rot (ShR, *Sarocladium oryzae*), panicle blast (PB, *Pyricularia grisea*), crown sheath rot (CShR, *Gaeumannomyces graminis*), and false smut (FS, *Ustilaginoidea virens*). These diseases can be transmitted by seeds (BS, ShR, PB, CShR) or survive as propagules in the soil or in plant debris (ShB, SR, BS, PB, CShR, FS) (Ou 1985). Glume discoloration (GD) symptoms were also considered because they are associated with the presence of different fungi, such as *P. grisea* and *C. miyabeanus*. Eight fields selected to represent a range of crops preceding rice were assessed: two with wheat (B3 and B6), one with rice (B4), one with sorghum (B1), one with maize (PP5), one with lentil (B9), one with fallow (PP2), and one with mint (PP3).

Diseases were assessed at the milk stage. In each field, 20 hills were sampled following a zigzag pattern. For each hill, the total number of tillers; number of tillers infected by ShB, SR, BS, and CShR; total number of panicles; number of panicles infected by ShR, PB, and FS; and number of panicles showing GD were recorded. Sheath blight, stem rot, brown spot, glume discoloration, and sheath rot were consistently observed in all eight
fields (see table). The other diseases, when present, occurred at low incidences (0-8%) and were not considered for multivariate analyses. The highest incidences were observed for ShB and BS (up to 68% and 85%, respectively), whereas ShR incidence remained below 20% in all fields (see table).

Sheath blight incidence was relatively high in all fields (around 20%) and reached 75% in PP5. Brown spot incidence varied widely between fields, from 0% to 90%. Stem rot was extremely variable too, but within a smaller range of incidence (2-35%). Sheath rot was observed in all fields, but at low incidence. Glume discoloration incidence was around 25% in all fields, except B4 and PP5, which had lower levels (10% and 3%, respectively).

Pearson coefficients of correlation were computed based on disease incidence data collected at the hill level. ShB and SR were negatively correlated (-0.388; P < 0.001), and BS was positively correlated with GD (+0.19; P = 0.013). Panicle blast was positively, negatively, and negatively correlated with ShB, SR, and GD, respectively, but these correlations should be interpreted cautiously, given the low levels of PB encountered. In a principal component analysis done on disease incidence, the first two axes explained 54% of total variance and the third axis explained 19% (see figure). The first axis mainly reflects a strong opposition between ShB and SR incidences. Axis 2 reflects the association between GD and BS. Axis 3 reflects the opposition between SR and BS.

These preliminary results point to different trends:

• Sheath blight and stem rot appear to be negatively correlated, perhaps because of differences in environments that favor these two diseases or competition between the corresponding propagules, during either the inoculum survival stage or the establishment of the first infections at the base of the rice plant.

• Glume discoloration is correlated with BS. Indeed, C. miyabeanus is reported as a fungus associated with GD.

• Sheath rot seems to be negatively associated with BS (see figure); this will have to be further documented.

• Linkages between rotations and disease levels can, cautiously, be hypothesized. For instance, in the case of ShB, PP5 showed an ShB level nearly twice that of other fields. This field was previously planted with maize, which can host R. solani AG 1-1A. The effect of the maize-rice system on ShB will have to be further documented.

Reference

Incidence of rice stripe necrosis virus in upland rice in West Africa

D.E. Johnson, M. Dingkuhn, S.N. Fomba, West Africa Rice Development Association, 01 BP 2551, Côte d’Ivoire; and F. Morales, Centro Internacional de Agricultura Tropical (CIAT), Colombia

Rice stripe necrosis (RSNV) is caused by a virus transmitted by the soil-borne fungus Polymyxa graminis. The disease is characterized by seedling death, leaf stripes and necrosis, and plant malformation. The disease was reported by Louvel and Bidaux in 1977 in Côte d’Ivoire, West Africa, and the virus was isolated by Fauquet and Thouvenel in 1983.

In 1991, the disease appeared in Colombia. Symptoms were initially attributed to soil and nutritional problems, aphids, and nematodes but subsequent studies identified the disease as RSNV. The disease spread rapidly and yield losses associated with
Number of rice hills with RSNV symptoms in a sample area of 160 hills at one upland site, 56 d after emergence, Côte d’Ivoire.

