Breeding rainfed rice for drought-prone environments: integrating conventional and participatory plant breeding in South and Southeast Asia
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drought-prone environments:
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plant breeding in South and Southeast Asia

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JR Witcombe, LB Parr and GN Atlin

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Preface

The papers in this volume were originally presented at a workshop held at the International Rice Research Institute (IRRI), 12–15 March, 2002. The workshop was jointly funded by the DFID Plant Sciences Research Programme (DFID-PSP) and IRRI.

The workshop brought together 50 participants, mostly from South and South East Asia, many of whom were plant breeders grappling with the problems of breeding varieties for difficult, water-limited environments.

As many of the papers recount, conventional breeding has had limited success in producing varieties for less-favourable environments. There is increasing interest in working more closely with farmers to overcome this constraint. Experiences described in the proceedings convincingly show how this approach can rapidly identify varieties that better meet the diverse needs of farmers.

There is recent evidence, from eastern India and Nepal, described in these proceedings, that working with farmers during the breeding process can produce varieties that not only yield more than the farmers’ current varieties, but also have superior quality traits. The cost-effectiveness of this approach depends on how widely farmers will adopt the varieties from participatory plant breeding (PPB). The adaptability and acceptability of these varieties indicates that the benefits from this approach should be far greater than the costs.

IRRI and DFID-PSP look forward to the results of what is hoped will be the highly successful collaborations in participatory plant breeding stimulated by this workshop.

Ronald Contrell
Introduction

Rainfed rice production environments, and the needs and preferences of the rural people who subsist in them, are extremely diverse. Rainfed environments are subject to high risk of crop loss due to such environmental stresses as drought and submergence. These risks, and the severe poverty of most rainfed rice farmers, limit the scope for increasing yields through the intensification of input use. Varietal improvement is therefore the most promising approach to increasing productivity and reducing risk in many rainfed production systems.

There is a widespread perception that conventional breeding approaches have been unsuccessful in developing improved varieties for rainfed environments. This perception is not entirely fair; conventional breeding approaches have been successful in developing several improved cultivars which are suited to low-input production and that have been widely adopted by farmers in rainfed environments. However, it is certainly true that the rate of development and adoption of improved cultivars has been lower in rainfed lowland than in irrigated environments, and that adoption of improved upland varieties has been minimal outside of very favourable environments.

The relatively limited impact of rainfed rice breeding has stimulated the development of approaches that emphasize farmer needs and preferences, and that focus on evaluating varieties under farmer management, in the often harsh and variable environments faced by rainfed rice farmers. This publication describes the efforts of many rainfed rice breeding programmes to increase their impact through the use of participatory methods and improved approaches to on-farm testing. The reports describe activities that range in scale from small participatory varietal selection (PVS) experiments conducted by individual research stations and involving 20 to 30 farmers through to an integrated programme of NGO- and GO-partnered participatory on-farm trials that collect varietal yield and preference data from hundreds of farms each year over a decade. The range in participatory methods is similarly great, covering degrees of farmer participation running from on-farm trials that are primarily researcher-managed, through PVS experiments that involve minimal researcher involvement and rely on farmer ratings, to programmes where farmers select in segregating generations. Common elements in these experiments include:

- Provision of a wider choice of germplasm for farmers to assess than is normally made available in minikit and demonstration-type, on-farm trials
- Planned collection of information on farmer preferences, and use of this information in selection decisions
- Evaluation of breeding materials under farmer management earlier in the varietal development process than is currently the norm

Several important technical and policy questions related to the effective incorporation of participatory methods in breeding and varietal selection programmes came into focus during the workshop. These include the following:

- How can PVS trials with more than one or two test varieties per farm be reliably conducted under full farmer management?
- How can cooking and eating quality be effectively evaluated in PVS programmes?
- How can information from PVS be incorporated into varietal release decisions?
- How can PVS be institutionalised in breeding programmes, and in the training of plant breeders?

Although these and other questions remain open, the workshop confirmed that rainfed rice breeders now have a suite of participatory methods of proven effectiveness available to them. The reports provide useful examples of successful approaches to PVS scale-up through the development of links with partners working in community-level agricultural development, and through the use of robust survey methods and farmer ratings to complement or replace conventional researcher-managed on-farm trials. The reports in these proceedings strongly support the hypothesis that the incorporation of broader choice, increased farmer participation, and more realistic evaluation in the target environment into rainfed rice breeding programmes can increase their effectiveness, and their impact on the food security and income of some of the world’s most impoverished farmers.

Gary Atlin and John Witcombe
Formal and participatory trials

The similarities and differences in the national varietal testing networks of India, Philippines, Kenya, Nepal and Bolivia were reviewed by Witcombe and Virk (1997). In these well-established systems varieties are tested in replicated, multilocational, on-station yield trials to identify varieties that should be released and recommended. We examine here how these trials function when they encounter such abiotic stresses as drought, a common constraint in rainfed rice.

The most common public-sector trial design is a randomised complete-block with three or four replications (Witcombe and Virk, 1997). Even though there are satisfactory statistical techniques of dealing with missing values in this experimental design, it is difficult for these to be accepted in a national varietal trial that involves entries from several breeders and institutions. Hence, during a drought if only a few entries actually produce grain, as in the example illustrated for India in Figure 1, a common practice is to discard the trial completely. Unfortunately, this means that the missing data are not considered, yet they are not really missing. Instead, they provide valuable information that, under severe drought, the varieties will fail.

Participatory varietal selection (PVS)

One way of solving the problem is not to discard the trials with missing values. However, in that case, at least some of the entries that have failed will need to be dropped or, missing values have to be calculated. Agreement on exactly what statistical rules to follow will be difficult to achieve, as different rules will favour different breeder’s entries. Participatory research – in particular PVS – offers a way out of this dilemma. If a new variety fails in a farmers’ field but the local variety survives, then this is valuable data that can easily be accommodated in assessing varietal performance. Unfortunately, participatory research is not simple and the history of obtaining poor-quality data from ‘minikits’ is a deterrent to its use. What is needed is reliable data from participatory trials. For scientists in the formal system this means:

- Having a partnership with a non-governmental organisation (NGO) or extension service that has already built a relationship with farmers
- Staff dedicated to research within the partner organisation. (This avoids a conflict between priorities for development activities and those for research)
- A systematic approach to participatory evaluation
Participatory crop improvement strategies in rice in DFID PSP

such as a Mother and Baby trials system as pioneered by Snapp et al., 1999 (see Appendix, page 79).

In PVS farmers are given a wide range of novel cultivars to test for themselves in their own fields.

A successful PVS programme has four stages:
1. Participatory rural appraisal (PRA) to identify farmers’ needs in a cultivar
2. A search for suitable material to test with farmers
3. Experimentation on the acceptability of this material in farmers’ fields
4. Wider dissemination of the cultivars farmers prefer.

It is important to note that this process is not simply a relabelling of old techniques such as front-line demonstrations or minikits. Traditional approaches do not start with a PRA; they offer little choice in new cultivars but only the few that have been selected after years of formal trials; they tend to involve only a few farmers; and management is improved by a ‘recommended package of practices’ that is beyond the resources and risk-taking capacity of most resource-poor farmers.

In the PSP Mother and Baby trials system all the varieties are grown in Mother trials in a one-field, one-replicate design. Typically, there are about 5–6 Mother trials. Baby trials are more numerous, with each farmer growing a single entry and comparing it to his or her local variety. In the Mother trials quantitative estimates of yield are obtained, but in the Baby trials PSP simply collects farmers’ perceptions on yield. A full protocol is available in the Appendix and on the PSP website (www.dfid-psp.org).

**PVS does not just identify better varieties**

One of the great strengths of PVS is that it is both an extension and a research method. For example, PVS trials in upland rice in Ghana resulted in a dramatic spread of new varieties to new villages over a single season (Craufurd et al., 2002).

**Participatory plant breeding (PPB)**

The breeding strategy that has been followed in PSP PPB programmes in Nepal and India involves:
- Making a careful choice of parents (often using PVS to help identify them)
- Making only a few crosses
- Using a large population size in each cross
- Selecting in the target environment with the participation of farmers
- Employing PVS to test the products derived from the PPB programme.

**Reason for the approach**

The capacity of any breeding programme is limited, and as more crosses are made the populations derived from them have to be smaller. However, theoretical considerations provide strong arguments for using large population sizes (Witcombe and Virk, 2001). Hence, one possible breeding strategy is to select a few crosses that are considered most likely to give desirable segregants and produce large populations from them. This strategy is well suited to the constraints and advantages of PPB in that:

- PVS aids the selection of parents. It is effective in identifying locally adapted parental material and in identifying breeding goals – for example, early maturity – that assists the selection of complementary parents
- Participatory breeding programmes conducted by NGOs will not have many resources to devote to such technical processes as making many crosses
- Large population sizes are easy to deal with when grown by farmers. For example, in collaborative breeding a farmer can cost-effectively grow and select from a very large population of rice. The farmer was, in any event, going to grow rice, and if the PPB material yields adequately, costs (or benefits) are only the difference between the yield of the population and the yield that the farmer would normally have obtained from his or her own variety.

There are two further important benefits from farmer participation:

- Selection is carried out in the target environment (minimising the untoward effects of genotype x environment interaction) and the selection is for traits that farmers consider important. When breeding for drought-prone environments in particular, conventional multilocational trials are difficult to analyse. Trials in the most drought-stressed environments produce many missing values and are often excluded for this reason, despite such trials being the most relevant to farmers. Participatory trials do not suffer from this disadvantage. Indeed, when a variety fails in a farmer’s field this gives valuable information on
We have adapted PPB methods to take advantage of the strengths of breeders and farmers. The breeders produce material that is genetically homozygous but highly heterogeneous by advancing the bulk populations from the F2 to the F5 generations with minimal selection (Figure 2). This means that we give bulks to farmers at a quite advanced generation when it is expected that there will be a good response to selection between plants, and when segregation in the next generation is no longer a major complicating factor.

A key element of PPB is the collaborative participation of farmers who grow a bulk on their own fields and select amongst it (see Gyawali et al., 2002 and Virk et al., 2002). Using this collaborative breeding, it is possible to replicate selection cost-effectively by giving seed of a particular bulk to many farmers. The selection is thus replicated across physical environments (different farmers’ fields) and across farmers (who may have different selection strategies and select for different traits that best meet their needs).

One great advantage of PPB is that it is much faster than conventional breeding (Virk et al., 2002). The economic value of this reduction in time can be very large (Pandey and Rajatasereekul, 1999).

Experimental evidence that the approach is effective
We now have empirical evidence that making few crosses in rice in PPB programmes is effective. The experiments, however, were not designed to make a comparison to such alternative approaches as a many-cross strategy. Nonetheless, the breeders involved in the programmes who have had experience of both few- and many-cross strategies appreciated the reduced complexity of a programme that uses fewer crosses. In Nepal, only three crosses are at a sufficient stage to have produced advanced lines. All three crosses have produced highly promising material, and farmers have already adopted several of them.

In India, three crosses are also at a stage where advanced lines have been produced, and again, all three crosses have been successful. If a low-cross-number strategy were incorrect it would be unlikely that of the five crosses attempted so far (one cross is common to both Nepal and India) all would have been successful.

We are aware that some of the parents we have used in our PPB programmes have been employed in many crosses in conventional breeding programmes, but have not produced advanced material. We assume that the most likely explanation is that F2 and F3 population sizes have been too small to recover and select desirable segregants.

PVS and PPB are combined
PVS is limited to employing the existing variation among cultivars, and sometimes well-accepted cultivars cannot be found. PPB, in which farmers select from segregating material, is particularly desirable when the PVS has failed to identify new varieties of significantly greater utility than existing ones. In our PPB programmes we exploit the results of PVS by using identified cultivars as parents of crosses. Weaknesses in cultivars are identified in the PVS programme and these cultivars can be crossed with varieties that have complementary traits to eliminate the potential acceptability of the variety and not just a missing value.

There is a very great reduction in the time needed to breed and test a new variety. Immediately a new product emerges from a PPB programme it is included in PVS, and rapid feedback on the desirability of the new material is gained.

Contrast to conventional breeding
The use of few crosses with large population sizes is not a common strategy. Many breeding programmes use many more crosses and hence restrict the size of the F2 populations that are evaluated. Depending on the circumstances, such a strategy may be correct. The optimum number of crosses will differ depending on how competitive the breeding is, how targeted it is to a specific environment, the type of parental material used, and whether the breeding can be considered strategic or adaptive.

Box 1

An example of PPB methods

We have adapted PPB methods to take advantage of the strengths of breeders and farmers. The breeders produce material that is genetically homozygous but highly heterogeneous by advancing the bulk populations from the F2 to the F5 generations with minimal selection (Figure 2). This means that we give bulks to farmers at a quite advanced generation when it is expected that there will be a good response to selection between plants, and when segregation in the next generation is no longer a major complicating factor.

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Figure 2. A schematic diagram of a PPB programme. Breeders control the process until the F4 generation, and then farmers collaborate from the F5 generation onward. Breeders include selected bulks in formal trials from the F6 generation. It is assumed that two crops of rice are grown per year.
those weaknesses, perhaps by crossing a high-yielding but low-grain-quality variety with one with superior grain characteristics, as exemplified by the cross Radha 32 x Kalinga III (Gyawali et al., 2002).

What we have found is that PVS and PPB are used in combination. We start with PVS and that helps to identify parents, then we carry out PPB. As soon as there are products from this PPB, we test them in PVS trials. This is a continuous process because new varieties whether introduced from classical breeding programmes or from PPB, are always becoming available and can be tested by PVS.

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References


Participatory plant breeding in rice in eastern India –
the success of an NGO/GO partnership

DS VIRK¹, DN SINGH², R KUMAR², SC PRASAD³, JS GANGWAR³ AND JR WITCOMBE¹

1. Department for International Development (DFID) Plant Sciences Research Programme (PSP), Centre for Arid Zone Studies (CAZS), University of Wales, Bangor, Gwynedd LL57 2UW, UK
2. Department of Plant Breeding and Genetics, Birsa Agricultural University (BAU), Kanke, Ranchi 834 006, Jharkhand, India
3. Eastern India Rainfed Farming Project, Gramin Vikas Trust (GVT), 280 Kanke Road, Near Pani Jahaj Kothi, Ranchi 834 008, Jharkhand, India

Abstract

We describe a participatory plant breeding (PPB) programme for upland rice targeted at the marginal areas where farmers appreciate very early-maturing varieties that can escape terminal drought. The PPB programme built on the results of participatory varietal selection (PVS) by using a variety identified in a PVS programme – Kalinga III – as a parent. Two types of farmer participation were employed – consultative and collaborative – and both were successful in producing varieties superior to those currently available.

Introduction

Farmers in the Chotanagpur plateau of eastern India still predominantly grow rice landraces. There are several reasons why the Green Revolution has bypassed these areas. There has been less investment in agricultural research for more marginal areas, and models of plant breeding that have worked for more productive, irrigated areas have been applied without any adaptation to harsher, lower-yielding environments. In addition, the needs of farmers in new varieties have been little considered. We used more participatory approaches to better meet the needs of farmers, and they are outlined in this paper.

Release of rice varieties from participatory plant breeding (PPB)

The first superfine, high-yielding and early-maturing rice varieties have recently been identified for release for rainfed uplands in eastern India, following a highly successful participatory plant breeding (PPB) programme. The programme was based on a unique partnership between an Indian non-governmental organisation (NGO), an Indian governmental organisation (GO), and a UK university funded by the DFID Plant Sciences Research Programme (PSP).

