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In Partnership

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Farmers and Plant Breeders in Partnership

second edition

Edited by C.M. Stirling and J.R. Witcombe

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CLARE M. STIRLING AND JOHN R. WITCOMBE

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Foreword

This second edition of *Farmers and Plant Breeders in Partnership* has undergone extensive revision since the first publication in 2001. This edition provides an up date on the DFID Plant Sciences Research Programme's participatory research in Asia and Africa. In addition, some new topics are included in the sections describing the impact of the research on end users, the importance of screening for post-harvest traits and the potential role of molecular marker technology in participatory plant breeding. A common theme throughout the book is the importance of orientating plant breeding programmes towards the needs of the farmers, who are essentially the clients of the research. We describe how this is achieved by first understanding what farmers need, and then by developing programmes that will meet those requirements. One of the most powerful tools in achieving this is the testing of products from the breeding programmes with farmers, a process that considerably reduces the time taken between development of a new variety and its widespread adoption.

The work described is the result of partnerships between farmers and plant breeders. Of significance, is the diverse range of partnerships that have been involved, including both national and international organisations, government and non-government sectors, and organisations concerned with both research and extension. Only by mobilising a network of partners concerned with all aspects of delivering new varieties to farmers can real impact be made.

John R. Witcombe and Clare M. Stirling

Acknowledgements

The results presented in this document are from research projects of the Plant Sciences Research Programme (see page 31) funded by the UK Department for International Development (DFID) and administered by the Centre for Arid Zone Studies (CAZS) for the benefit of developing countries. The views expressed are not necessarily those of DFID. We wish to thank all the scientists of the institutes involved in the projects reported here and the farmers in Ghana, India and Nepal who have enthusiastically participated in the research. Work in India has been co-funded by DFID India and the Government of India.

Participating Institutes

ASA	Action for Social Advancement, Sahyog Nagar, Dahod, Gujarat 389 151, India.
BAU	Birsa Agricultural University, Kanke, Ranchi 834 006, Jharkhand, India.
CAZS	Centre for Arid Zone Studies, University of Wales, Bangor, Gwynedd, UK.
CPP	UK Department for International Development Crop Protection Research Programme, Aylesford, Kent, UK.
CRI	Crops Research Institute, PO Box 3785, Kumasi, Ghana.
DADOs	District Agricultural Development Offices of the Ministry of Agriculture, Nepal.
GVT(E)	Gramin Vikas Trust (East), 280 Kanke Road, Near Pani Jahaj Kothi, Ranchi 834 008, Jharkhand, India.
GVT(W)	Gramin Vikas Trust (West), Western India Rainfed Farming Project, Bhopal 462 013, India.
HCRP	Hill Crop Research Programme, Kabre, Nepal.
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics, Patancheru 502 324, Andhra Pradesh, India.
JIC	John Innes Centre, Norwich, Norfolk, UK.
LI-BIRD	Local Initiatives for Biodiversity, Research and Development, PO Box 324, Bastolathar, Mahendrapul, Pokhara, Nepal.
MPUATU	Maharana Pratap Agricultural and Technology University, Banswara 327 001, Rajasthan, India.
NARC	Nepal Agricultural Research Council, Singhadurbar, Plaza, Kathmandu, Nepal.
NRCS	National Research Centre for Sorghum, Rajendranagar, Hyderabad 500 030, Andhra Pradesh, India.
NRI	Natural Resources Institute, Chatham Maritime, Chatham, Kent, UK.
PAC	Pakhribas Agricultural Centre, Dhankuta, Nepal.
PAU (L)	Punjab Agricultural University, Ludhiana 141 008, Punjab, India.
PAU (P)	Punjab Agricultural University, PO Box 22, Patiala 147 001, Punjab, India.
PEL	Plant Environment Laboratory, Department of Agriculture, University of Reading, Shinfield, Reading Berkshire, UK.
SAFS	School of Agricultural and Forest Sciences, University of Wales, Bangor, Gwynedd, UK.
SARI	Savanna Agricultural Research Institute, PO Box 52, Tamale, Ghana.
UAS	University of Agricultural Sciences, GKVK, Bangalore 560 065, Karnataka, India.

Contents

Why should scientists collaborate with farmers ?

Poor farmers in marginal areas continue to grow old varieties that are often low-yielding and susceptible to pests and disease. They have had little exposure to new varieties and those that have been released are often not suitable for rainfed conditions on marginal lands.