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Weed-free</th>
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<tr>
<td>WAB56-50*</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>WAB99-1-1*</td>
<td>6</td>
<td>36</td>
</tr>
<tr>
<td>ITA257*</td>
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<td>AUS257*</td>
<td>7</td>
<td>27</td>
</tr>
<tr>
<td>Digba Youba*</td>
<td>13</td>
<td>22</td>
</tr>
<tr>
<td>YS236*</td>
<td>8</td>
<td>9</td>
</tr>
<tr>
<td>WAB04325*</td>
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</tr>
<tr>
<td>WAB02097*</td>
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<td>0</td>
</tr>
</tbody>
</table>

*Improved Oryza sativa.  †Traditional O. sativa.  ‡O. glaberrima.

the presence of RSNV in Colombia averaged 20%, with some areas incurring losses above 50%.

In an experiment in Jan 1995, the reaction of rice cultivars to RSNV was compared in plots that were either hand-weeded once or maintained weed-free. This experiment revealed differences in RSNV incidence between cultivars at different weed control levels, especially between Oryza sativa cultivars that were affected to a great extent in plots with weeds (see table). The increased disease incidence in plots with weeds suggested that the disease may be encouraged by the presence of alternative hosts or that the rice plants when stressed due to competition with weeds, become more susceptible. The O. glaberrima cultivars in the experiment, however, were unaffected. The presence of RSNV in rice grown in Côte d’Ivoire in 1997 at the same experimental site which was affected in 1995 was positively confirmed by serological tests at CIAT, Colombia.

The high and increasing levels of crop loss caused by RSNV in Colombia necessitate studies on its distribution, mode of transmission, and control measures. Host resistance to RSNV clearly exists within O. glaberrima, and this could be exploited through interspecific hybridization with O. sativa to produce resistant cultivars. Nowadays in West Africa, RSNV incidence is at an extremely low level, which may be a function of the extensive nature of the upland rice production systems in the region and of the low level of mechanization. At sites in Sierra Leone and Côte d’Ivoire, where the disease has become a local problem, rice production was mechanized and relatively intensive. With the current intensification of rice-based farming systems in West Africa, the disease threatens to become increasingly more prevalent.

References


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Integrated pest management — diseases

Fifteen seed-borne fungi were detected from these seed lots (table). Of these, Bipolaris oryzae, Pyricularia oryzae, Fusarium moniliforme, Trichocomis padwickii, Rhizoctonia solani, and Microdochium oryzae have been reported to cause field diseases in Pakistan. The incidence of seed-borne fungi varied from one locality to another. Cercospora oryzae, M. oryzae,
Table continued.

<table>
<thead>
<tr>
<th>Locality</th>
<th>Samples tested (no.)</th>
<th>Fungi</th>
<th>% range</th>
<th>Samples tested (no.)</th>
<th>Fungi</th>
<th>% range</th>
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</tr>
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<td></td>
<td>19</td>
<td>(no.)</td>
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<td>37</td>
<td>(no.)</td>
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</table>

and *P. oryzae* prevailed in the Lahore area only. *Fusarium equiseti* was recorded only on seed from Hyderabad and Sukkur. Fewer seed-borne fungi were observed in seed samples from D.I. Khan. The involvement of *C. oryzae*, *Nigrospora oryzae*, *Phoma* spp., *Rhizoctonia oryzae*, and *Stemphylium* sp. in actual disease development has not yet been demonstrated.

Seed health testing is important to control crop diseases. The use of chemical seed treatment to improve seed quality and planting value has already been reported. Considering the prevalence and incidence of fungal pathogens in rice seed lots, Pakistan's seed health certification program should include fungicide treatment of prebasic seeds to control field diseases.