The PPB programme focused on the strategy of using carefully chosen parents, few crosses and large populations (Witcombe and Virk, 2001). Parents for crosses were selected by participatory varietal selection (PVS) so that at least one parent was locally adapted. The second parent was chosen to have complementary traits and be high-yielding and genetically distant in order to target a range of rice ecosystems. We used bulk-population and pedigree-bulk breeding.

Three crosses were made: Kalinga III x IR36, Kalinga III x IR64 and Kalinga III x Vandana. Of these, the Kalinga III x IR64 cross is the most advanced and is described below.

A cross between Kalinga III and IR64 was made by the International Rice Research Institute (IRRI) at the request of the Centre for Arid Zone Studies (CAZS). The F1 seed of the cross obtained from IRRI was grown in the rainy season of 1997 at the Gramin Vikas Trust–Birsa Agricultural University (GVT–BAU) research farm, Ranchi, Jharkhand, and advanced in the off-season of 1997/8 at the Central Rice Research Institute, Cuttack.

In the subsequent F2 generation two types of farmer participation were employed:

- Collaborative participation: Farmers participated collaboratively using bulk-population breeding. Farmers were provided with the entire F1 bulk from the cross to grow in their own fields and make selections in the main season of 1998.
- Consultative participation: This involved farmers visiting the research station to evaluate F1 pedigree-
PPB in rice in eastern India – the success of an NGO/GO partnership

bulks (each F₄ pedigree-bulk was derived from the bulk seed of a single F₃ progeny row derived from a single F₂ plant). These F₄ pedigree-bulks were grown by scientists at the GVT–BAU research station in Ranchi, in the main (rainy) season of 1998. The farmers, both male and female, came from villages served by the GVT Indo-British Rainfed Farming Project.

After advancing the material by one generation during the dry season of 1998/9, the two most-selected pedigree bulks on the research station (Ashoka 228 and Ashoka 238), and one selected bulk population produced by a farmer from an F₄ bulk grown in his field (Ashoka 200F), were promoted to formal research trials. These trials, conducted in the main season of 1999, were the state trials in Jharkhand and the All India Coordinated Rice Improvement Project trials (Initial Variety Trial – Very Early).

The performance of Ashoka 200F and Ashoka 228 in the varietal trials at BAU, Ranchi was outstanding (Table 1). In these trials, both new varieties matured in less than 95 days and were more resistant to lodging than Kalinga III. They have slender grains of good cooking quality — particularly Ashoka 228. Farmers like both varieties for the rainfed uplands.

Although Ashoka 238 performed almost as well as the other two varieties in yield trials it was dropped because of its poor grain quality. This illustrates the importance of testing for quality before entering varieties in yield trials to save resources (Gyawali et al., 2002). The varieties performed better in Mother and Baby trials (see Witcombe, 2002) particularly so in the Baby trials that were closest of all to farmers’ conditions (Table 2).

As a result of their good performance in the trials, BAU released Ashoka 200F (as Birsa Vikas Dhan 109) and Ashoka 228 (as Birsa Vikas Dhan 110) in May 2001 for general cultivation in Jharkhand in rainfed uplands. The breeding strategy of using a few crosses and large populations with both consultative and colla-borative participation has rapidly produced improve-ments over Kalinga III, the most widely adopted upland rice variety in India.

PPB is also producing promising genotypes for situations other than uplands. In F₄ population bulks of two crosses we monitored farmers’ selection in their fields in Jharkhand and West Bengal. One farmer, Saikya Mahato, of Jhabra village in West Bengal selected semi-dwarf segregants in the Kalinga III x IR64 cross that were high-yielding and early-maturing, to produce a promising variety for the medium-upland rice ecosystem (Figure 1).

The farmer used such multiple-selection criteria as plant height (68 cm), early maturity (100–115 days), disease/pest resistance, no lodging, drought tolerance, more straw, high yield and superior grain quality. It can be

### Table 1. Grain yield of Ashoka 200F and Ashoka 228 compared to the control varieties, Birsa Gora 102 and Kalinga III, in the main cropping seasons of 1999, 2000 and 2001

<table>
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<tr>
<th>Entry</th>
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<th>Yield (% of BG 102)</th>
<th>Yield (% of Kalinga III)</th>
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<tr>
<td>Ashoka 200F</td>
<td>2.58*</td>
<td>128</td>
<td>119</td>
</tr>
<tr>
<td>Ashoka 228</td>
<td>2.55*</td>
<td>127</td>
<td>118</td>
</tr>
<tr>
<td>Birsa Gora 102</td>
<td>2.01</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Kalinga III</td>
<td>2.16</td>
<td>–</td>
<td>–</td>
</tr>
</tbody>
</table>

* significantly higher than Kalinga III and BG 102 at \(P<0.05\)

### Table 2. Gramin yield of Ashoka 200F and Ashoka 228 compared to the control varieties, Birsa Gora 102 and Kalinga III, in the main season 2000 and 2001

<table>
<thead>
<tr>
<th>Entry</th>
<th>Yield (t ha⁻¹)</th>
<th>LSD 5%</th>
<th>Yield (% of BG 102)</th>
<th>Yield (% of Kalinga III)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mother trials</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ashoka 200F</td>
<td>1.38</td>
<td>–</td>
<td>151</td>
<td>119</td>
</tr>
<tr>
<td>Ashoka 228</td>
<td>1.42</td>
<td>–</td>
<td>156</td>
<td>123</td>
</tr>
<tr>
<td>Birsa Gora 102</td>
<td>0.91</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Kalinga III</td>
<td>1.16</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
</tbody>
</table>

| **Baby trials** |               |        |                     |                         |
| Ashoka 200F v BG 102 | 1.52 v 1.08 | 0.42   | 141                 | –                       |
| Ashoka 200F v Kalinga III | 1.46 v 1.17 | 0.29   | –                   | 125                     |
| Ashoka 228 v BG 102 | 1.64 v 1.26 | 0.19   | 130                 | –                       |
| Ashoka 228 v Kalinga III | 1.57 v 1.33 | 0.12   | –                   | 118                     |
PPB in rice in eastern India – the success of an NGO/GO partnership

Figure 1. Saikya Mahato of Jhabra village, West Bengal in his selected F₇ bulk of the Kalinga III x IR64 cross, rainy season 2001

seen from Figure 1 that by the F₇ generation in 2001 the uniformity of the variety is, at the least, acceptable. Saikya Mahato selected this variety from the F₄ generation starting in 1998 and continued to grow it until at least 2002.

This is an example of the self-motivated interest that farmers can take in collaborative PPB, and how cost-effective the process can be for both the farmer (who gains early access to superior material) and the breeder (who can replicate selection across environments and farmers with limited input from salaried staff).

Another farmer in Jharkhand is continuing to grow selections from the Kalinga III x IR36 bulk for the same ecosystem. He applied a mild selection pressure, employing all the criteria used by the West Bengal farmer. The resultant variety still retains much variation. These farmer selections will be evaluated in on-station and on-farm trials in the main season of 2002.

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References


Participatory plant breeding in rice in low-altitude production systems in Nepal

S Gyawali1, KD Joshi2 and JR Witcombe3

1. Local Initiatives for Biodiversity, Research and Development (LI-BIRD), PO Box 324, Bastolathar, Mahendrapul, Pokhara, Nepal
2. Department for International Development (DFID) Plant Sciences Research Programme (PSP), Centro Internacional de Mejoramiento de Maiz y Trigo (CIMMYT), South Asia Office, Singh Dubar Plaza Marg, Bhadrakali, Kathmandu, Nepal
3. Department for International Development (DFID) Plant Sciences Research Programme (PSP), Centre for Arid Zone Studies (CAZS), University of Wales, Bangor, Gwynedd LL57 2UW, UK

Abstract

Since 1998 we have undertaken a participatory plant breeding (PPB) programme in rice targeted at the more-favourable rice-production environments in low-altitude areas of Nepal. We used a few crosses from which large bulk populations were derived, and the bulks were selected using various methods and differing degrees of farmer involvement. Results showed that collaboration with farmers was effective in improving the efficiency and cost-effectiveness of the breeding programme. Several varieties have been produced by the programme for contrasting niches that have performed better than existing check varieties in participatory trials.

Introduction

We describe a participatory plant breeding (PPB) programme for low-altitude rice-growing environments in the inner Terai of Nepal. Although the target population of environments (TPE) was initially the rice fields of high-potential production systems (HPPSs), less-favourable rainfed environments, or those with limited irrigation water were increasingly targeted.

The objectives of the project were to test the applicability of PPB in more-favourable environments, to develop varieties of greater utility to farmers through PPB, and to promote them more widely in the target environments, using participatory methods.

Breeding strategy

The PPB programme used only a few crosses from which large populations were produced (Witcombe and Virk, 2001). This was because PPB fits well with the particular constraints and advantages of working with farmers, and because the approach is soundly based in theory. Because few parents are employed, their choice is crucial. Participatory varietal selection (PVS) can help a great deal in this process because it can identify both parents and important target traits. Carefully chosen parents were crossed and a large population size maintained in subsequent generations, all of which were grown in farmers’ fields in different production systems, from upland to lowland, in both the early (Chaite) and main seasons.

We used bulk, modified-bulk and pure-line-from-bulk breeding methods (Figure 1). In the modified-bulk method, a bulk population derived from a single cross (Kalinga III × IR64) was divided at the F4 generation into sub-bulks on the basis of traits that were known from participatory rural appraisals to be important to farmers, i.e., plant height, maturity and grain type (length × breadth ratio and length). At this stage, many of the sub-bulks were eliminated after farmers were consulted on desirable grain shapes and target maturities.

The sub-bulks were still heterogeneous because seed was harvested from many selected F4 plants. Hence, farmers were given a heterogeneous bulk of nearly homozygous plants for selection in their fields for what we termed ‘collaborative modified-bulk breeding’ (Figure 1).

The modified bulks were also used as sources from which pure lines were extracted for joint evaluation by farmers and plant breeders – consultative pure-line-from-bulk breeding in Figure 1.

The collaborative breeding programme allowed the cost-effective replication of selection across a range of environments (farmers’ fields in several rice ecosystems) and across farmers who employed varying selection
criteria and techniques. Overall, the modified-bulk breeding programme has produced a range of promising genotypes for all of the target rice ecosystems. Farmers are involved in the evaluation of these entries using standard PVS techniques. We often refer to this as ‘PVS on PPB products’ to distinguish it from the initial process of PVS that aided parental identification, or from PVS on introductions from classical breeding programmes.

**Results and discussion**

**Collaborative breeding has produced at least one promising variety**

One of the most promising entries from the Chaite season in 2001 participatory trials was Judi 141F, a farmer-selected bulk from sub-bulk ET (Early tall) of the Kalinga III x IR64 cross. It was preferred in these trials to Chaite variety CH 45, the most widely grown variety in this season. It was greatly preferred to the breeder-selected ET bulk because the breeders’ bulk was later-maturing without having a higher yield.

This confirms the findings in Chaite rice of Joshi et al., (2002) that breeders can be misled into selecting for a maturity that matches the most popular variety that farmers currently grow. In pure-line-from-bulk breeding (Figure 1) breeders’ and farmers’ selections were compared in a nursery of several hundred advanced Chaite rice lines. Lines selected by neither of the two breeders but only by farmers were all earlier-maturing than CH 45. In all cases, breeders had not selected them because they had a high incidence of disease.

Nonetheless, it underlines that farmers place higher emphasis on earliness than breeders. Farmers rarely selected entries that matured at the same time as CH 45, let alone later entries, thus indicating their dissatisfaction with the long duration of this variety.

**Early participatory testing of grain quality is cost-effective**

We have also undertaken a breeding programme for quality rice based on a very large irradiated population of Pusa Basmati 1. This breeding programme, however, cannot be simply described as a mutation breeding programme, since molecular marker studies (Katherine Steele, CAZS, pers. comm.) have shown that the original population had many segregants derived from natural outcrossing. We found that participatory organoleptic testing cost-effectively eliminated many entries before the yield trial stage. It is much cheaper to eliminate an entry for poor grain quality (grain shape, milling percentage, cooking quality, and taste) than to eliminate it for poor field performance in either participatory or on-station trials.

**Selecting for disease resistance**

In PPB it is important to select strongly for disease resistance and, during the initial generations advanced by breeders, resources are devoted to removing plants with disease symptoms from the bulks. In collaboration with the Nepalese Agricultural Research Council (NARC) the advanced PPB entries are tested in disease nurseries (leaf and neck blast, and bacterial leaf blight).
10 Participatory plant breeding in rice in low-altitude production systems in Nepal

and none of the 15 lines tested so far has been rejected for disease susceptibility.

This result is a combination of exerting strong selection pressures and using crosses where both parents were disease-resistant under Terai conditions. We would not recommend using resistant x susceptible crosses for PPB unless there are adequate resources for disease screening.

Conclusions

With limited resources and no research station facilities this PPB programme, conducted entirely in farmers’ fields has produced 11 varieties for a range of ecosystems that were preferred over farmers’ current varieties in participatory trials (Table 1). These varieties are under seed multiplication and their acceptability is being tested in further trials. In collaboration with the Department of Agriculture and several NGOs, seed is being supplied to the informal seed supply system in 18 of the 21 districts in the Terai of Nepal.

Table 1. Promising genotypes in participatory trials, main season 2001 and Chaite season 2002, from the PPB programme and the ecosystem and seasons to which they are adapted

<table>
<thead>
<tr>
<th>Variety</th>
<th>Pedigree</th>
<th>First tested in PVS</th>
<th>Ecosystem¹</th>
<th>Grain type</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Chaite</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Judi 141F²</td>
<td>Kalinga III x IR64</td>
<td>2002</td>
<td>U</td>
<td>Medium coarse</td>
</tr>
<tr>
<td>Judi 503</td>
<td>Kalinga III x IR64</td>
<td>2002</td>
<td>MU, ML</td>
<td>Medium coarse</td>
</tr>
<tr>
<td>Judi 580</td>
<td>Radha 32 x Kalinga III</td>
<td>2002</td>
<td>ML, L</td>
<td>Coarse long</td>
</tr>
<tr>
<td>Judi 582²</td>
<td>Radha 32 x Kalinga III</td>
<td>2002</td>
<td>ML, L</td>
<td>Coarse long</td>
</tr>
<tr>
<td><strong>Main season</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sugandha 1</td>
<td>Irradiated PB 1³</td>
<td>2001</td>
<td>U, MU</td>
<td>Medium coarse, aromatic</td>
</tr>
<tr>
<td>Barkhe 1027</td>
<td>Kalinga III x IR64</td>
<td>2001</td>
<td>U</td>
<td>Medium coarse</td>
</tr>
<tr>
<td>Barkhe 2001</td>
<td>Irradiated PB 1³</td>
<td>2001</td>
<td>MU, ML</td>
<td>Medium fine</td>
</tr>
<tr>
<td>Barkhe 2026</td>
<td>Irradiated PB 1³</td>
<td>2001</td>
<td>MU, ML</td>
<td>Medium coarse</td>
</tr>
<tr>
<td>Barkhe 2027</td>
<td>Irradiated PB 1³</td>
<td>2001</td>
<td>MU, ML</td>
<td>Medium coarse</td>
</tr>
<tr>
<td>Barkhe 3004</td>
<td>Kalinga III x IR64</td>
<td>2001</td>
<td>ML</td>
<td>Medium fine</td>
</tr>
<tr>
<td>Barkhe 3010</td>
<td>Kalinga III x IR64</td>
<td>2001</td>
<td>ML, L</td>
<td>Medium</td>
</tr>
</tbody>
</table>

1. U = upland; MU = medium upland; ML = medium lowland; L = lowland
2. Also suitable for upland main-season conditions
3. PB1 = Pusa Basmati 1

Acknowledgement

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References


The role of participatory crop improvement for upland rice in Ghana

W Dogbe¹, R Bam³, PQ Craufurd², K Marfo³, P Dorward², A Opoku-Apau³, J Bimpong¹, D Djagbeti¹, K Gyasi¹, E Asiedu¹

1. Savanna Agricultural Research Institute (SARI), PO Box 52, Nyankpala, Tamale, Ghana
2. Plant Environmental Laboratory, The University of Reading, Cutbush Lane, Shinfield, Reading, RG2 9AD, UK
3. Crops Research Institute (CRI), PO Box 3785, Kumasi, Ghana

Abstract

To date, few improved cultivars of rice adapted to upland or hydromorphic conditions have been released in Ghana, and seed of improved cultivars is not readily available. A formal Seed Release Committee exists in Ghana but there is no multilocational testing system to identify new rice varieties. Most upland rice farmers continue to grow traditional Oryza glaberrima or old O. sativa varieties or landraces obtained from informal sources. High yield and weed competitiveness are important characteristics wanted by all farmers, male and female. However, female farmers also rank harvest and post-harvest characteristics highly.