Every season farmers sow their crops. They understand seeds and crop varieties and know how to use them. They are usually very willing to try new varieties, but our[1] work in India, Nepal and West Africa shows that formal plant breeding and varietal release systems are not fully meeting farmers' needs. In particular, resource-poor farmers in marginal areas benefit less from high-yielding varieties (HYVs) compared to farmers in more favourable regions.

In India, the percentage adoption by area of HYVs of rice was mapped for six states at a district level. In many districts the adoption of HYVs was below 50% and in these districts mean yields were also low (i.e., $1\ t\ ha^{-1}$) and only half that of districts with high adoption rates (Figure 1). These large differences in average yield cannot be explained solely in terms of genetic differences resulting from adoption or non-adoption of HYVs. The districts that had low adoption of HYVs also had the most marginal agricultural environments where farmers use less inputs.

Many farmers also grow old varieties or landraces, some released decades ago. This is because they seldom have access to mod-

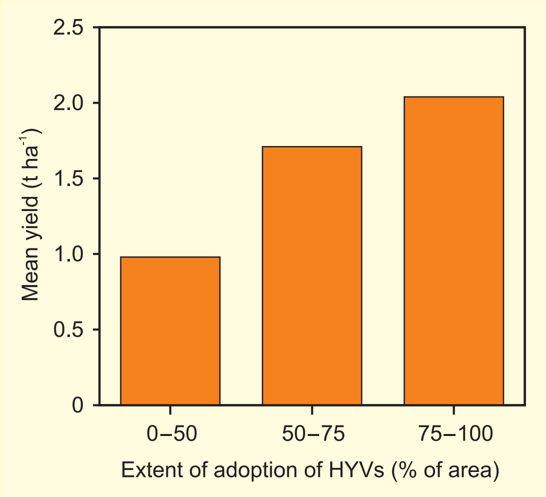


Figure 1. Yield of rice in 149 districts in six Indian states. Data are categorised by three levels of adoption of high-yielding varieties (HYVs) of rice.

ern technologies, such as new varieties, and the poorest farmers are often less able or willing to take risks and so are less likely to adopt new varieties. One means of addressing this problem is to place the seed of novel cultivars directly in the hands of the farmers. In this way, farmers have the opportunity to test new cultivars for themselves in their own fields.

By fostering collaboration between plant breeders and farmers, our work aims to provide even the poorest farmers with a chance to benefit from such technologies as new varieties. In West Africa, where many farmers are women, their views and experiences are often ignored or not represented. Participatory research can resolve issues relating to gender or wealth, by involving men and women, both rich and poor. Evaluations and discussions can be conducted separately by gender and the poor can be identified and then helped by giving them seed to try in their own fields.

[1] The evidence we present is from research projects commissioned by the *Plant Sciences Research Programme* of the UK Department for International Development (DFID). "We" and "our" relates to any of the scientists in this programme and participating institutes are listed on page 1.

Farmers in developing countries are often insufficiently involved in the breeding, selecting and testing of new varieties. Our participatory plant breeding programme involves farmers in all these processes in order to help identify or create varieties that suit local needs and conditions. We use two approaches; participatory varietal selection (PVS) and participatory plant breeding (PPB), the benefits of which can be applied to both marginal and high-potential, production systems (HPPSs).

Participation allows plant breeders and farmers to learn from each other. Breeders have a broad knowledge of available genetic resources and of appropriate breeding methods. Farmers contribute local knowledge and test varieties under local conditions. Involving farmers speeds up the process of varietal adoption and increases the varietal biodiversity in farmers' fields.

Participatory Varietal Selection (PVS)

PVS assumes that varieties exist that are better than those currently grown, but which farmers have not had the opportunity to test. In PVS, farmers are given varieties to test in their own fields. These varieties are chosen carefully. To save time and to ensure that seed is available we have used seed of cultivars that have already been released, not only from the target region but also from other regions or countries. A successful PVS programme has four phases:

i. participatory evaluation to identify farmers' needs in a cultivar,
ii. a search for suitable material to test with farmers,
iii. evaluation of its acceptability in farmers fields, and
iv. wider dissemination of farmer-preferred cultivars.

One of the great strengths of PVS is that it is both an extension and a research method. Varieties tested in PVS can rapidly spread from farmer to farmer. As well as exposing farmers to novel cultivars, PVS is effective in identifying locally adapted parental material and in identifying breeding goals – for example, early maturity – that assists the selection of complementary parents.