### Integrated pest management — other pests

**Pratylenchus zeae** in upland rice as influenced by ratio of intercropped maize

D.L. Coyne, Natural Resources Institute, Chatham Maritime, Kent ME4 4TB, UK; A. Ndondigila, West Africa Rice Development Association (WARDA), 01 BP 2551, Bouaké, Côte d'Ivoire; I. Oyediran, E.A. Heinrichs, Department of Entomology, University of Nebraska, 202 Plant Industry-East Campus, Lincoln, NE 68583-0816, USA; and R.A. Plowright, International Institute of Parasitology, 295a Hatfield Road, St. Albans, Hertfordshire, UK

In West Africa, maize is commonly relayed or intercropped with upland rice in traditional low-input systems. The density of maize as an intercrop may vary depending on many factors, including individual farmer preferences or country or region. Some nematodes that parasitize rice are common to maize, notably *Pratylenchus zeae*, which is a pest of both crops. This study was done to examine the influence of maize - rice intercropping on the population density of *P. zeae* in rice.

Nematode densities were recorded in a trial at WARDA, established to monitor the influence of crop ratios on the incidence of stem borer pests on upland rice. The migratory endoparasite *Pratylenchus zeae* and the ectoparasite *Helicotylenchus dihystera* were present in...
the trial area. The trial was first established in Jun 1995, continued for two successive seasons, and was irrigated when necessary. Nematode sampling was conducted on three occasions: at maturity of the second season, at 40 d after sowing (DAS), and at maturity of the third season.

Nematode populations from rice and maize in the different treatments were compared (see table). Populations at maturity across all treatments, combined by crop, were also compared (see figure).

Five maize plants and 5 hills of rice with soil were removed from each plot and bulked. Nematodes were extracted from a 100-mL soil and 5-g root subsample using the modified tray method.

Maize cv EV 8744 SR (BC6F2B # Sine’ 94B [110-d duration] and rice WAB 56-50 [115-d duration]) were direct-sown at 3 and 5 seeds hill⁻¹, respectively, on 12 × 12-m plots. Treatments were arranged in a randomized block design with four replications. The same design was retained throughout sole crops and maize-rice intercrops at ratios of 1:3 and 1:5. Treatment effects on nematode population densities were analyzed with two-way ANOVA.

Results indicated that intercropping with maize had no significant effect on the population density of *P. zeae* in rice roots. Furthermore, although maize is clearly a very good host for *P. zeae* (see figure), intercropping did not increase the population density of the nematode in either rice or maize in the second consecutive year of the trial.

In contrast, *P. zeae* numbers in soil from the rhizosphere of rice increased as the proportion of maize in the mixture increased (*P < 0.01*) (see table). This increase in soil population densities of *P. zeae* likely resulted from the migration of nematodes from heavily infested and senescing roots of neighboring maize crops at maturity. The impact of this migration on rice growth is likely to be greater where maize is sown early and harvested early in the rice season, as is often the case in West Africa, thereby releasing high populations of nematodes to invade rice roots. *P. zeae* is a recognized pest of both crops and is responsible for production losses. Using cultivars that express tolerance for resistance to nematodes would therefore be an advantage for these low-input systems.

**Table 1.** Mean nematode populations recovered from maize and rice plants under different ratios of intercrop.

<table>
<thead>
<tr>
<th>Nematode</th>
<th>2nd season (maturity)</th>
<th>3rd season (40 DAS)</th>
<th>3rd season (maturity)</th>
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<tr>
<td></td>
<td>Maize:Rice</td>
<td>Maize</td>
<td>Rice</td>
</tr>
<tr>
<td><strong>P. zeae (5 g roots)</strong></td>
<td>1:0</td>
<td>815</td>
<td>–</td>
</tr>
<tr>
<td></td>
<td>1:3</td>
<td>1210</td>
<td>455</td>
</tr>
<tr>
<td></td>
<td>0:1</td>
<td>1330</td>
<td>282</td>
</tr>
<tr>
<td>LSD</td>
<td></td>
<td>646</td>
<td>236</td>
</tr>
<tr>
<td><strong>P. zeae (100 mL soil)</strong></td>
<td>1:0</td>
<td>603</td>
<td>–</td>
</tr>
<tr>
<td></td>
<td>1:3</td>
<td>735</td>
<td>106*</td>
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<tr>
<td></td>
<td>0:1</td>
<td>590</td>
<td>28</td>
</tr>
<tr>
<td>LSD</td>
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<td>687</td>
<td>64</td>
</tr>
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</table>

* = significantly different (*P < 0.05* from rice monocrop), – = not sampled.