Since 1997, a participatory varietal selection (PVS) programme has been implemented in one or two communities in the forest zone (Volta and Western Regions) and savanna zone (Northern, Upper East and Upper West Regions) of Ghana. Rice in the forest zone is pure upland, while in the savanna zone it is hydromorphic. These programmes vary in whether they are researcher, non-governmental organisation (NGO) and extension, or community managed. In Volta Region, where the PVS process first started, a number of varieties have been adopted and given local names (e.g., 'You'll not be tired' to reflect the ease of threshing). Seed has spread rapidly, initially from kin to kin both within and between neighbouring villages, and seed has also been sold on the open market at a premium.

In fora where farmers, extension officers and plant breeders have discussed these participatory activities, there seems to be a consensus that participatory methods are a good way to promote new varieties and are useful to breeders because farmer preferences can be determined and farmer practices better understood. However, there is no agreement on how to combine these approaches with a conventional multilocational testing and release system. Neither is there agreement on how to test and release varieties using participatory means in the absence of a conventional multilocational testing system. Experience from upland rice in Ghana and elsewhere in West Africa has shown the potential of participatory crop improvement approaches, but these approaches are yet to be incorporated into the formal testing and release process.

Introduction

Rice is an important staple food crop in Ghana and per capita consumption has increased steadily. However, most of the increase in consumption is met from imports. Increasing rice production in Ghana is a priority. About half the rice area is in the upland and hydromorphic ecosystems divided equally between the northern and southern parts of the country. To date, few improved cultivars of rice adapted to upland or hydromorphic ecosystems have been released and their seed is not readily available. This paper reports data and experience from a PVS programme initiated in Ghana in 1997 (Opoku-Apau, 2001).

Upland and hydromorphic rice production environments and practices

In northern Ghana (Northern, Upper East and Upper West Regions), which is in the savanna agroecological zone, rice is grown under predominately hydromorphic conditions (i.e., some standing water for part of the season). Mean annual rainfall is about 1000 mm, and falls between May and October. Drought is a major constraint. Rice is usually sown on ridges prepared by animal traction or tractor. Weeding and harvesting are done manually. Fertilizer is used, but there are no other inputs. All rice is par-boiled during post-harvest processing. Both male and female farmers grow rice.
A wide range of cultivars is grown in this region – up to 11 in one village, ranging in age from 5 to >50 years old, and none of them has been formally released.

In southern Ghana (Volta Region in the east, and Western Region), which is in the humid forest zone, rice is grown in inland valleys (rainfed-lowland) and on the slopes (uplands). Mean annual rainfall is about 1500 mm and the rainfall pattern is weakly bimodal; rains start in March and end in December, with a break in August. There are therefore two seasons; a major season from March to July and a minor season from September to December. Upland rice is grown as part of a slash-and-burn system and is usually broadcast or dibbled following clearing and burning. All operations are done by hand and few inputs are used. Both male and female farmers grow rice. Cultivar diversity is low in the forest zone, and in Volta Region most farmers continue to grow cultivars of *Oryza glaberrima*, such as Viono or Kawumo. These are valued for the preparation of local dishes. In contrast, in Sayerano in the Western Region, 95% of the area is sown to a single variety, Agya Amoah. It is an *indica* type that was introduced from Côte d’Ivoire in 1983 by Mr Agya Amoah.

**Production constraints**

Male and female farmers identify a number of different production constraints. In the forest zone male farmers cite weeds as the biggest constraint, followed by bird damage, drought and seedling damage by rodents. Female farmers regard birds as the main constraint, followed by a lack of fencing (to keep out rodents).

In the savanna zone, weeds are also a major constraint, along with low fertility, access to seed, and drought. Female farmers also cite lack of access to animal traction for land preparation as a constraint.

**Characteristics farmers would like to see in new varieties**

Male and female farmers in the savanna and forest zones identified and ranked characteristics they considered important (Table 1). This was done by considering the good and bad characteristics of traditional cultivars and by showing farmers plant and grain samples of new varieties. Male farmers in both zones wanted varieties that were high-yielding (and also chose characteristics associated with yield) and suppressed weeds. Disease resistance was wanted in the forest zone and drought tolerance (early maturity) in the savanna zone. Female farmers also regarded high yield, drought tolerance and early maturity that allow escape from terminal drought as important. However, in contrast to male farmers, female farmers also identified several post-harvest characteristics as important. These included taste, aroma, ease of threshing, good expansion ability and good milling quality without par-boiling.

**Participatory varietal selection (PVS) in Ghana**

PVS programmes have been conducted at four locations in Ghana: Hohoe in Volta Region, Sayerano and Aferi in Western Region, Nyankpala and Tolon in Northern region and Tambalug and Nyorigu in Upper East Region. These PVS programmes have all used nurseries (i.e., a Mother trial) in the first year and then seed distribution to individual farmers in the second or subsequent years (i.e., Baby trials). However, the way in which these nurseries and seed distribution have been managed has varied from the whole process being managed by researchers, through to NGO and extension facilitation, to trials being wholly community-managed.

The first PVS in Ghana started in 1997 at Hohoe. Approximately 100 varieties were selected for the PVS from throughout the West African region along with new interspecific (*O. sativa* × *O. glaberrima*) progenies. These were grown in 10-m² plots at a favourable upland site under either improved (clean weeding, added fertilizer) or farmer (one weeding, no fertilizer) management. Approximately 30 male and female farmers evaluated the varieties several times during the growing season. Post-harvest cooking and taste evaluations were also conducted with farmers and with rice traders in two major markets. This process was repeated in 1998 with about 50 varieties selected from the original 100.

<table>
<thead>
<tr>
<th>Forest zone</th>
<th>Savanna zone</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Men</strong></td>
<td><strong>Women</strong></td>
</tr>
<tr>
<td>High yield</td>
<td>High yield</td>
</tr>
<tr>
<td>Suppress weeds</td>
<td>Taste</td>
</tr>
<tr>
<td>Disease resistant</td>
<td>Suppress weeds</td>
</tr>
<tr>
<td>High tillering</td>
<td>Early maturity</td>
</tr>
<tr>
<td>Will not lodge</td>
<td>Aroma</td>
</tr>
<tr>
<td>Large grains</td>
<td>Large grains</td>
</tr>
</tbody>
</table>

Source: unpublished PRA in Hohoe, Sayerano, Tambalug and Nyorigu
In Hohoe, variety IDSA 85 was chosen by all male and female farmers in the flowering and harvest evaluations (Figure 1). It was chosen because of its long slender grains and hence its high market price (i.e., it had similar grain to that of imported rice). IDAS 85 is also high-yielding and easy to thresh. Subsequent on-farm comparisons confirmed its acceptability, along with several other varieties chosen by farmers during the PVS. These have all been given local names (Table 2) and are spreading rapidly from farmer to farmer.

**Seed dissemination pathways**

Following the PVS in Hohoe, seed of eight varieties was distributed to farmers around Hohoe in 2000 through a number of different 'channels'. These included: individual farmers who participated in the PVS evaluations; a seed producer group; through the chief farmer or lead farmer; through an extension officer; by wealth categories; and through a mobilisation officer/local politician. Seed given to six villages in 2000 had spread up to 40 km by 2001 (Figure 2). In general, seed was distributed first to kin or sold outside the village, though in some communities farmers did not sell or give any seed away, preferring to multiply it for themselves. Word about the new varieties spread rapidly through kin relations, and demand for seed was very high. Where seed was sold, it fetched a premium of 20 to 30% above the price for local seed.

The most successful dissemination mechanism was that of the mobilization officer, who set up a village seed committee to run a seed fund on the basis of 1 kg borrowed and 2 kgs returned. After the first year, when the seed fund had grown, the original seed committee set up similar committees in neighbouring villages.

**PVS and varietal release in Ghana**

Ghana has a formal variety or seed release system and a publicly funded foundation seed production system. For release the Seed Release Committee requires evidence

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**Table 2. Local names give by farmers in Todzi, near Hohoe, Volta Region to cultivars selected from a PVS in 1997 and 1998**

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Local name</th>
<th>Translation</th>
</tr>
</thead>
<tbody>
<tr>
<td>IDSA 85</td>
<td>Idana</td>
<td>You'll not be tired (threshes easily)</td>
</tr>
<tr>
<td>Iguape Cateto</td>
<td>Leyawor</td>
<td>I will not perish</td>
</tr>
<tr>
<td>WAB 340-B-B-9-13-4-B</td>
<td>Kaeme</td>
<td>Remember me</td>
</tr>
<tr>
<td>WAB 209-5-H-HB</td>
<td>Elebode</td>
<td>Is good to eat</td>
</tr>
<tr>
<td>WAB 160-24-H-HB</td>
<td>Adime</td>
<td>Saviour</td>
</tr>
<tr>
<td>WAB 224-16-HB</td>
<td>Eleme</td>
<td>It's good for me</td>
</tr>
<tr>
<td>WAB 450-24-3-2-P18-HB</td>
<td>Malamany</td>
<td>I'll take care and see</td>
</tr>
<tr>
<td>WAB 56-50</td>
<td>Eteyale</td>
<td>It will be well</td>
</tr>
</tbody>
</table>

Source: Crops Research Institute (CRI), unpublished
The role of participatory crop improvement for upland rice in Ghana

of yield and stability, evidence of organoleptic quality and consumer acceptance, and evidence of on-farm performance and farmer acceptance. However, no varieties have been formally released for upland or hydromorphic ecosystems. One reason for this is that there is no multilocational testing system for rice. Given the above, can a PVS programme contribute to the release and seed dissemination mechanisms?

In discussions with breeders and those involved in seed release, most felt that PVS and participatory on-farm testing processes are useful and appropriate means for disseminating released cultivars. However, these approaches were not deemed appropriate for release. There was a clear difference between those who took the view that all that mattered was whether farmers grew a new variety or not, and that therefore the priority should be to get seed to farmers to test on their own farms, and those who thought the decision should rest with the research institutes. One of the major objections to PVS and on-farm testing processes for release was that the quantitative data needed for the release process could not, or would not, be collected. To a large extent, the Mother and Baby trial system advocated by many experienced PVS practitioners meets these objections.

Conclusions and recommendations

Based on the experience gained with PVS in Ghana since 1997, we recommend the following:

- Any proposed PVS programme should be preceded by a seed multiplication and a Cultivar Needs Assessment (see below). The success of the PVS process is highly related to the availability of an adequate quantity of seed and this should be produced before starting the programme. Seed multiplication can also be used for evaluation by farmers.
- A Cultivar Needs Assessment, i.e., focussed participatory rural appraisal (PRA) to discuss desired varietal characteristics is very valuable. We propose that this should be done in the growing season when plants and grain samples can be shown. This can be combined with, or replaced by, a visit by some members of the community to another PVS nursery. The process is also facilitated by researchers being able to visit farms and see the local cultivars. This needs
The role of participatory crop improvement for upland rice in Ghana

assessment should include traders and consumers, as well as farmers. If possible, cooking and taste evaluations of candidate varieties for PVS should be included at this stage, as these are such important characteristics. Time spent on post-harvest traits at the start of the process will save time and effort later, but they do require the availability of sufficient seed.

- In the first year a nursery or Mother trial(s) is necessary, and this should probably be researcher- or facilitator-managed. However, the community should be actively involved and decide how many such trials there should be and where they should be sited. Researchers can collect meaningful quantitative data from these trials for release purposes.

- In the second and subsequent years, a Mother and Baby trial system or, if data for release are not needed, a Baby system (i.e., on-farm, paired comparisons) is preferred.

- Data collection. In our experience communities have been more than capable of keeping good records when they are motivated.

- Community managed PVS. We have had mixed results with this, at least in the first year of a PVS process. Initially, many farmers lack motivation and are unsure of the benefits and sometimes suspicious of the motives of others. It may be preferable to initially target lead or respected farmers if the trial is not going to be researcher-managed.

Reference

Combining molecular marker technology and participatory techniques: A case study for drought-tolerant rice in eastern India I: Molecular breeding strategy

KA STEELE, G EDWARDS AND JR WITCOMBE

Department for International Development (DFID) Plant Sciences Research Programme (PSP), Centre for Arid Zone Studies (CAZS), University of Wales, Bangor, Gwynedd LL57 2UW, UK

Abstract

Participatory plant breeding (PPB), like conventional breeding, is predicted to give a low response to selection for traits with low heritability. These include many traits that farmers consider desirable, such as drought resistance. The technology of marker-assisted selection (MAS) can be used to make selection for traits with low heritability more effective. We describe how MAS can be used to assist in breeding for drought tolerance in upland rice.

Introduction

We are carrying out marker-assisted selection (MAS) for drought-tolerance-related traits. We have done this on large populations of young rice plants grown in the glasshouse at Bangor, or on rice plants grown in India from which DNA has been sampled. We are following three different strategies for combining participatory plant breeding (PPB) with molecular marker techniques. These are:

1. Backcross-MAS to pyramid root quantitative trait loci (QTLs) that should impart tolerance to drought, and a QTL controlling aroma in the grain
2. Modified single large-scale MAS, to create bulk populations for PPB
3. Marker-evaluated selection in which changes in allele frequency are assessed in a range of PPB products to enable the design and creation of ideotype varieties.

Strategy 1. MAS for root QTL and aroma

Drought is a serious abiotic constraint for rice farmers of eastern India (Pandey et al., 2000) Their land is often drought-prone because of sloping fields and shallow soils, and rainfall is unpredictable. These farmers predominantly grow landraces or varieties that are selections from landraces. Modern, improved varieties often have poorer drought tolerance than landraces. This can, in part, be due to poorly developed root systems so farmers prefer to grow local landraces with deep root systems (Ekanayake et al., 1985; Lafitte et al., 2001). PPB and participatory varietal selection (PVS) in eastern India have been successful (Virk et al., 2002) indicating that farmers appreciate being given a greater choice of varieties and are willing to adopt them if they are superior.

The popular variety Kalinga III is susceptible to lodging and has a poor root system, making it prone to early season drought. Several mapping studies have identified QTLs for root traits in segregating populations and have identified QTLs in the variety Azucena which increase root length, thickness and penetration ability (Price and Tomos, 1997; Price et al., 2000; Price et al., 2002; Yadav et al., 1997).

We targeted four QTLs from Azucena controlling root traits (on chromosomes 2, 7, 9 and 11) that had large effects and were stable across experiments. These regions have all been shown to contain QTLs for drought-related traits in several crosses evaluated by other workers (for review see Zhang et al., 1999). We selected for these four target regions in a backcross marker-assisted selection (BC-MAS) programme using Kalinga III as the recurrent parent. A fifth, highly heritable QTL for aroma on chromosome 8 was also selected. The purpose of the backcrossing was to test the effectiveness of the QTL mapping in identifying regions that would contribute to drought tolerance and aroma.