**Table 2.** Mean nematode densities for 100 mL soil and 5 g root

**Figure 1.** *Pratylenchus zeae* and *Helicotylenchus dihystera* densities: combined treatments for rice and maize sampled at maturity in the 2nd and 3rd cropping seasons.
Rodent pests of upland and lowland rice at a derived savanna site in Nigeria

A.A. Asimalowo, A.I. Ayodele, Wildlife and Fisheries Management Department, University of Ibadan; and B.N. Singh, c/o International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria

Rodents are one of the major pests damaging the rice crop in Nigeria. Their population, damage, and species variation were monitored in upland, rainfed, and irrigated lowland areas in the 1994-95 dry and wet seasons. These fields were located at different sites within the experimental farm at IITA, Ibadan. The location represents a derived savanna agroecological zone, with an average bimodal rainfall of 1,400 mm.

Rodent species were sampled by mechanical trapping, fecal droppings, and use of poisoned baits for identification. Damage was monitored at various growth stages of the crop. The total of all catches was used to calculate percentage of occurrence of individual species. Varietal preferences based on damage in different replicates were monitored in breeders’ trials. Zinc phosphide was first administered followed by coumatetralyl (0.375 ai) rodenticide to capture and manage the rodent population.

Ten rodent species were trapped (see table). In the uplands, three species—Arvicantis niloticus rufinus (Nile rat), Rattus morio (jumping mouse), and a lagormorph Xerus erythropus (ground squirrel)—were observed in the wet season. Three other species—Dasymys incomtus (shaggy rat), Mastomys natalensis (multimammate rat), and Steatomys caurinus (fat mouse)—were observed in the irrigated lowlands in both dry and wet seasons. All three species dig burrows in levees around fields.

Two other species, Malacomys longipes (swamp rat) and Rattus rattus frugivorus (black rat), overlap in both rainfed and irrigated lowlands. One species, Taterillus gracilis (slender gerbil), was observed in rainfed lowland fields only. Another large-sized species, Thryonomys swinderianus (cane rat), was observed in all three rice-growing ecologies and at all crop growth stages. In irrigated lowlands, it invades only during crop maturation, when fields are dry. The table shows crop damage stage and frequency of occurrence of each rodent pest. The multimammate rat occurred in the highest frequency (36%).

Rodent activities were mostly nocturnal but, at high population density, they were also seen during daytime. Only the ground squirrel was diurnal. All rat species, except for the cane rat, cut individual tillers at maturity. The cane rat damaged all tillers in a hill before proceeding to other hills. It also did not accept any poisoned or unpoisoned bait and therefore was controlled by wire fencing. Among the rice varieties tested, DJ11-307-15 was selectively attacked by the cane rat in the rainfed lowland yield trial in all three replications. The cane rat may have certain preference traits compared with other rodents. Many other rice varieties were attacked in one or two replications.

| Rodent species and crop damage stage in different rice-growing environments. |
|---------------------------------|------------------|-----------------|------------------|
| Common name                     | Scientific name  | Rice-growing    | Occurrence (%)   | Crop damage  | Months of damage |
|                                 |                  | environment and season |               | stage        |                 |
| Ground squirrel                 | Xerus erythropus | U;              | 3.3              | Tillering    | May to Aug      |
|                                |                  | WS              |                  |              |                 |
| Nile rat                        | Arvicantis      | U;              | 17.3             | Maturity     | Sep to Oct      |
|                                | niloticus       | WS              |                  |              |                 |
|                                | rufinus         |                 |                  |              |                 |
| Jumping mouse                   | Rattus morio    | U;              | 2.5              | Maturity     | Sep to Oct      |
|                                |                  | WS              |                  |              |                 |
| Fat mouse                       | Steatomys       | I;              | 5.3              | Maturity     | Apr to Aug      |
|                                | caurinus        | DS              |                  |              |                 |
| Shaggy rat                      | Dasymys         | I;              | 14.0             | Maturity     | Jun             |
|                                | incomtus        | DS              |                  |              |                 |
| Multimammate rat                | Mastomys        | I;              | 35.8             | Maturity     | Jun             |
|                                | natalensis      | DS              |                  |              |                 |
| Swamp rat                       | Malacomys       | I;              | 3.5              | Maturity     | Mar to Oct      |
|                                | longipes        | R;              | 5.1              |              |                 |
|                                |                  | WS, DS          |                  |              |                 |
| Black rat                       | Rattus rattus   | I;              | 0.3              | Maturity     | Mar to Oct      |
|                                | frugivorus      | R;              | 0.5              |              |                 |
|                                |                  | WS, DS          |                  |              |                 |
| Slender gerbil                  | Taterillus      | R;              | 6.6              | Maturity     | Oct to Dec      |
|                                | gracilis        | WS              |                  |              |                 |
| Cane rat                        | Thryonomys      | U;              | 2.3              | Vegetative   | May to Dec      |
|                                | swinderianus    | R;              | 1.5              |              |                 |
|                                |                  | I;              | 2.0              |              |                 |
|                                |                  | WS              |                  |              |                 |

*U = uplands, I = irrigated lowlands, R = rainfed lowlands, DS = dry season, WS = wet season.*
Farming systems

Potential of rice and potato inter/relay cropping system with sugarcane

G.P. Singh and S.N. Singh, Uttar Pradesh Council of Sugarcane Research, Shahjahanpur 242001, Uttar Pradesh, India

The planting spindle bud culture method was developed to exploit productivity and profitability per unit area. The method uses inter/relay cropping of rice and potato with sugarcane, and two sugarcane cuttings from the same piece of land in 1 1/2 yr. With this, the profitability of the system can be further improved by growing wheat as an intercrop after the cane’s second cutting in Nov-Dec.

After field preparation, 1-mo-old plantlets of sugarcane developed by the spindle bud culture technique were transplanted in rows at a distance of 90 cm on 20 Jun. Thereafter, five rows of rice (Saket 4) were transplanted 18 cm apart (normal spacing is 20 cm) in interrow spaces of sugarcane after flooding, followed by semipuddling by a plow. The rice crop, with a plant population of 100% on a per unit area basis, was harvested during the second half of Oct. After that, one row of potato was sown by the ridge method after field preparation, maintaining 50% of the plant population at a row-to-row distance of 45 cm. Potato tubers were harvested in the first half of Feb and yield was recorded.

The sugarcane crop planted on 20 Jun formed sparse canopies. The mature canes (first crop cutting) were harvested during the last week of Mar. Thereafter, stubbles along with water shoots and late-formed tillers were left to grow from Apr onward. Final harvesting was done in Nov and cane yield and quality characters were recorded. A split-plot statistical design was used, with planting technique as the main plot and inter/relay cropping system as the subplot.

The nutrient needs of all three crops were met separately based on standard recommendations. The field was fertilized with 180 kg N ha⁻¹ for sugarcane, and 120-60-60 kg NPK ha⁻¹ for rice and potato. In sugarcane, a basal dose of 1/4 N was applied at transplanting and the remaining 3/4 dose in four equal splits (two top-dressed after harvesting of rice and potato and the remaining two top-dressed after harvesting of mature canes after Mar at tillering). In addition, two foliar sprays of urea at 10% were given to the second crop of sugarcane in Jul. In rice and potato, the above nutrient doses were given based on the recommended application method.

Moreover, five manual hoeings/weedings were done in the interrow spaces of sugarcane to allow it to develop a full canopy.

The mean yield of transplanted rice intercropped with sugarcane was 4.3 t ha⁻¹, 17.4% more than that of direct-seeded rice (see table). Rice yield in this system was not affected adversely to a large extent due to sparse canopy and less tillering of sugarcane brought about by decreasing temperature, as shown by the sugarcane yield in the first cutting. But yield of intercropped cane averaged 18.2% less than that of sugarcane alone. Potato intercropped with transplanted sugarcane plantlets yielded more because of sufficient space for cultural operations. The yield of sugarcane using transplanted plantlets was 35% higher than the standard method, which reduced germination.