The target QTL are not fine-mapped and hence are quite large genomic regions. The flanking markers for the BC-MAS programmes are 61 cM apart for the QTL on chromosome 2, 53 cM for chromosome 7, 33 cM for
Combining molecular marker technology and participatory techniques: Molecular breeding strategy

chromosome 9, and 39 cM for chromosome 11. The flanking markers for the aroma QTL were 22 cM apart, but we have also used a single marker that is estimated to be near the QTL (Lorieux et al., 1996).

The flanking markers used for selection were restriction fragment length polymorphisms (RFLPs) and simple sequence repeats (SSR or microsatellites). Selection was made for the target regions in BC1, BC2, and BC3. At the BC3 generation, lines with at least two of the target regions were also screened with 30 background markers at non-target regions; two lines with higher frequencies of Kalinga III alleles at background regions were selected. These lines were advanced to fix the target Azucena alleles. Crosses between lines containing different target regions were made in order to pyramid all five target QTLs in the Kalinga III genetic background (Figure 1a).

Root screening of partial pyramid lines (containing 1, 2 or 3 target root QTLs) was carried out in soil-filled pipes under field conditions in Bangalore, India, (HE Shashidhar, pers. comm.) and in root boxes under greenhouse conditions in Aberdeen, UK (A Price, pers. comm.). In preliminary experiments, some combinations of Azucena alleles at root QTLs were shown to significantly increase root length, thickness and volume compared with Kalinga III (HE Shashidhar, pers. comm.)

A locus in the target root QTL on chromosome 7 was found to considerably delay flowering in the greenhouse at Bangor, and experiments are planned to test if this is due to linkage drag or pleiotropy.

**Strategy 2. SLS-MAS**

The approach of single large-scale MAS (SLS-MAS) has been described (Ribaut and Betrán, 2000). This interactively combines the use of DNA markers and conventional breeding. It involves screening a large population of F2 or F3 plants for favourable loci while still maintaining, as much as possible, the allelic segregation in the rest of the genome. We used a population of more than 500 lines, derived from the previously selected BC3, and screened them for markers at the four target root QTLs (Figure 1b). To reduce costs and the time required we did not use flanking markers but a single SSR marker within a maximum of 50 cM of the target QTL. In contrast to the conventional SLS-MAS method, we only attempted to identify lines with one root QTL. We detected, on average, 25 lines that were fixed (homozygous) for each Azucena target locus. The selected lines with at least one root QTL were then screened with a marker linked to aroma to identify a subset of lines containing aroma. Of these, four were homozygous and seven were heterozygous for the aroma

![Figure 1. Backcross-marker-assisted selection programme used to transfer five target regions from Azucena to Kalinga III, indicating the number of plants genotyped at each generation.](image-url)
locus. The lines with QTLs identified by the markers were used to make bulks for PPB (Table 1). All of the bulks were segregating for Azucena alleles in the non-target genomic regions.

**Table 1. Bulks selected via modified SLS-MAS for PPB, indicating target regions from Azucena present**

<table>
<thead>
<tr>
<th>Bulk</th>
<th>Target regions present</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>None (control)</td>
</tr>
<tr>
<td>II</td>
<td>Root QTL (Chromosome 7)</td>
</tr>
<tr>
<td>III</td>
<td>Root QTL (Chromosome 9)</td>
</tr>
<tr>
<td>IV</td>
<td>Root QTL (Chromosome 11)</td>
</tr>
<tr>
<td>V</td>
<td>Root QTL (any one target) and aroma (Chromosome 8)</td>
</tr>
<tr>
<td>VI</td>
<td>Root QTL (Chromosome 2)</td>
</tr>
</tbody>
</table>

**Strategy 3. Marker-evaluated selection**

In PPB we used material from Kalinga III crossed to:

- IR64 and IR36, both are elite modern varieties for irrigated conditions
- Vandana, an Indian upland variety
- Radha 32, a popular Nepalese variety (Gyawali et al., 2002).

These populations generated successful genotypes in eastern India (Kumar et al., in press) and Nepal. Some of the lines and bulks performed well across both countries, and in different seasons and ecosystems. These lines and bulks represent a significant genetic resource for testing the usefulness of marker-evaluated selection. The most promising lines selected by farmers may hold the key to the best choice of future PPB crosses. We are currently using molecular markers to evaluate 62 populations from these crosses (bulks and pure lines), that were selected in PPB.

Farmer-preferred traits are those with adaptive or commercial value. Markers linked to these farmer-preferred traits can theoretically be identified using marker-evaluated selection, and we aim to test this hypothesis and develop the technique. DNA fingerprint linkage blocks (DFLBs, Zhu et al., 1999) are being used to determine farmer-preferred genomic regions. If marker allele frequency in the PPB-selected population differs significantly from the allele frequency in a non-selected population derived from the same cross, it is assumed to be linked to a locus that contributes to a farmer-preferred trait. This is a one-tailed selective genotyping (OTSG) approach, similar to the trait-based analysis for detection of marker-QTL linkage of Lebowitz et al. (1987). QTLs explaining a large portion of the genetic variance may be detected in large samples of selected lines, but linkages involving QTL of smaller effects are unlikely to be detected (GN Atlin, pers. comm.). We expect that loci controlling plant height and flowering time will definitely be detected, and that other farmer-preferred traits might also be identified. The unselected population used as a control will prevent detection of false DFLBs, which differ in allele frequency due to segregation distortion. Segregation distortion in rice mapping populations is often found in regions containing gametophytic gene loci and/or sterility loci (He et al., 2001).

By exploring the graphical genotypes of farmer-selected lines, 'ideotype' plants can be designed for specific environments and crosses will be made to select for those ideotypes in the progeny using MAS. The optimum combinations of genomic regions for farmer-preferred traits and root QTL could be readily transferred, through MAS, to any farmer-preferred variety.

**Acknowledgement**

This publication is an output from projects R7281 and R7542 funded by the UK Department for International Development (DFID) Plant Sciences Research Programme (PSP) for the benefit of developing countries. The views expressed are not necessarily those of DFID.

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Combining molecular marker technology and participatory techniques: Molecular breeding strategy


Price AH, Steele KA, Moore BJ, Barraclough PB, Clarke LJ (2000) A combined RFLP and AFLP linkage map of upland rice (Oryza sativa L.) used to identify QTLs for root penetration ability. Theor Appl Genet 100: 49–56


Combining molecular marker technology and participatory techniques: A case study for drought-tolerant rice in eastern India II: Farmer evaluation of SLS-MAS bulks in participatory plant breeding

KA STEELE¹, DN SINGH², R KUMAR², SC PRASAD³, DS VIRK¹, JS GANGWAR³ AND JR WITCOMBE¹

1. Department for International Development (DFID) Plant Sciences Research Programme (PSP) Centre for Arid Zone Studies (CAZS), University of Wales, Bangor, Gwynedd LL57 2UW, UK
2. Department of Plant Breeding and Genetics, Birsa Agricultural University (BAU), Kanke, Ranchi 834 006, Jharkhand, India
3. Eastern India Rainfed Farming Project, Gramin Vikas Trust (GVT), 280 Kanke Road, Near Pani Jahaj Kothi, Ranchi 834 008, Jharkhand, India

Abstract

We wish to test if participatory approaches and modern molecular marker techniques can be effectively combined. To do this we have integrated participatory plant breeding (PPB) with marker-assisted selection (MAS). MAS was used to fix regions containing a QTL for aroma and four QTLs for root traits. The PPB has been carried out on six bulks selected with molecular markers via modified single large-scale MAS (SLS-MAS). Bulks were given to farmers in three states of eastern India for evaluation over two seasons of collaborative PPB. The same bulks were also tested on-station through consultative PPB, with off-season seed multiplication.

Background

Modern biotechnologies have the capacity to create rapidly varieties with new combinations of genes, that are unlikely to be derived through conventional breeding methods. Marker-assisted selection (MAS) is a potentially valuable strategy for breeding resistance to abiotic stresses but its value can only be proved by the products of MAS being tested in marginal environments by the end-users i.e., small-scale farmers. By involving farmers directly in the MAS breeding programme through participatory plant breeding (PPB) methods, the two technologies address the needs of farmers. However, the PPB methods that can be used in combination with MAS can differ greatly according to the degree of farmer participation (Witcombe et al., 1996) with the extremes being on-station selection by farmers (consultative) and on-farm, farmer-led PPB (collaborative).

Six bulks were derived from the second backcross generation between Kalinga III and Azucena where Kalinga III was the recurrent parent (see Steele et al., 2002). Four of the bulks had been selected to contain a quantitative trait locus (QTL) for root growth. One bulk was a selected subset of those with root QTLs which had also inherited a marker for aroma. A control bulk was selected from the same generation, which contained none of the targets and was used to test the effect of the target root QTL.

Results from collaborative PPB

In collaborative PPB farmers are given material amongst which to select that they grow on their own farms (Witcombe, 2002; Virk et al., 2002). Three farmers, one in each of the three states, Orissa, Jharkhand and West Bengal, were given the six bulks (at the BC₁F₁ generation) to grow in plots alongside Kalinga III in the rainy season 2000. Harvested seed was returned to the breeder only from the farmer in Orissa.

In the 2001 rainy season 10 farmers were given the bulks, but a full set of yield data was only received from seven farmers. In both years farmers used their usual practices and they were asked to make selections within each bulk. The farmers will be able to continue the PPB programme with the selected material from all six MAS bulks in the rainy season of 2002 (Figure 1).

There was a great deal of variation within all the bulks in both years for height, tiller number, spreading or
Combining molecular marker technology and participatory techniques: Farmer evaluation

compact plant type, maturity, awn pigmentation, stem thickness and panicle length. To a lesser extent, grain shape varied, although all bulks had fine, slender grains. The bulks all had increased panicle length compared to Kalinga III, and were less prone to lodging. All bulks containing Azucena genes had greater biomass than Kalinga III and were not significantly earlier.

In the rainy season 2001 the farmers were asked to rank the plots (six bulks and check variety Kalinga III) in their order of preference. A score of 1 was given to the least-preferred plot and 7 to the most-preferred plot, for each criterion. The criteria used for ranking were: maturity, height, yield, straw, lodging, pest attack, grain colour and overall preference. Four farmers responded and they ranked all six of the MAS bulks higher than Kalinga III for overall performance, including the control bulk with no QTL (Table 1). Farmers’ rankings for other criteria were confounded by the high levels of intra-bulk variation.

In making selections the farmers generally, although not exclusively, selected early lines in all bulks (Figure 2). They stated that earliness was the most important selection criterion, with plant height (tall plants with more straw for fodder) the second. Farmers differed in their opinion about grain shape, and while most farmers said that possession of fine grains was the third most important selection criterion, one farmer said that bold grains were more important.

Many farmers ranked the aromatic bulk highly and were excited to smell the aroma in the field during flowering. Due to limited seed availability the cooking quality still remains to be evaluated. This is the first time that aromatic upland rice has been available in eastern India, and farmers’ reactions were generally positive. Aromatic lines have greater market value than non-aromatic varieties and this could benefit poor farmers economically. However, the introduction of aroma may have both environmental and economic consequences. The incidence of insect pests on the aromatic bulk was greater than on non-aromatic bulks. This, combined with the greater market value, could lead to increased use of insecticides.

<table>
<thead>
<tr>
<th>Collaborative</th>
<th>Consultative</th>
</tr>
</thead>
<tbody>
<tr>
<td>Off-season 1999-2000</td>
<td>BC,F5 CRRI, Cuttack</td>
</tr>
<tr>
<td>Rainy season 2000</td>
<td>BC,F6, 3 farmers GVT-BAU farm</td>
</tr>
<tr>
<td>Rainy season 2001</td>
<td>BC,F6, 10 farmers GVT-BAU farm</td>
</tr>
<tr>
<td>Off-season 2001-2002</td>
<td>BC,F6 CRRI, Cuttack</td>
</tr>
<tr>
<td>Rainy season 2002</td>
<td>BC,F6, 7 farmers continue GVT-BAU farm Drought trials AICRIP trials Collaborative PPB</td>
</tr>
</tbody>
</table>

Figure 1. Schemes for collaborative and consultative PPB using SLS-MAS bulks. Each generation consisted only of selected materials from the previous generation, and all six bulks were advanced simultaneously.

Figure 2. Upland farmers in Udali district, Orissa, September 2000, making selections in segregating bulks selected via modified SLS-MAS for root trait QTLs and aroma from Azucena

Photo: AK Paria, Community Organiser, GVT East

Results from consultative PPB

Consultative PPB was carried out at the Gramin Vikas Trust – Birsa Agricultural University (GVT–BAU) upland farm and off-season multiplication carried out at the Central Rice Research Institute (CRRI) Cuttack, Orissa. In the 2001 rainy season all six bulks plus two check varieties, Kalinga III and Birsa Gora 102, were grown in a randomised-block experiment. Within all the bulks and checks there was no significant difference for plant height or flowering time. For yield, three bulks were significantly different from Kalinga III; bulks IV and V yielded less, while bulk VI had a greater yield.

Twenty-one farmers (men and women) visited the plot 81 days after sowing. Selection and tagging of plants was carried out for four different environments: upland, medium upland, medium lowland and lowland. These selected bulks were advanced in the off-season and the BC,F generation will be given to farmers for paired comparisons with Kalinga III in the 2002 rainy season (Figure 1). In the off-season the selected bulks II and III were uniform after two generations of consultative
selection. They have been recommended by BAU for entry into the All India Coordinated Rice Improvement (AICRIP) trials and in state trials. All six bulks at the BC2F7 generation will be tested in replicated field trials in both eastern and western India for drought resistance in the 2002 rainy season. They will be grown under upland conditions with no irrigation to test the hypothesis that bulks containing root QTLs are more adapted to withstand drought than the control bulk.

An additional 16 individual lines selected for target QTLs by pure MAS (from the BC3F4 and pyramid generations) were also grown on the BAU farm in the 2001 rainy season. Eleven of these were aromatic, four bulks were partial pyramids for two or three target root QTLs and one was an advanced generation control line with no target QTL. Visiting farmers made selections within these plots and tagged selected plants according to four target environments.

**Conclusion**

From these preliminary results, MAS appears to be successful in producing promising material. However, whether this is the result of introducing target QTLs, or more generally the result of introducing small genomic contributions of Azucena into Kalinga III is not yet known. So far, the bulk with contributions from Azucena but without the target QTLs also appears superior to Kalinga III. Moreover, of the assessments to date have been made on the heterogeneous bulks rather than in selections from them. We can conclude that there is no barrier to combining ‘high-technology’ breeding approaches with participatory ones. This strategy of taking the results of MAS straight to the farmer provides an acid test for the real value of the target QTLs.

### Acknowledgement

This publication is an output from projects R7281 and R7542 funded by the UK Department for International Development (DFID) Plant Sciences Research Programme (PSP) for the benefit of developing countries. The views expressed are not necessarily those of DFID.