In the second cutting, sugarcane yield was much higher under inter/relay cropping than in sole cane. This is due to the dense canopy and greater

Production potentials of rice and potato inter/relay cropping system with sugarcane.a

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Rice yield (t ha⁻¹)</th>
<th>Potato yield (t ha⁻¹)</th>
<th>Yield of sugarcane (t ha⁻¹)</th>
<th>Commercial cane sugar (%)</th>
<th>Cost of cultivation (Rs ha⁻¹)</th>
<th>Gross return (Rs ha⁻¹)</th>
<th>Net return (Rs ha⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>First cutting</td>
<td>Second cutting</td>
<td>Total</td>
<td>First cutting</td>
<td>Second cutting</td>
</tr>
<tr>
<td>T1: Transplanting of sugarcane plantlets alone</td>
<td>-</td>
<td>-</td>
<td>43.4</td>
<td>89.2</td>
<td>132.6</td>
<td>10.8</td>
<td>11.0</td>
</tr>
<tr>
<td>T2: Transplanting of plantlets + rice (transplanted) – potato</td>
<td>4.2</td>
<td>16.5</td>
<td>37.2</td>
<td>101.5</td>
<td>138.7</td>
<td>10.7</td>
<td>10.7</td>
</tr>
<tr>
<td>T3: Transplanting of plantlets + rice (broadcast) – potato</td>
<td>3.5</td>
<td>15.4</td>
<td>36.3</td>
<td>99.4</td>
<td>135.8</td>
<td>10.4</td>
<td>10.7</td>
</tr>
<tr>
<td>T4: Sett® planting of sugarcane alone</td>
<td>-</td>
<td>-</td>
<td>29.7</td>
<td>74.1</td>
<td>103.9</td>
<td>10.5</td>
<td>10.3</td>
</tr>
<tr>
<td>T5: Sett planting + rice (transplanted) – potato</td>
<td>4.4</td>
<td>14.2</td>
<td>23.7</td>
<td>89.6</td>
<td>113.4</td>
<td>10.3</td>
<td>10.0</td>
</tr>
<tr>
<td>T6: Sett planting + rice (broadcast) – potato</td>
<td>3.7</td>
<td>13.0</td>
<td>22.5</td>
<td>86.8</td>
<td>109.3</td>
<td>10.4</td>
<td>10.7</td>
</tr>
</tbody>
</table>

aNet plot size used: 8 × 4.5 = 36.0 m². bPrevailing market prices: Sugarcane, Rs70 q⁻¹, Rice, Rs360 q⁻¹, Potato, Rs215 q⁻¹. cA sett is a mature cane cut into pieces of 2-3 internodes/nodes (eyes) and used for planting as a seed material.
number of cane plants caused by favorable temperature in April as well as by the residual effect of potato on cane plants. The commercial cane sugar (CCS) percentage in cane was more or less identical under different cropping systems. Overall performance for yield and economic returns of rice, potato, and sugarcane were higher under the inter/relay cropping system of sugarcane + rice-potato (preferably with transplanted plantlets) than under the sole cane crop. This method can be successfully adopted by small and marginal farmers after the May harvest of late-sown wheat.

### Farm machinery

**Rice-cum-green manure culture with modified drum seeder under lowland condition**

P. Rajendran, A. Tajuddin, and C. Ramaswami, Tamil Nadu Agricultural University, Coimbatore 641003, India

We initially investigated *Sesbania aculeata* as an intercrop in wet-seeded rice. Compared with rice alone, rice intercropped with green manure (GM) had a yield advantage when GM was incorporated at about 35–40 cm height. Mean height of the rice crop was 32 cm. Further work is required, however, to find cheaper ways of incorporating GM and weeding to reduce cultivation costs.

A modified seeder was developed based on the IRRI drum seeder design (Fig. 1). The seeder was field-tested in a 0.03-ha unreplicated plot in 1998. It has two wheels and sows rice and GM in alternate rows 12.5 cm apart. The seeder width is 0.75 m. The walking speed is around 1.5 km h⁻¹. Including time loss for unhooking and hooking the handle after each pass, two men can cover 0.54 ha d⁻¹. The advantages of the seeder are shown in Table 1.