### References


### Table 1. Target QTL present in six bulks selected through modified SLS-MAS and the overall rank scores given by farmers in two states during collaborative PPB evaluation alongside Kalinga III check, rainy season 2001

<table>
<thead>
<tr>
<th>Bulk</th>
<th>QTL from Azucena present on chromosome</th>
<th>Total score (from a maximum of 24 given by four farmers for overall rank)</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>None (control)</td>
<td>19</td>
</tr>
<tr>
<td>II</td>
<td>7 (root length and mass)</td>
<td>22</td>
</tr>
<tr>
<td>III</td>
<td>9 (root length)</td>
<td>15</td>
</tr>
<tr>
<td>IV</td>
<td>11 (root length and penetration)</td>
<td>14</td>
</tr>
<tr>
<td>V</td>
<td>8 (aroma) plus one of either 2, 7, 9 or 11 root QTL</td>
<td>12</td>
</tr>
<tr>
<td>VI</td>
<td>2 (root length, thickness and penetration)</td>
<td>18</td>
</tr>
<tr>
<td>Kalinga III</td>
<td>None (check variety)</td>
<td>7</td>
</tr>
</tbody>
</table>
Development of New Rice for Africa (NERICA) and participatory varietal selection

HE GRIDLEY, MP JONES AND M WOPEREIS-PURA

West Africa Rice Development Association (WARDA), 01 BP 2551, Bouaké, Côte d’Ivoire

Abstract

One of the major research thrusts of the West African Rice Development Association (WARDA), to meet the ever-increasing demand for rice in West and Central Africa (WCA), has been the development of higher-tillering varieties. By 1996 WARDA had developed a range of new interspecific varieties derived from crosses between the Asian rice, Oryza sativa and the African rice, O. glaberrina. These varieties, later termed NERICAs (New Rice for Africa), have shown stable and high yields and tolerance to major biophysical production constraints in a range of upland environments. Their rapid dissemination to small-scale rice farmers in WCA has been achieved through participatory varietal selection (PVS), an applied and adaptive research mechanism in which farmers play an active role in varietal selection, development and spread. PVS lasts for 3 years during which farmers select and evaluate varieties on their own farms. PVS was initiated at Côte d’Ivoire in 1996 and by 2000 all 17 WARDA member countries had initiated PVS, involving 4000 farmers at 105 sites. Particular progress has been made in Guinea where from 1997 to 2000 the number of farmers participating in PVS rose from 116 to 20,000 and the area sown to NERICAs from 50 to 8,000 hectares.

Introduction

Demand for rice in West and Central Africa (WCA) has been growing at the rate of 6% per annum since 1973, and now amounts to over 8 million tonnes per annum. Increased consumption is due both to population growth (average of 2.9% per annum) and to the increased share of rice in the diet of the African population. Over the same period, production of rice has been expanding at the rate of 5.1% per annum, with 70% of the growth due to an increased area of cultivated rice, but only 30% due to higher yields. Much of the expansion has been in the rainfed systems, particularly the two major ecosystems that make up 78% of rice land in WCA: namely, the upland and rainfed lowland systems.

To cover the increasing gap between rice demand and supply, rice is being imported at an increasing rate. Shipments of rice to Africa rose by 11% to slightly more than 5 million tonnes in 1999/2000, Nigeria being the major importer at 0.9 million t, closely followed by Côte d’Ivoire. The cost of this importation is approximatively US$1 billion of foreign exchange each year. With population growth rate exceeding that of regional food production, and limited foreign exchange for increased levels of imports, the future for Africa’s poor appears grim. For food security, WCA needs to increase production capacity for when cheap rice can no longer be imported.

The birth of a new rice for Africa

The Asian rice Oryza sativa was brought to Africa over 500 years ago. Within a short period, because of its high yield potential, it replaced most of the indigenous African rice, Oryza glaberrima, which was pushed to inhospitable, scraggy and infertile upland soils or flood-prone inland valleys and deltas. In Africa, however, O. sativa suffered attack by pests and diseases known only on the African continent. Toxic soils with limited nutrients also reduced its yield potential. The hardy African rice, O. glaberrima, with a history of 3,500 years of cultivation, withstands these problems better than O. sativa. To combine the best traits of the Asian and African rice species, the challenge is to transfer into the high-yielding but stress-prone O. sativa the desirable genes in O. glaberrima while shedding its undesirable traits of lodging, fewer grains and grain shattering.
Conventional breeding efforts to develop interspecific hybrids had failed due to a high level of sterility in the hybrids. In 1991, WARDA launched a new effort to combine the genetic potential of the two rice species, using conventional and anther culture techniques to overcome sterility and to hasten the breeding process. Crosses were made and embryo rescue was used to remove fertilized embryos and grow them in artificial media. Anther culture allowed rapid fixation and helped to retain interspecific lines combining desirable features of the two rice species. The generous support of donors in Japan and the Rockefeller Foundation in the USA to the Joint Interspecific Hybridization Project allowed considerable progress to be made, and by the late1990s interspecific lines of a radically different plant type, tailored for dryland rice farmers of WCA, had been developed and were being tested and evaluated in a range of environments.

**Agronomic characteristics of interspecific lines**

Since the mid-1990s many interspecific lines have been generated, evaluated and characterised for a range of agronomic traits and reaction to important diseases and pests (WARDA 1999, 2000a, 2000b, and 2001a, and 2000b). In 2000, these interspecific lines were dubbed NERICA (New Rice for Africa).

NERICAs have been identified with one or more of the following characteristics:

- Wide and droopy leaves that help to smother weeds in early growth stages
- Strong stems that can support heavy heads of grain
- More tillers with longer grain-bearing panicles than either parent and non-shattering grains
- Stems with secondary branches on their panicles that can carry up to 400 grains
- Early maturity, 30–50 days earlier than currently grown cultivars
- A good height that allows easy harvest of panicles
- Good tolerance to drought
- Resistance or tolerance to Africa’s most serious pests and diseases – African rice gall midge, rice yellow mottle virus and blast (*Magnaporthe grisea*)
- Tolerance to acidic soils but responsive to limited organic and inorganic fertilizers.

NERICAs have shown stable yields under both low- and high-input conditions and are expected to reduce risk and increase productivity in farmers’ fields, thereby reducing the need to clear new land. Reduced risk will also give farmers incentives to use more inputs, intensify land use, and gradually abandon shifting cultivation, thus improving system sustainability. The rapid introduction of NERICAs to small-scale farmers in WAC was, therefore, considered a vitally important first step towards the sustainable intensification of Africa’s fragile uplands. The NERICAs were not intended as a total replacement for local varieties but for integration into the existing varietal portfolio of farmers.
Participatory varietal selection (PVS) methodology

In conventional breeding schemes selection and testing procedures involve a series of multilocational trials over 8 to 12 years of a diminishing number of varieties (Figure 1). This favours the selection of a few, widely adapted lines for release, often with little regard to farmer and consumer preferences, or to addressing the myriad farm-level microenvironments.

At WARDA, this conventional approach to transfer of new varieties has given way to an applied and adaptive research mechanism, termed PVS, that favours farmers playing an active role in varietal selection, development and spread (Figure 1).

The goal of PVS is to efficiently transfer improved rice varieties to farmers in order to:

- Reduce the time required to move varieties onto farmers' fields
- Determine the varieties that farmers want to grow
- Learn the traits that farmers value in varieties to assist breeding and selection
- Determine if there are gender differences in varietal selection criteria

WARDA's approach to PVS research (PVS-R) is a 3-year programme (Figure 1). In the first year, breeders identify centralised fields near villages and plant a 'rice garden' trial of up to 60 upland varieties. The varieties range from traditional and popular O. sativas to NERICAs, African O. glaberrimas and local checks. Men and women farmers are invited to visit the plot informally as often as possible, but the farmers are brought as groups for formal evaluation of the varieties at three key stages: maximum tillering, maturity and post-harvest. For the first two, farmers compare agronomic traits, including weed competitiveness, growth rate, height, panicle type and growth cycle, whilst the third focuses on grain quality attributes such as size, shape, shattering, ease of threshing and husking and palatability. Each farmer's varietal selection and the criteria for selection are recorded and later analyzed.

In the second year, each farmer receives as many as six of the varieties he or she has selected in the first year to grow on his or her farm. Thus genetic diversity enters the communities. PVS observers, who may compromise breeders and/or technicians from NGOs and extension services, visit participating farmers' fields to record performance and farmer appreciation of the selected varieties. At the end of the year, farmers evaluate threshability and palatability to provide an overall view of the strengths and weaknesses of the selected varieties. For the third year, farmers are asked to pay for seeds of the varieties they select, thereby providing evidence of the value they place on them. Thus, in 3 years, PVS-R allows the farmers to select varieties with specific adaptation and preferred plant type and grain quality characters. These, in turn, can be integrated into the breeding programmes to tailor varieties for farmers. In the conventional scheme at least 12 years are necessary to reach this point and, even then, farmers and consumers may not appreciate the varieties selected.

A PVS extension (PVS-E) phase has recently been introduced to compliments PVS-R and accelerate dissemination and official release. Four to six of the more commonly selected varieties in the second year of PVS-R in an ecoregion are disseminated widely to farmers within the region for evaluation in the third year. After 2 years of PVS-E, the more-preferred of these varieties are enrolled in multilocational trials to generate data for official release. Simultaneously, these varieties enter community-based seed systems (CBSS) for multiplication to ensure adequate seed supplies for rapid dissemination of the varieties officially approved for release.

PVS activities in West Africa

PVS-R was initiated in 1996 through a small project in Boundiali in Côte d’Ivoire, where farmers were provided with a rice garden of 57 varieties amongst which they were able to select those that met their own needs. The results were so encouraging that WARDA decided to extend the participatory approach. By 1999 all 17 WARDA member countries had instigated PVS-R at 64 sites with 2,491 farmers participating; by 2000 over 4,000 farmers at 105 sites were involved (Table 1) (WARDA 1999).

As early as 1997, significant gender differences in varietal selection were detected at Danane in Côte d’Ivoire, but further analysis of the large body of data collected from other countries is needed to determine if this is common. Marked specificity in varietal selection between countries, however, was evident (Table 2),

<table>
<thead>
<tr>
<th>Year</th>
<th>Countries with PVS-R activities</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>1996</td>
<td>Côte d’Ivoire</td>
<td>1</td>
</tr>
<tr>
<td>1997</td>
<td>Benin, Ghana, Guinea, Togo</td>
<td>5</td>
</tr>
<tr>
<td>1998</td>
<td>Burkina Faso, The Gambia, Guinea-Bissau, Nigeria, Sierra Leone</td>
<td>7</td>
</tr>
<tr>
<td>1999</td>
<td>Cameroon, Chad, Liberia, Mali, Mauritania, Niger, Senegal</td>
<td>17</td>
</tr>
<tr>
<td>2000</td>
<td>17 WARDA member countries</td>
<td>17</td>
</tr>
</tbody>
</table>

Table 1. Evolution of PVS-R activities by year in West Africa, 1996–2000

The table shows the evolution of PVS-R activities by year in West Africa from 1996 to 2000, listing the countries and the number of sites and farmers involved. The data are organized in a table format with columns for Year, Countries with PVS-R activities, Countries, Sites, and Farmers.
Table 2. The 58 varieties in advanced PVS testing by West African countries, 2000

<table>
<thead>
<tr>
<th>Type</th>
<th>Variety</th>
<th>Benin</th>
<th>Burkina Faso</th>
<th>Cameroun</th>
<th>Côte d’Ivoire</th>
<th>Ghana</th>
<th>Guinea-Bissau</th>
<th>Guinea</th>
<th>Mali</th>
<th>Mauritania</th>
<th>Niger</th>
<th>Sénégal</th>
<th>Sierra Leone</th>
<th>Chad</th>
<th>The Gambia</th>
<th>Togo</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>S</td>
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Total 6 4 6 6 3 4 7 5 3 5 6 5 7 5 7 77

1. S = *O. sativa*; I = interspecific (*O. sativa* × *O. glaberrima*)
reflecting a combination of differing varietal adaptation to the wide range of on-farm (micro-) environments and diverging consumer preference. Of the 58 varieties in advanced PVS-R testing in 15 countries in 2000, 46 were selected in only one country. These accounted for 79% of the varieties, with the rest accounting for 1% or less — namely, six in two countries, five in three countries and one in four countries (Table 2).

The most frequently selected varieties were derived from WARDA crosses designated by the code ‘WAB’, and amongst these the NERICAs were as popular as the _O. sativa_ varieties. The NERICAs were particularly popular in Côte d’Ivoire, accounting for all varieties selected there, and in Guinea, where NERICAS were all but one of the varieties selected. Five NERICAs have now been released in Côte d’Ivoire and two in Guinea. On average, five varieties were selected in each country, ranging from a minimum of three for Mauritania to a maximum of seven for Guinea and Chad (Table 2).

Selection criteria applied by farmers amongst 17 countries were more consistent (Table 3). The most frequently applied criteria across countries were:

- **Yield (14)**
- **Height (13)**
- **Short growth cycle (11)**
- **High tillering (11)**
- **Grain size (9)**
- **Large grain (9)**

Thus across countries, high-yielding, early varieties with profuse tillering and large grain are the most desired, but breeders must be alert to variation between countries, especially taking account of the less-frequently noted characters.

### PVS in Guinea

PVS-R and NERICAs have made a major impact in Guinea. The first phase of PVS-R began in 1997 with support from the World Bank that enabled The Institut de recherche agronomique de Guinea (IRAG) and Service National de la Promotion Rurale et de la Vulgarisation (SNPRV) to collaborate with WARDA to identify varieties that could be rapidly transferred to farmers. A second phase was started in 1999.

The number of farmers participating rose from 116 in 1997 to 20,000 in 2000, with the area of NERICAs sown over this period increasing from 50 to 8,000 hectares (Table 4) (WARDA 2001). In 2000, the gain in production and in income from NERICAs was estimated at 15,000 tonnes of rice worth US$2.5 million with additional income estimated to rise to US$300,000 in 2002 (Table 4).

### Table 3. Farmers’ selection criteria applied in PVS-R in 17 West African countries, 1999

<table>
<thead>
<tr>
<th>Country</th>
<th>Yield</th>
<th>Height</th>
<th>Short growth cycle</th>
<th>High tillering</th>
<th>Grain size</th>
<th>Weed competitiveness</th>
<th>Grain colour</th>
<th>Grain-bold</th>
<th>Good response to fertilizer</th>
<th>Lodging resistance</th>
<th>Panicle size</th>
<th>Taste</th>
<th>Non-sticky grain</th>
<th>Drought tolerance</th>
<th>Medium growth cycle</th>
<th>Brid damage resistance</th>
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Table 4. PVS in Guinea: Number of farmers participating, area sown to NERICAs, and estimated gain in production and income from NERICAs, 1997–2002

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<th>Year</th>
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<th>Area (ha) sown to NERICAs</th>
<th>Estimated gain in production and income</th>
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<td>2002</td>
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References

WARDA (West Africa Rice Development Association) (2001a) Bintu and her new rice for Africa. WARDA (West Africa Rice Development Association), Bouaké, Côte d’Ivoire. 32 pp
Enhancing on-farm conservation of traditional rice varieties in situ through participatory plant breeding at three contrasting sites in Nepal

BR STHAPIT1, J BAJRACHARYA2, A SUBEDI3, KD JOSHI4, R RANA3, SP KHATIWADA2, S GYAWALI3, P CHAUDHARY3, PR TIWARI3, DP RIJAL4, K SHRESTHA3, BK BANIYA2, A MUDWARI2, MP UPADHAYA2, D GAUCHAN3 AND D JARVIS1

1. International Plant Genetic Resources Institute (IPGRI), 10 Dharmasahila Buddha Vihar Marg, Nadipur Patan, Ward 3, Kaski, Pokhara 3, Nepal
2. Nepal Agricultural Research Council (NARC), Singhadurbar, Plaza, Kathmandu, Nepal
3. Local Initiatives for Biodiversity Research and Development (LI-BIRD), PO Box 324 Bastolathar, Mahendrapul, Pokhara, Nepal
4. Department for International Development (DFID) Plant Sciences Research Programme (PSP), Centro Internacional de Mejoramiento de Maiz y Trigo (CIMMYT), South Asia Office, Singh Dubar Plaza Marg, Bhadrakali, Kathmandu, Nepal

Abstract

Participatory plant breeding (PPB) is one of the strategies employed for on-farm management of traditional rice varieties in three contrasting in situ conservation villages of Nepal. PPB programmes in Nepal were designed to investigate whether:

1. Traditional farmers' cultivars can be conserved per se
2. PPB contributes to the enhancement of biodiversity by broadening the genetic base that provides benefits to community
3. The PPB process encourages farmers to maintain the evolutionary processes that allow the crop to evolve over time, while remaining adapted to diverse, local production niches
4. Landraces can be conserved by improving them for traits that farmers consider important to make them more competitive against alternative varieties.