The low seeding rate of GM (20 kg ha⁻¹) was due to seed availability.

The GM intercrop was trampled both manually and by using the IRRI single-row conoweeder at 36 DAS (Fig. 2). Table 2 shows the benefits of the technology.

This trial indicated the possibility of intercropping rice with GM as a potentially useful technology. Fine-tuning of the intercropping technology considering rice duration, cultivation season, and location is the focus of future research.

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<table>
<thead>
<tr>
<th>Table 1. Advantages of the seeder.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modified seeder for rice + GM intercropping</td>
</tr>
<tr>
<td>Duration, wet biomass addition, seeding rate of GM</td>
</tr>
<tr>
<td>Green manure height and number of nodules plant⁻¹</td>
</tr>
<tr>
<td>Rice establishment charges over same preparatory cultivation</td>
</tr>
</tbody>
</table>

*Includes additional cost for proper leveling.

<table>
<thead>
<tr>
<th>Table 2. Benefits of using the modified seeder.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trampling-cum-weeding by IRRI single-row conoweeder</td>
</tr>
<tr>
<td>Labor requirement (man-days)</td>
</tr>
<tr>
<td>Cost involved ha⁻¹</td>
</tr>
<tr>
<td>Additional benefit compared with no intercrop</td>
</tr>
</tbody>
</table>
CABI Bioscience training courses

Insect Pathology
30 Mar to 23 Apr 1999
This course draws on the expertise of the CABI Bioscience multidisciplinary biopesticide team and offers participants the opportunity to learn about the stages of biopesticide production, from exploration to registration. The course fee is £4,000. This does not include accommodation, although inexpensive university accommodation can be booked through CABI Bioscience for this course.

International Course on the Identification of Fungi of Agricultural and Environmental Significance
12 Jul to 13 Aug 1999
Training on the identification and classification of economically important fungi, particularly those associated with plant diseases and those that are difficult to identify. The course will take account of both tropical and temperate examples in all sections. The course fee of £3,900 includes all materials and the cost of self catering accommodation.

Entomology Foundation Course
23 Aug to 24 Sep 1999
This popular, intensive and practical course is designed to give participants the knowledge and skills they need to identify a broad range of insects, and to give an insight into their biology. The
course is intended for those with some previous experience of entomology, working in agriculture, forestry, or environmental protection worldwide. Advanced modules will be available on some orders immediately after the course. The course fee of £4,400 includes self-catering accommodation.

**Biological Control of Arthropod Pests and Weeds**

*30 Aug to 24 Sep 1999*

This course is aimed at agricultural researchers and extension workers, including crop protection staff who wish to broaden their knowledge of pest management. Participants will learn the principles and basic methodology of biological pest management, how to conserve predators and parasites, how to introduce natural enemies from the native habitat of exotic pests, and how to culture arthropod and microbial control agents for field release. The course fee of £3,600 includes tuition, all materials, and self-catering accommodation. ■

Note: For further details on all courses, please contact Mrs. Stephanie Groundwater, CABI Bioscience, UK Center, Egham, Surrey, TW20 9TY, UK. Tel: +44(0) 1784 470111. Fax: (01491) 829100. Email: S.Groundwater@CABI.org.

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**Errata**

- In vol. 23, No. 2 (1998), on page 45 (column 3), *Cnaphalocrosis* should be *Cnaphalocrocis*.
- *Leptocorisa acuta* should be *Leptocorisa oratorius*. The former is a misidentification and if it is present in the IRRI farm, its population is very low. *L. oratorius* is the most common and most abundant rice bug around. ■

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**IRRI 1999 Calendar of International Training Courses**