This paper describes the processes of PPB that encourages farmers to locate rice diversity and their custodians; understand the amount of rice diversity (the number of local and modern varieties at both the household and community level) and its distribution (the frequency of households growing each variety); analyse the preferred traits of rare, endangered and locally common farmers' varieties; and develop options for adding benefits to cultivating local landraces. It describes preliminary results on understanding genetic diversity in terms of its value to local communities and the participatory methods used to select landrace parents for PPB. Participatory methods, such as biodiversity fairs, diversity blocks, diversity kits and community biodiversity registers, were integrated to sensitise the local community to varietal diversity issues, to understand the value of local crop diversity, and to strengthen the roles of farmers and the informal sector in the local crop development process.

Introduction

The study was initiated in 1998 and is part of the activities of the International Plant Genetic Resources Institutes (IPGRI) global project, Strengthening the Scientific Basis of in situ Conservation of Agricultural Biodiversity in Nepal. It was jointly implemented by the Nepal Agricultural Research Council (NARC), a non-governmental organisation (NGO) Local Initiatives for Biodiversity Research and Development (LI-BIRD) and local institutions including community-based organisations (CBOs), a network of nodal farmers, and farming communities.

Understanding rice diversity

We found that communities maintained a rich varietal diversity ranging from 21 cultivars (100% of which were landraces) at the high-mountain Jumla site to 69 cultivars (91% local, farmer-named cultivars) at the middle-hill Kaski site. Farmers at the highly accessible Bara village, where extension services had made many interventions, and who are close to the national rice research centre and the Indian border maintained 33 cultivars (62% of them landraces). More landraces were maintained at both the household and community level rather than modern cultivars at all three sites. The area covered by
rice landraces in Bara was 17%, followed by 73% in Kaski and 100% in Jumla.

**Landrace enhancement**

We found that resource-poor farmers, compared to resource-endowed households, were more dependent on landraces for their food security. This was particularly true in marginal rather than in better-off environments (Rana *et al.*, 2002). We also found that some landraces were very competitive to modern cultivars in certain niches and that such landraces could be promoted more widely for similar agroecological niches without further improvement. Results also indicated that a few culturally important cultivars, such as Anadi, could be conserved through market links and consumer awareness.

**Genetic diversity of landraces**

We also assessed the genetic diversity of a few locally common and well-known landrace populations of landrace Jetho Budho in Kaski district, and landraces Kariya Kamod and Lalka Basmati in Bara district. The landraces from Jumla had a low level of diversity (Jaccard similarity index of 0.87 and 12.8% of polymorphic loci) (Bajracharya *et al.*, 2001).

This high degree of similarity indicates a possibility that these landraces, that have unique traits for tolerance to cold water chilling injury but are susceptible to neck blast, could have originally come from the same source. Compared to the low diversity among Jumla landraces, landraces from Kaski and Bara had a considerable level of genetic diversity (Jaccard similarity index = 0.48–0.50), reflecting the high ethno-botanical variability indicated by many different farmer-given names and diverse seed-related phenotypes (Bajracharya *et al.*, 2001). Although the intra-population genetic variation of Jetho Budho and Basmati was generally low, variation for quality traits has been found and is a potential opportunity for landrace enhancement. Through consumer surveys we have established the quality traits of Jetho Budho. These include (in order): softness of cooked rice, aroma, elongation ability, and taste. The Project plans to help farmers market locally produced, quality-assured rice seed and grain using local brand names as a way of improving rural livelihoods and conserving genetic diversity.

**Social seed network**

We found that 96–100% of farming households are dependent upon an informal seed source (Baniya *et al.*, 2002). The seed flow occurs basically through farmers' social networks. The community managed a rich rice diversity through this social system, that involved: exchange on a barter basis (60–63%), gift (20–25%), borrowing of either seed or seedlings (10–12%), and purchase (<5%) (Subedi *et al.*, 2002). Nodal farmers who search, select and maintain rice diversity have been found to play an important role in seed flow in the informal seed system and were selected as collaborators in the PPB programme.

**Performance of PPB bulks**

The 13 segregating materials from crosses between local landraces, and local landraces with exotic varieties, were distributed to interested and nodal farmers for growing an F2 or F3 bulk of their choice, and a farm walk was carried out by researchers and farmers to assess the field performance of different populations.

In Begnas village F2 segregants of Mansara (locally adapted to marginal, drought-prone rainfed and low-input conditions) and Kumal 4 (a good-quality modern cultivar having the local variety Pokhereli Masino as one of its parents) showed promising results in upper Begnas areas (1000–1300 m) (Figure 1). The breeding goal is to incorporate the good ‘eating’ quality and yield potential of Kumal 4 into Mansara without losing the adaptive traits of Mansara. The cross between Pusa Basmati 1 and Jetho Budho (a local high-quality rice in high market demand) was also doing well in Kholakochew environments (650–690 m). In Bara district, six large segregating populations were evaluated in farmers’ fields, among which farmers preferred the populations of the cross Lajhi x IR62161–22–1–2–1–1 and selected among them for lodging resistance and post-harvest traits. The performance of these segregants was very good.

**Future plans**

Selected populations of Jetho Budho landraces will be evaluated for quality traits and taste with diverse consumers — hoteliers, millers, housewives, farmers, and researchers.

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*Figure 1. Promising plants in the bulk of the cross Kumal 4 x Mansara*
The PPB bulks of the Mansara x Khumal 4 have been divided into three bulks based upon grain colour and phenotypes. These bulks have been distributed to all nodal farmers and interested farmers for on-farm testing and selection. Researchers will monitor the spread of these PPB bulks in 2003 through farm walks (Figure 2) and household interviews.

Figure 2. Participants in a farm walk, Begnas, 2002

References


Farmer participatory breeding and participatory varietal selection in eastern India: Lessons learned

TR Paris1, RK Singh2, GN Atlin1, S Sarkarung3, G McLaren1, B Courtois4, K McAllister5, C Piggin6, S Pandey1, A Singh7, BN Singh11, ON Singh8, S Singh8, RK Singh8, NP Mandal8, K Prasad7, RK Sahu9, VN Sahu9, ML Sharma9, RKP Singh10, RT Tekur10, NK Singh10, D Chaudhary10, S Ram11

1. International Rice Research Institute (IRRI), DAPO Box 7777, Metro Manila, Philippines
2. International Rice Research Institute (IRRI), Liaison Office, 1st Floor, CG Block, NASC Complex, Dev Prakash, Shanstri Marg, Pusa, New Delhi 110 012, India
3. Rice Research Institute, Department of Agriculture, Chatuchak, Bangkok 10900, Thailand
4. Centre de coopération internationale en recherche agronomique pour le développement (CIRAD), 34398 Montpeiller, Cedex 5, France
5. 4 Armshore Drive Halifax, Nova Scotia, Canada
6. Australian Council for International Agricultural Research (ACIAR), GPO Box 1571, Canberra, New South Wales, Australia
7. Narenda Deva University of Agriculture and Technology (NDAUT), Kumarganj, Faizabad 224 229 Uttar Pradesh, India
8. Central Rainfed Upland Rice Research Station (CRURRS), PO Box 48, Hazaribagh 825 301, Jharkhand, India
9. Indira Gandhi Agricultural University F/2 Krishak Nagar, Rapir, 492 012, Madhya Pradesh, India
10. Rajendra Agricultural University, Pusa, Samastipur 848 125, Bihar, India
11. Central Rice Research Institute (CRRI), Indian Council of Agricultural Research (ICAR), Cuttack, 753 006, Orissa, India

Abstract

This paper describes the objectives and methods used in a participatory breeding (PPB) project in several rice ecosystems in eastern India. Farmers were interested in a large range and combinations of traits. The selection criteria of farmers were determined by hydrological conditions (water depth) and land types (toposequence) followed by the adaptation of the variety to different user needs (food, livestock fodder, thatching, cash). Other factors determining preference were: the compatibility of the variety in the cropping systems, socioeconomic status, gender and culture. Several lessons learned from the three years' experience led to the refinements in the participatory methods in the next phase of the project.

Introduction

Poverty in Asia is most severe in rainfed areas where people depend on rice for subsistence. To these rural poor, rice is not only the staple food but also has many livelihood uses. Sustaining livelihoods and alleviating poverty require a major increase in agricultural productivity. This means, among other factors, developing higher-yielding well adapted rice varieties.

Classical breeding approaches have been successful in developing improved varieties of rice for favourable rice environments. However, these approaches have been less successful in rainfed environments because they fail to account for the high levels of social and agro-ecological diversity in these areas. Witcombe et al. (1998) report weaknesses in the formal testing system in India that have reduced the chances that varieties released for marginal areas would meet farmers' needs. The failure of the system is evidenced by, for example, the rejection of many varieties by farmers, and the rapid and high adoption by farmers of such non-released varieties such as Mashuri rice that had been rejected in the formal testing.

The goal of this project was to increase food security by providing varieties capable of producing for high and stable yields. The specific objectives were to:

- Test the hypothesis that farmer participation in rainfed rice breeding can help develop suitable varieties more efficiently
- Identify the stages along a breeding programme where farmer participation is most necessary.
- Enhance the capacities of the national agricultural research systems (NARS) in farmer participatory research and gender analysis for rice plant breeding and varietal selection (Courtois et al., 2000).
Methodologies and major findings

Selection of the research sites

This project was conducted in eastern India, (eastern Uttar Pradesh, eastern Madhya Pradesh, Assam, Bihar, West Bengal, and Orissa). Eastern India is the largest rice-growing region in the country and accounts for about 63% of India's rice area (26.8 million ha). However, about 80% of the rice farming in this region is rainfed.

The project involves two rice ecosystems and six sites: one in the upland ecosystem and five in the rainfed lowland ecosystem representing different agro-ecologies (drought-prone, submergence-prone, or both). At each site, two to three villages were chosen on the basis of their access to market, agro-ecological diversity and extent of adoption of improved varieties. A team of social scientists (mostly agricultural economists) and plant breeders from each centre conducted this research.

Finding out farmers' selection criteria based on their agro-ecological and socioeconomic environment

Farm household surveys and participatory rural appraisals (PRA) were conducted to characterise farmers' agro-ecological and socioeconomic environments, farming systems, rice diversity, farmers' crop management practices, gender roles, and seed management practices. Farmers' were consulted about their preferred traits and the positive and negative traits of local and improved varieties. Through graphic illustration of traits, male and female farmers valued the importance of varietal traits according to land types (lowland, midland and upland), by socioeconomic groups and by gender. The criteria for varietal choice were:

- Adaptation of the variety to the hydrological conditions (water depth) and land type (topo-sequence location) of their fields. For the lowlands and submergence-prone ecosystems, long-duration, photoperiod-sensitive, semi-tall and tall varieties were well adapted. For the uplands and shallow-depth medium lands, short to medium duration varieties were preferred to escape the terminal drought (Courtois et al., 2001; IRRI, 2001)
- Adaptation to different user needs such as food, livestock fodder, thatching and cash. Farmers grew more than one variety not only because they farm heterogeneous rice fields but also for different end-uses. Different varieties fulfilled different livelihood functions (food, livestock fodder, thatching, and cash). For example, farmers like varieties with long fine aromatic grain, because these are used as gifts for special occasions (marriage) and for religious ceremonies.

Poor farmers were more interested in the quality of leftover rice that should remain tender and soft – characteristics found in traditional varieties. Similarly, traditional varieties were perceived to be better for preparing puffed rice and other rice products (Paris et al., 2001a). In the uplands, farmers preferred such tall varieties as Brown Gora, Vandana, RR 151-3 and Kalinga III because they need the straw for animal fodder (IRRI, 2001). Other farmers grew traditional varieties with a purple-pigmented base in drought-prone areas in Bihar, Madhya Pradesh, and Cuttack. This trait helped farmers distinguish weeds from rice especially in direct-seeded fields where weeds are a major problem (Sahu et al., 2001)
- Compatibility with existing cropping systems. For medium lands farmers preferred medium-height varieties in the medium lands of short duration (90–110 days) that allowed the timely sowing of a following crop of pulses, wheat, or vegetables. In Bhubaneswar, Orissa, farmers rejected certain rice varieties that had dense root growth because these inhibited the establishment of a relay crop of pulses (black gram) broadcast into the standing rice crop (IRRI, 2001).
- Socioeconomic status of farmers. Farmers preferred different grain types according to their socioeconomic status or degree of market integration. For example, in Faizabad, eastern Uttar Pradesh, farmers and field workers of lower castes with small landholdings preferred varieties with coarse grains, that give them a feeling of fullness due to their slow digestibility. The higher-caste farmers with large landholdings who sell rice to the market preferred fine slender grains, that command a higher price. In general, smallholder farmers from the lower castes used rice mainly for consumption, while farmers from the upper caste with more land sold their surplus (Paris et al., 2001b). Farmers in the uplands of Hazaribagh preferred varieties that do not require high inputs. Farmers who depend on family labour preferred varieties with a range of maturity dates so that harvests can be staggered (IRRI, 2001).
- Gender-specific roles in rice production, post harvest, consumption, and livestock care. At all the sites, there were gender-specific tasks in rice production. Women from poor farming households provided most of the labour in rice production (pulling seedlings, transplanting, weeding), post-harvest (winnowing, hand threshing, seed drying), and seed management (selection, storage). Men were mainly responsible for land preparation, application of chemicals, and transporting inputs and products. Male and female farmers in Faizabad agreed that grain yield and duration were the most important traits when choosing varieties for upland and lowland areas. However, women gave more importance to such traits as competitiveness to weeds and post-harvest qualities such as ease of dehusking, or threshing, and high milling recovery or suitability for different food preparations (e.g., puffed rice). In Raipur, Madhya Pradesh, women consistently identified straw quantity and quality as important, whereas the men never
Sensory evaluation showed that the mode of rice yield and duration were important traits considered when selecting rice varieties for farmer participation. These lessons are related to the concerns:

- **Choice of representative sites.** During the first year, a few of the sites selected for on-farm trials were not representative of the environments targeted in the breeding work. They were chosen for convenience reasons (e.g., close to the research station). Thus new trial sites, which better represented farmers’ environments, replaced some of the sites.

- **Choice of the varieties to be included in the experiments.** The material chosen for the PVS trials was not always ideal. The lack of clear-cut differences between some of the varieties included in the PVS made it more difficult for the farmers to rank them. The number of varieties tested should be balanced between what is useful for the breeders (many lines), acceptable to the farmers (fewer lines) and what is possible on a reasonable plot size. Farmers had difficulty in visually ranking too many (13–25) rice lines. Orgonoleptic tests should be modified so that the varieties are not mixed.

- **Constraints in post-harvest operations of too many lines.** The need to harvest, thresh, and weigh the different varieties in small quantities was too cumbersome. Moreover, this work increased the burden of the women cooperators who did the post-harvest work. The number of lines for testing and selection should be reduced. A local field technician is required to assist in post-harvest work and to ensure that the varieties are not mixed.

- **Number of varieties to include in sensory evaluation.** Men and women found it difficult to evaluate the cooking and eating quality of too many lines. Organoleptic tests should be modified so that fewer varieties are tested at any one time.

- **Access to new seeds.** During the first 2 years of the project, the availability of seeds was quite limited and not all farmers who wanted to participate in the selection of new rice lines on their own farms could be included.