<table>
<thead>
<tr>
<th>Course/venue</th>
<th>Number of trainees</th>
<th>Duration in weeks</th>
<th>Inclusive dates</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basic Experimental Design and Data Analysis (IRRI)</td>
<td>15</td>
<td>2</td>
<td>1-12 Feb</td>
</tr>
<tr>
<td>Rice Production (IRRI)</td>
<td>25</td>
<td>2</td>
<td>18-29 Jan</td>
</tr>
<tr>
<td>Introduction to IRRIStat Statistical Software (IRRI)</td>
<td>15</td>
<td>1</td>
<td>1-5 Mar</td>
</tr>
<tr>
<td>Hybrid Rice Breeding</td>
<td>24</td>
<td>8</td>
<td>1 Mar-23 Apr</td>
</tr>
<tr>
<td>Introduction to SAS (IRRI)</td>
<td>15</td>
<td>1</td>
<td>26-30 Apr</td>
</tr>
<tr>
<td>Precision Rice Farming for Asia (IRRI)</td>
<td>20</td>
<td>4</td>
<td>Apr-May†</td>
</tr>
<tr>
<td>Instructional Video Production (IRRI)</td>
<td>12</td>
<td>4</td>
<td>7 Jun-2 Jul</td>
</tr>
<tr>
<td>Introduction to New Developments in G × E Analysis and Interpretation of Results (IRRI)</td>
<td>15</td>
<td>1</td>
<td>7-11 Jun</td>
</tr>
<tr>
<td>Analysis of Unbalanced Data (IRRI)</td>
<td>15</td>
<td>1</td>
<td>31 May-4 Jun</td>
</tr>
<tr>
<td>Analysis of Categorical Data (IRRI)</td>
<td>15</td>
<td>1</td>
<td>21-25 Jun</td>
</tr>
<tr>
<td>Rice Seed Health Training (IRRI)</td>
<td>10</td>
<td>12</td>
<td>5 Jul-24 Sep</td>
</tr>
<tr>
<td>Adaptive Research with a Farming Systems Perspective† (FSSRI, UPLB, College, Laguna, Philippines)</td>
<td>20</td>
<td>6</td>
<td>19 Jul-27 Aug</td>
</tr>
<tr>
<td>Integrated Pest Management in Rice‡ (NCPC, UPLB, College, Laguna, Philippines)</td>
<td>20</td>
<td>8</td>
<td>Aug-Oct‡</td>
</tr>
<tr>
<td>Soil &amp; Water Biochemistry Ecotoxicology (IRRI)</td>
<td>9</td>
<td>3</td>
<td>23 Aug-10 Sep</td>
</tr>
<tr>
<td>Applications of Molecular Tools to Study Rice Viruses§ (China / IRRI)</td>
<td>15</td>
<td>2-3</td>
<td>Sep</td>
</tr>
<tr>
<td>Genetic Evaluation and Utilization for Rainfed Rice Ecosystems‖ (URRC, Ubon, Thailand)</td>
<td>15</td>
<td>4</td>
<td>Sep-Oct‖</td>
</tr>
<tr>
<td>Transgenic Rice: Production and Deployment with Special Reference to Sheath Blight and Rice Stem Borer Resistance</td>
<td>13</td>
<td>3</td>
<td>27 Sep-17 Oct</td>
</tr>
<tr>
<td>Rice Production Research§ (PTRRC, Pathum Thani, Thailand)</td>
<td>25</td>
<td>8</td>
<td>Oct-Nov</td>
</tr>
</tbody>
</table>

† Two venues are being explored; to be finalized later. † Tentative schedule.

**Collaborative Regional Training Courses**

† Farming Systems and Soil Resources Institute (FSSRI), PhilRice, UPLB, and IRRI.
‡ National Crop Protection Center (NCPC), University of the Philippines Los Baños (UPLB).
§ Ubon Rice Research Center (URRC) and IRRI.
‖ Pathum Thani Rice Research Center (PTRRC) and IRRI.

Note: For more information about the IRRI training activities, please visit us at http://www.cgiar.org/irri/training
Instructions for contributors

NOTES

General criteria. Scientific notes submitted to the IRRN for possible publication should:
- 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 ordinarily accepted. Examples are single-season, single-trial field experiments. 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
- flood-prone (deepwater and 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. Restrict 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, and flood-prone (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 the International System of Units for measurements. For example, express yield data in metric tons per hectare (t ha⁻¹) for field studies. Do not use local units of measure.
- 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.

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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