Several lessons were learned from the 3 years of experience in developing and testing the methodologies for farmer participation. These lessons are related to the concerns:

- **Choice of representative sites.** During the first year, a few of the sites selected for on-farm trials were not representative of the environments targeted in the breeding work. They were chosen for convenience reasons (e.g., close to the research station). Thus, new trial sites, which better represented farmers’ environments, replaced some of the sites.

- **Number of villages to represent a specific agro-ecology.** Due to limited resources and staff, only two or three trials and farmers were included in each village. Thus, the risks of losing information due to severe drought, poor management of trials, etc. were high. The Mother and Baby trial model may provide an alternative way of reliably testing a large number of cultivars under farmer management (Atlin et al., 2001; Appendix).

**Lessons learned**

- There was strong agreement among farmers’ visual rankings, but not always among those of plant breeders.
- Agreement of breeders with farmers was fairly good on plant traits but many quality traits were overlooked by breeders.
- Agreement between visual ranking of traits by men and women during the pre-harvest stage was good. However, they differed during post-harvest assessment.
- Yield and duration were important traits considered by farmers. However, ranking preferences were not always correlated, indicating that these traits are not the only factors taken into consideration by farmers when selecting rice varieties.
- Sensory evaluation showed that the mode of rice preparation (parboiled or not parboiled) influences farmer selection. Sensory ranking did not correlate with results of classical physico-chemical analysis (Singh et al., 2001).
• **Institutional constraints.** There was a lack of plant breeders at centres and NARS with experience on participatory approaches. In some centres, it was difficult for the breeders to change their practices and incorporate the participatory approach into their formal breeding programme. There were fears that farmer participatory breeding will replace, rather than supplement, conventional breeding. Moreover, the skills in doing this kind of work, that involves multi-institutional participation, diverse socio-cultural settings and many stakeholders, were not well developed. In many of the centres, there were no female social scientists or female plant breeders included in the team. Thus, it was difficult at the beginning for the male plant breeders to increase the number of women cooperators in the PVS on-farm trials. Thus, there is a need to develop partnerships with NGOs and extension research institutions.

**Conclusions**

PVS is essential in unfavourable rainfed environments and diverse socioeconomic groups that use rice for their livelihoods. Farmer participation improved the selection of suitable varieties for complex rainfed environments in eastern India because: farmers screened new varieties on their own farms under their own levels of management, and breeders better understood farmers' quality requirements.

The close collaboration between scientists and farmers helped ensure that farmers had access to useful germplasm that was adapted to their circumstances and met the requirements of the community for quality and livelihood use. Providing farmers with diverse materials also helped to enhance genetic diversity. Continuous feedback mechanisms between breeders and farmers should be established to ensure appropriate materials are disseminated to farmers.

There was little evidence of major differences in the way farmers and breeders visually rated varieties in the field. Hence, simply having farmers take over the early generation visual selection is unlikely to result in significant improvements in the acceptability of cultivars. On the other hand, extensive farmer-managed trials appear to be a promising approach to reducing the effects of random variability and increasing gains from selection.

Although it is too early to show the impact of PVS through the spread of the materials generated from that PVS, there are promising signs that farmer-selected varieties are spreading easily through farmer-to-farmer exchange. Plant breeders are beginning to change their mindsets and have realised the necessity of interacting with both farmers, and socio-economists. However, the challenge lies in institutionalising farmer participation as integral in the formal breeding programmes and in scaling up PVS and disseminating high-quality new seeds.

**References**


Integrating conventional and participatory crop improvement in rainfed rice

GN Atlin1, TR Paris1, B Linquist2, S Phengchang3, K Chongyikangutor3, A Singh4, VN Singh4, JL Dwivedi4, S Pandey4, P Cenas5, M Laza1, PK Sinha3, NP Mandal3, Suwarno6

1. International Rice Research Institute (IRRI), DAPO Box 7777, Metro Manila, Philippines
2. International Rice Research Institute (IRRI), Lao Project, PO Box 600, Luang Prabang, Lao PDR
3. Northern Agricultural and Forestry Research Institute (NAFRI), Luang Prabang, Lao PDR
4. Narendra Deva University of Agriculture and Technology (NDUAT), Faizabad 224 229, Uttar Pradesh, India
5. Central Rainfed Upland Rice Research Station (CRURRS), Central Rice Research Institute (CRRI), PO Box 48, Hazaribag, 825 301, Jharkand, India
6. Balai Penelitian Padi (BALITPA), Jalan Raya No. 9, Sukamandi, West Java, Indonesia

Abstract

To increase the impact of rainfed rice breeding programmes, participatory varietal selection (PVS) must be institutionalised in the varietal screening process. PVS can be conveniently integrated in two steps: 1. preliminary PVS, in which a relatively large number of lines is screened for adaptation and acceptability on a few farms, with a high level of researcher involvement per farm; 2. advanced PVS, in which a small set of varieties is screened by many farmers, with minimal researcher involvement per farm.

Use of farmer ratings for yield and other agronomic traits, collected via surveys during and after the growing season instead of through crop cuts and researcher measurements, permits even small breeding programmes to scale up advanced PVS, sampling the large numbers of farmers and environments needed to reliably detect differences among varieties. Research in rainfed rice systems in India, Laos, Indonesia, and the Philippines has shown that farmer pre-harvest yield ratings are highly correlated with researcher-measured yields and with farmer preference ratings taken at the same stage. Little cultivar × farm interaction is observed in rainfed rice PVS trials, indicating that broadly adapted cultivars can be identified.

Introduction

IRRI’s participatory crop improvement research is focussed on increasing the impact of rainfed rice breeding programmes. Particularly in upland rice, these breeding programmes have had only limited success in:

- Identifying the traits that are important to farmers
- Identifying lines that outperform traditional varieties in the most stressful environments
- Giving farmers access to new varieties.

IRRI is collaborating with national programmes in India, Laos, and Indonesia in participatory varietal selection (PVS) research that addresses the problem of the limited power of on-station experimentation to predict farmer adoption of new lines, and on reducing the high costs of introducing effective participatory research into formal breeding programmes. This research recognises that random genotype × environment interaction (G × EI), or variation in ranking among experimental lines across trials, even within narrowly defined target environments, is large in rainfed rice (Cooper et al., 1999). The only reliable way to minimise the effects of random G × EI is to evaluate new cultivars over many farms and several seasons (Atlin et al., 2001).

The experience of IRRI and its national partners indicates that linking small rainfed rice breeding programmes into collaborative breeding and variety testing networks is an effective way to achieve the environmental replication needed to make genetic gains in stressful environments. This paper summarises the research results of IRRI and its collaborators on approaches to integrating and scaling up PVS within national rainfed rice programmes.

Key points for introducing participation

Experience has identified three key points where participation is needed in breeding programmes:

**Identifying traits valued by farmers through participatory assessment**

It is important to identify at the outset quality and production traits preferred by farmers, in order to allow...
the selection of genotypes with preferred traits early in the on-station evaluation process. Failure to determine and screen for traits critical to farmer preference means that resources are expended on developing and increasing lines that have no hope of being adopted. This is particularly important in upland systems where farmer quality and plant-type preferences are often not well understood by breeders, but it is also a necessary prerequisite to the scaling up of PVS. This is because large-scale PVS, in which dozens or even hundreds of farmers are asked to assess the performance of new lines, must rely on quantitative survey instruments involving fixed questions and numerical rating scales that permit statistical summary and analysis, rather than on open-ended questionnaires. The questions included in quantitative surveys must therefore be designed to capture information on the traits most valued by farmers.

We have found that several participatory techniques can be used to elicit farmer priorities and preferences. Among the most effective of these is preference analysis undertaken with individuals or small farmer groups in the field. In these exercises, farmers view a variety trial (usually just before maturity), and discuss the strengths and weaknesses of particular varieties by explaining why they like, or dislike, a particular variety.

**Preliminary farmer-managed screening of fixed lines: PVS with many genotypes**

A second point at which farmer participation is needed is the preliminary evaluation of fixed lines that have been developed and evaluated agronomically on-station. Typically, rainfed rice breeding programmes in Asia promote about 20 such lines annually from a preliminary on-station yield trial to advanced yield testing in multi-environment trials (MET) or in replicated on-station trials. Information on farmer acceptability and performance under farmer management is needed on this relatively large set of lines. Without it, there is a high probability that the lines will fail in wide-scale PVS.

PVS strategies permitting the evaluation of *many genotypes on few farms* are useful for this purpose. We have found that the Mother and Baby PVS trial design can permit a set of up to about 20 varieties to be evaluated under farmer management. An incomplete-block design is used, with three to eight varieties tested per farm, and each variety tested on three to five farms. This design requires considerable researcher involvement, but is useful in getting a preliminary farmer assessment of a large number of varieties, allowing varieties that perform well on-station but fail under farmer management to be quickly eliminated.

The importance of this step was confirmed in a PVS programme conducted by the Indonesian upland rice programme in the wet season of 2002, in which 11 varieties were evaluated on six farms (Suwarno et al., 2002). Although all the lines performed well on-station, several failed on-farm due to blast or brown-spot disease that had not appeared with severity in screening trials on-station, probably because of differences in fertility management. Differences in plant density and weed pressure between the station and farmers' fields may also have contributed to the poor performance of some lines on-farm.

It is important for the credibility and success of advanced PVS trials that lines with a high probability of non-acceptance by farmers be excluded. This PVS step is at least as important as replicated on-station or MET testing. Most formal breeding programmes can directly manage such trials on a small number of farms, but may need to shift resources into them and out of other on-station activities.

**Advanced PVS and the use of farmer ratings**

The products of the preliminary PVS trials described above must be evaluated in advanced PVS trials by large numbers of farmers in all the conditions that occur within the target environment. Such trials, which may require the participation of hundreds of farmers, must be designed to require limited researcher involvement in each trial. The informal research and development (IRD) design described by Witcombe et al. (2001), in which each participating farmer evaluates only one test variety, is suitable for this purpose.

Farmer assessments are collected through surveys in which farmers use a simple numerical scale to rate test cultivars as better than, the same as, or worse than their own cultivar for agronomic and quality traits. Survey questions must be carefully designed to target the characteristics that are important to farmers, and administered in a way that facilitates quantitative analysis. Questions can be developed using information obtained in the steps above.

Some breeding programmes will be unable to manage direct farmer contacts on the scale needed for advanced PVS, but will need to link with extension or development organisations to recruit farmers, distribute seed, and administer surveys. However, advanced PVS can be efficiently undertaken directly by researchers linked in multi-station breeding networks, if each station manages the programme in several nearby villages.

**The use of farmer ratings to replace agro-economic measurements in advanced PVS**

**The relationship between farmer yield ratings and researcher-measured yield**

Successful implementation of large-scale PVS programmes in rainfed rice will require the use of methods that minimise researcher involvement per trial. In general, this will involve the use of farmer ratings rather than quantitative measurements of yield and other traits.
It is important, therefore, to estimate the correlation between farmer ratings and quantitative measurements. This has been done for grain yield in PVS trials in several countries and ecosystems (Table 1). In both upland PVS trials in the Philippines and a rainfed lowland trial in eastern India, farmer ratings of cultivar yield were highly correlated with researcher-measured yields. Farmer perception of yield captured by a simple rating system therefore appears to be strongly associated with grain yield measurements taken by researchers. It is likely that yield ratings collected in surveys may substitute for crop-cut measurements in large-scale PVS trials, greatly reducing their cost.

### Table 1. Correlations among researcher-measured yields, farmer yield ratings, and farmer preference ratings in on-farm PVS trials in India, Laos, and the Philippines

<table>
<thead>
<tr>
<th>Trial location</th>
<th>Correlation</th>
<th>Source of variation</th>
<th>Variance component</th>
</tr>
</thead>
<tbody>
<tr>
<td>Farmer yield ratings versus researcher-measured yields</td>
<td></td>
<td>Cultivar</td>
<td>0.077</td>
</tr>
<tr>
<td>Batangas, Luzon, Philippines</td>
<td>0.72</td>
<td>Cultivar X location</td>
<td>0</td>
</tr>
<tr>
<td>Faizabad, Uttar Pradesh, India</td>
<td>0.90</td>
<td>Cultivar X year</td>
<td>0</td>
</tr>
<tr>
<td>Researcher-measured yields versus farmer preference ratings</td>
<td></td>
<td>Cultivar X location X year</td>
<td>0.246</td>
</tr>
<tr>
<td>Tamanbogo, Sumatra, Indonesia</td>
<td>0.66</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Faizabad, Uttar Pradesh, India</td>
<td>0.67</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Luang Prabang, Laos (medium-maturing)</td>
<td>0.82</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Luang Prabang, Laos (early-maturing)</td>
<td>0.54</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Farmer yield ratings versus farmer preference ratings</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Faizabad, Uttar Pradesh, India</td>
<td>0.81</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Batangas, Luzon, Philippines</td>
<td>0.80</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### The relationship between grain yield and farmer preference

Questions have been raised about the extent to which rainfed rice producers, who grow rice mainly for food security, are concerned with grain yield in comparison with other production parameters. This question was addressed by examining the correlation between farmer preference ratings and grain yield measurements or ratings in PVS trials conducted in the Philippines, India, Indonesia, and Laos. In all cases, although there were high-yielding cultivars that were not preferred, there was a strong correlation between measured grain yield and preference ratings (Table 1). The relationship between farmer yield ratings and farmer preference at harvest was at least as strong as the relationship between researcher-measured yield and preference. Grain yield, either as measured by researchers or as visually perceived by farmers, appears to be an important criterion determining farmer preference.

### Genotype x environment interaction in PVS trials

One of the proposed effects of increased farmer participation in plant breeding is increased local or specific adaptation of cultivars. This would imply that cultivars emerging from PPB and PVS programmes exhibit increased G x E interaction. This hypothesis was tested in farmer-managed, multilocational PVS trials in Jharkhand, India and in northern Laos. Little cultivar x village interaction was observed for grain yield in the Indian trial (Table 2). No significant cultivar x province interaction was observed for grain yield in Laos, but a strong interaction was observed for farmer preference among early cultivars (Table 3). The reasons for this province-specific preference are unknown.

### Table 2. Variance components for upland rice cultivars evaluated under farmer management in four villages over 3 years near Hazaribag, Jharkhand, India

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>Variance component</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cultivar</td>
<td>0.077</td>
</tr>
<tr>
<td>Cultivar X location</td>
<td>0</td>
</tr>
<tr>
<td>Cultivar X year</td>
<td>0</td>
</tr>
<tr>
<td>Cultivar X location X year</td>
<td>0.246</td>
</tr>
</tbody>
</table>

### Table 3. Significance level of F-tests of cultivar and cultivar x province interaction for eight early-maturing and eight late-maturing cultivars evaluated in Luang Prabang and Sayabouly provinces, Laos, 2001

<table>
<thead>
<tr>
<th>Trait</th>
<th>Cultivar</th>
<th>Cultivar x province</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yield of early cultivars</td>
<td>*</td>
<td>ns</td>
</tr>
<tr>
<td>Yield of late cultivars</td>
<td>ns</td>
<td>ns</td>
</tr>
<tr>
<td>Preference rating for early cultivars</td>
<td>ns</td>
<td>*</td>
</tr>
<tr>
<td>Preference rating for late cultivars</td>
<td>*</td>
<td>ns</td>
</tr>
</tbody>
</table>

Overall, these results indicate that superior cultivars identified in PVS trials may be broadly adapted and perform well at a regional level, a finding that has also been reported by Joshi *et al.* (2001), and is consistent with the broad farmer-to-farmer diffusion of preferred rainfed rice cultivars such as Mahsuri (Mackill *et al.*, 1996).

However, local preferences for cultivars with particular agronomic traits may also be detected in PVS trials with sufficient replication within environmental subclasses such as regions or management regimes to permit cultivar x class interactions to be tested against the pooled cultivar x farm variance within classes (Atlin *et al.*, 2000).
In general, our results show that participatory approaches can be usefully integrated at several points in rainfed rice breeding programmes, including identification of farmer priorities, initial elimination of unsuitable genotypes, and the final stage of cultivar evaluation. Farmer ratings for grain yield are closely associated with both preference and measured yield, and can serve as the basis for selection decisions in large-scale PVS trials, permitting low-cost scaling-up of participatory selection. PVS products appear to be broadly adapted across farms within the target environments sampled in these studies.

**Integrating PVS in rainfed rice breeding networks**

Because of the sporadic nature of drought and flooding stresses in rainfed rice production environments, resulting in a large random G x E variance, large-scale, multilocational testing systems that link small breeding programmes together have proved to be an effective approach for increasing breeding progress. In the Eastern Indian Rainfed Lowland Shuttle Breeding Network, IRRI collaborates with nine Indian breeding programmes at Indian Council of Agricultural Research (ICAR) research stations and state agricultural universities to jointly develop and evaluate lines across the spectrum of rainfed rice production environments.

A similar interstation network, involving eight sites, has been operating for 2 years in northeast Thailand. These breeding networks annually evaluate over 130 lines in multilocational trials at high levels of precision, and are ideally structured to implement large-scale PVS as the final step in the varietal evaluation process. Networks in which each individual centre manages a preliminary Mother and Baby PVS trial requiring researcher layout in three or four communities, with the participation of three to five farmers per community, could, in collaboration, obtain information on varietal performance and farmer preference from 70–150 farmers in a single season at a manageable cost in time and resources.

Large-scale advanced PVS networks relying on the use of farmer ratings could sample many hundreds of farmers in the target region, permitting local adaptation to be reliably detected if it exists. Lines selected from such networked PVS trials are likely to be broadly adapted, stress tolerant, and acceptable to farmers.

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Participatory scaling up of participatory varietal selection

KD JOSHI1, S GYAWALI2 AND JR WITCOMBE3

1. Department for International Development (DFID) Plant Sciences Research Programme (PSP), Centro Internacional de Mejoramiento de Maiz y Trigo (CIMMYT), South Asia Office, Singh Durbar Plaza Marg, Bhadrakali, Kathmandu, Nepal
2. Local Initiatives for Biodiversity Research and Development (LI-BIRD), PO Box 324, Bastolathar, Mahendrapul, Pokhara, Nepal
3. Department for International Development (DFID) Plant Sciences Research Programme (PSP), Centre for Arid Zone Studies (CAZS), University of Wales, Bangor, Gwynedd LL57 2UW, UK

Abstract

Farmers are the ultimate beneficiaries of new agricultural technologies and the best indicator for the success of a technology is its acceptance and uptake by them. We discuss the benefits of the active involvement of farmers in scaling up the results of participatory varietal selection (PVS) and participatory plant breeding (PPB). We discuss the stakeholders and partnerships for participatory scaling up of varieties. In Nepal, we describe the evolving partnerships between government organisations (GOs) and non-government organisations (NGOs), and community-based organisations (CBOs) that is designed to combine the strengths of the stakeholders whilst sharing responsibilities and resources.

Background

For over 5 years in Nepal, Local Initiatives for Biodiversity Research and Development (LI-BIRD), in collaboration with the Centre for Arid Zone Studies (CAZS), has been developing and promoting participatory crop improvement (PCI) and participatory plant breeding (PPB) approaches. These approaches have been found to be simple, rapid and effective in identifying and disseminating farmer-preferred technologies (Joshi et al., 2001; Joshi and Witcombe, 2002).

The next important step was to find better ways of scaling up to improve cost effectiveness. The first assumption was that the active involvement of farmers in this process – ‘participatory scaling up’ – would greatly improve cost effectiveness. Participatory scaling up involves farmers as seed producers and disseminators. When there is a high degree of farmer involvement it is easier to benefit resource-poor farmers in remote regions, but the technique also works well for more favourable environments. Another important advantage is that technology verification and adoption take place simultaneously. We begin by briefly reviewing the role of farmers before discussing the different stakeholders in this process and the partnerships that are evolving in Nepal.

The role of farmers’ participation

Participatory scaling up is designed to maximise the contribution of farmers in the process. For example, farmers who are key individuals in the informal seed supply system in the village are identified. Such farmers are contracted to produce seed for the project for dissemination by informal research and development methods (see Appendix), or they are given good-quality source seed and asked to grow it and disperse the harvest through their usual informal network. During the participatory scaling up process individual initiatives, the actions of farmers’ groups (FGs), and the results of informal farmers networks have been documented to illustrate the role of farmers in the process.

One example of the role of an individual is Daya Ram Khandka, Chairman of the Dhadwar Village Development Community (VDC), Bardiya District. He is also a farmer, and a member of the Kulanath Krishak Samuh (an FG). Khandka took on the responsibility of distributing seeds, periodically monitoring activities, and maintaining records of the yield and yield components of all the varieties on offer from a LI-BIRD and District Agricultural Development Office (DADO), Bardiya collaboration.

The FG saved all the seeds of all the varieties for sowing in the following year. They have their own norms for exchanging seeds; any farmer wishing to obtain seed...
of new a variety shortly after harvest within the month of Mangsir (16 Nov–15 Dec) can do so just by exchanging seed for rice grains. However latecomers will have to buy the seed paying cash at a rate of two rupees less than the standard price for seed fixed by the Agricultural Inputs Corporation (AIC). This community initiative for varietal evaluation and seed management indicates a sustainable way of achieving impact from PVS.

One of the greatest displays of interest in testing and adopting new varieties from a single-season’s exposure was at Beladevipur village, Kailali District. Most of the people in the village whom the monitoring team were able to see could tell the names of all the varieties tested at that site, the relative performance of all the varieties, and which particular variety they would grow next year. Such interest is only possible when an external agency has been the catalyst in providing seeds and information so that farmers have interacted intensively with their fellow farmers on the merits of the new varieties.

There was also good evidence of farmer-to-farmer seed spread in Kailali District. Nearly 1.5 t rice seed of the new varieties will be sown in the 2002 season at all the sites in Kailali from an initial 300 kg that was distributed (Ram Ayoudhaya Mahato, Chief DADO, Kailali, pers. comm.)

The spread of variety BG 1442 in Chitwan and Makwanpur Districts provides one of the most convincing examples of the effectiveness of farmer networking. The variety was introduced in farmers’ field trials during the early 1990s as a Chaite (early season) rice variety but it is yet to be formally released by the national research system. The variety is promising for the Chaite season. It is adapted to partly irrigated well-drained conditions as a main-season rice variety and is equally suitable for the Bhadiya system (rainfed land in the Terai where early-maturing rice varieties are grown). The crop is sown in May and is called Bhadiya because it is harvested in the Nepali month of Bhadra (late Aug–Sept).

The variety is spreading very quickly from farmer to farmer since LI-BIRD introduced a few kilos of seed of this variety in participatory varietal selection (PVS) trials in 1998 and 1999, and subsequently in informal research and development (IRD) from 2000 to 2002. The variety increased rapidly in area grown from 2001 to 2002 to cover nearly 1200 ha, about one third of the Chaite area in Chitwan District. The spread was encouraged by the breakdown of the predominant variety CH 45 to blast diseases. BG 1442 is also spreading in villages in the neighbouring district of Makwanpur where it covered nearly 50 ha in the main season of 2002. Most of this is from farm-saved seed spreading through the farmer to farmer network, facilitated by distribution of source seed by DADO, Chitwan, LI-BIRD and some farmer cooperatives in eastern Chitwan.

Although farmer-to-farmer spread of seed is very important and has been the major source of seed in most developing countries, including Nepal, it is not the fastest system. Farmers consume seed on-farm and sell it as grain in the markets, so only a proportion can be used as seed for sowing. Our experience with most of the farmer-to-farmer spread has been that a three-to four-fold increase is often found, but a sixty-fold increase can easily be achieved with an organised seed increase and distribution programme. This efficient source of officially multiplied seed can be used most effectively when it is distributed widely and to many farmers.

Stakeholders and modes of partnership

Once the central role of farmers has been established, a first step in scaling up is the identification of stakeholders and devising the most appropriate mode of partnership (Table 1). The lack of lasting effects of some of the research and development projects designed and run through a top-down approach in the past was due to the lack of farmers’ participation, and ignoring the central role that farmers can play. There was also a lack of identification of all stakeholders and their roles and responsibilities.

Scaling up is more complex than simple technology generation or verification because it involves more stakeholders. Technology generation often ignores farmers and multi-partner approaches. A multi-partnership in which farmers play a central role is the most suitable one for scaling up (Table 1).

The benefits of this approach are particularly important when, as is common, linkages between research and extension are poor and government extension services are restricted by limited resources to serving only the more accessible areas.

Table 1. Stakeholders1 for participatory scaling up

<table>
<thead>
<tr>
<th>Stakeholders</th>
<th>Mode of partnership</th>
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<td>Donor CGIAR</td>
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<tr>
<td>Donor NGOs</td>
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<tr>
<td>Farmer NARS</td>
<td>NAES</td>
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<tr>
<td>NGOs CGIAR</td>
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1. CGIAR = Consultative Group on International Agricultural Research; NARS = National Agricultural Research System; NAES = National Agricultural Extension System; NGO = non-governmental organisation; GO = governmental organisation
Partnership modes for participatory scaling up

NGO and community partnerships
An important form of collaboration that is emerging for participatory scaling up is collaboration between NGOs and community-based organisation (CBOs). The CBOs are usually FGs that were already established for cooperative enterprises or for specific users’ interest – e.g., drinking water.

Three CBOs were as follows:
1. Women’s group (Narayani Mahila Milan Club, Amlatari, Kumarti-9)
2. Mixed FG (Gramin Swablamban Bikas Kendra, Bishaltar, Devchuli-1) and
3. Water-users’ group (Naya Belhani Khanipani Upabhokta Samiti, Naya Belhani-2)

LI-BIRD signed a Letter of Agreement (LoA) with three CBOs in Nawalparasi. One of which was formed by the DADO office while the other two were self-organised. In this type of partnership, both organisations have a high degree of institutional flexibility. Its success will depend on both types of partners respecting each other’s roles and responsibilities (Box 1) and, in the case of LI-BIRD and the three CBOs there were three separate LoAs to make these facts clear. However, the scale of operation of NGO and CBO partnerships will usually be limited as most FGs are local organisations.

NGO and GO partnerships
LI-BIRD and DADO Chitwan. One mode of working is collaboration between an NGO and a GO. An example in Nepal is the partnership between LI-BIRD and the government line agency DADO in Chitwan District. One unique feature of this partnership was the signing of an LoA for 3 years, which defined the role and responsibilities of the two partners (Box 2). However, the sustainability of this approach could be improved if funding were from the recurrent budget of His Majesty’s Government of Nepal rather than a special project funded by the Plant Sciences Research Programme.

This agreement between an NGO and a GO may be one of the first examples of its kind in Nepal (LoA signed by the District-level Authority of the Department of Agriculture (DoA) rather than at the Department level) although there are other examples of GO–NGO collaboration for specific development objectives at the Department level, such as the collaboration between CARE Nepal and the Departments of Soil and Water Conservation and the Department of Health Services.

The initial interest in formal collaboration came from the GO. However, informal collaboration started before that. When LI-BIRD initially set up the research project it consulted DADO Chitwan on the identification of project villages and DADO staff regularly participated in the monitoring of the participatory varietal trials. DADO then started scaling up unreleased farmer-preferred crop varieties using their own funds for over a year.

Expanding the collaboration to more district offices.
A stakeholders meeting was held in Kathmandu in February 2001 to discuss building on the existing partnership between LI-BIRD and DADO, Chitwan. The meeting agreed on the advantages of participatory scaling up and set up a joint Working Group of the DoA, Nepal Agricultural Research Council (NARC) and LI-BIRD. The Working Group developed a proposal to scale up the activities in Chitwan to four more districts: Dhanusha, Sarlahi, Bardiya and Kailali. This was subsequently approved by the authorities from DoA,

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**Box 1**

**Scaling up through farmers’ groups in Nawalparasi District, Nepal**

**The process**
- Participatory rural appraisals (PRAs) to identify community-based organisations (CBOs) suitable for participatory scaling up, and the analysis of secondary information through agricultural service centres
- Documentation of profile of short-listed farmers’ groups (FGs) by PRA
- Selection of established FGs
- Letter of Agreement (LoA) signed with three FGs, two mixed and one of women farmers
- Implementation of programme through FGs.

**Role of FGs**
- Responsible for carrying out all field activities: farmer identification, (focus on poor and medium-poor farmers), distribution of seeds, record keeping, including the monitoring of varietal adoption
- Seed production and farmer-to-farmer distribution
- Group decision making.

**Role of LI-BIRD**
- Impart necessary skills for scaling up through orientation, training and exposure visits
- Provide technical backstopping
- Assist in monitoring and evaluation
- Provide financial and institutional support for scaling up.
Box 2

**Letter of Agreement between DADO Chitwan and LI-BIRD for participatory scaling up**

**Roles of DADO**
- Full responsibility for implementing scaling-up activities through their networks
- Preparing a joint annual plan and obtaining the approval of the Ministry through the regular planning process
- Periodical monitoring – collecting field information and preparing progress and technical reports
- Providing financial and other institutional support to seed production of the new, unreleased varieties, as applicable to released varieties
- Farmer and staff skill development on participatory approaches through orientation, training and exposure visits
- Organising periodical coordination and review meetings with LI-BIRD.

**Roles of LI-BIRD**
- Arranging source seeds of farmer-preferred varieties for scaling up
- Assisting in preparing the annual plan
- Imparting skills to DADO staff through joint activities and through orientation and training programmes
- Sharing in data analysis and report writing
- Organising seasonal monitoring tours involving DADO, DoA, NARC and IAAS staff
- Providing agreed financial and institutional support.

NARC and LI-BIRD. The World Bank-funded Agricultural Research and Extension Project (AREP) agreed to provide a small grant for this work.

Farmer-preferred rice varieties were produced and disseminated in 2001 in the major rice-growing domains in each of four districts. Farmers tested the new rice varieties in long-standing water, irrigated, partially irrigated, and rainfed conditions, and for the Bhadiaya system.

**Consolidation and further expansion to more organisations**

A workshop was jointly organised in January 2002 by DoA and LI-BIRD to share the findings from the five collaborating district offices. Representatives from seven DADOs participated and developed seven project concept notes (PCNs) for participatory scaling up of PVS-identified and PPB-produced varieties.

The possibility of incorporating the work plans of the PCNs into the regular planning process of the DoA to attract regular funding was discussed. Some of the DADOs have already done so, indicating a greater acceptance and uptake of the approach by the DoA.

Although the extent of activities differs greatly, currently activities have been extended to 17 Terai and two hill districts. In these initiatives, LI-BIRD is also collaborating with such other NGOs as FORWARD, REGARDS, CARE and PLAN International, in addition to working closely with the DoA.

**Opportunities**

Currently there is a helpful environment for participatory research and scaling up in Nepal. The Ministry of Agriculture and Cooperatives has adopted partnership as one of the main approaches to agricultural research and development. His Majesty’s Government of Nepal has set up a competitive funding system for action research and scaling up called the National Agricultural Research and Development Fund (NARDF). Agricultural extension will very soon be devolved to the local government, which necessarily involves decentralisation and a greater emphasis on people’s participation. DADOs are also considering contracting out of some of their service delivery functions to improve their efficiency.

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