Most of the PVS programmes use a mother and baby trial system. The mother trials compare all the entries together in a farmer's field. In baby trials, farmers compare a single variety with the variety they have grown in the past.

Participatory Plant Breeding (PPB)

PPB is more powerful than PVS as it creates new variability rather than relying on existing varieties. In our PPB programmes we exploit the results of PVS by using cultivars as parents of crosses. Weaknesses in cultivars are identified in the PVS programme so that such cultivars can be crossed with varieties that have complementary traits to eliminate those weaknesses. A key PPB method is the collaborative participation of farmers who grow a bulk in their own fields and select amongst it. Using this collaborative breeding, it is possible to replicate the selections 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). In other methods breeders consult farmers who may, for example, give opinions on material grown by breeders on research stations. One great advantage of PPB is that it is much faster than conventional breeding.

PVS makes use of existing varieties to give farmers more choice

In conventional plant breeding few varieties ever make it to the stage of on-farm testing and even fewer are formally recommended and released. Therefore, in any one year farmers have access to a very limited choice of varieties. PVS gives farmers more choice by providing seed from a wide range of varieties that have already been released.

Participatory varietal selection (PVS) increases farmers' varietal choice. In DFID-funded research, it has been successful in several countries and with many different crops (see opposite). We usually give participating farmers a choice from three to six varieties. However, a wider choice can be given when we produce many suitable lines in our participatory plant breeding programmes.

A young farmer comparing two rice varieties.

PVS and PPB programmes have increased farmer choice in several countries

PVS	PPB
• Upland rice (Ghana, eastern and western India)	• High-altitude rice (Nepal)
• Rainfed maize (eastern and western India)	• Low-altitude upland and lowland rice (Nepal)
• Sorghum on residual moisture (central India)	• Upland rice (eastern and western India)
• Rainfed wheat (Nepal and western India)	• Rainfed maize (western and eastern India)
• Rainfed finger millet (central India)	• Black gram (western India)
• Chickpea (western India)	• Cassava (West Africa)
• Pigeonpea (western India)	
• Black gram (eastern and western India)	
• Soybean (western India)	
• Mung bean (western India)	
• Irrigated rice (western India)	
• Irrigated wheat (western India)	
– Usually the most preferred variety is not a recommended one	**– In rice, annual genetic gain of 3% from first cross to impact in farmers' fields**
	– In maize, annual genetic gain of 3.5–5% from first cross to farmers' fields

In Ghana, upland rice is grown by resource-poor farmers, often on sloping land, in drought-prone areas. Few varieties suitable for these upland conditions have been formally released and most farmers, particularly in the forest zone, still grow landraces of African rice (*Oryza glaberrima*) or informally introduced varieties.

New varieties of rice being evaluated by farmers on their own farms in Ghana.

PVS programmes have been conducted in three locations in Ghana; in the forest zone at Hohoe, in the transition zone at Aframso, and in the savanna zone at Nyankpala. These PVS programmes have all used nurseries in the first year and then distribution of seed to individual farmers in the second and subsequent years. Approximately 100 varieties were selected for PVS from throughout the West African region along with high- and low-input conditions and evaluated by both men and women farmers. In addition, we conducted post-harvest assessments with farmers and market traders, because varietal characteristics such as how well a rice can be milled (high grain recovery and few broken grains), expansion ability on cooking, and taste are also very important in determining varietal choice (see page 15).

Farmers selected a wide range of varieties and gave many different reasons for their choices (see Table 1). Both men and women farmers wanted varieties that were high-yielding and suppressed weeds. Disease resistance was wanted in the forest zone and drought tolerance (early maturity) in the savanna zone (Table 1). Women farmers also identified several post-harvest characteristics such as: taste, aroma, ease of threshing and good milling quality without par-boiling.

Several varieties were consistently selected by farmers in both low- and high-input conditions (Figure 2). However, some varieties were chosen more frequently under low-input conditions and some under high-input conditions, indicating specific adaptation.

Table 1. Characteristics considered important in new upland rice cultivars by male and female farmers in two agroecological zones in Ghana.

Forest zone		Savanna zone	
Men	**Women**	**Men**	**Women**
High yield	High yield	Supress weeds	High yield
Supress weeds	Taste	Drought-tolerant	Drought-tolerant
Disease-resistant	Suppress weeds	High market value	Easy to thresh
High-tillering	Early maturity	High yield	Grows well at low fertility
Will not lodge	Aroma	High-tillering	Good grain expansion
Large grains	Large grains	Early maturity	Mill without par-boiling

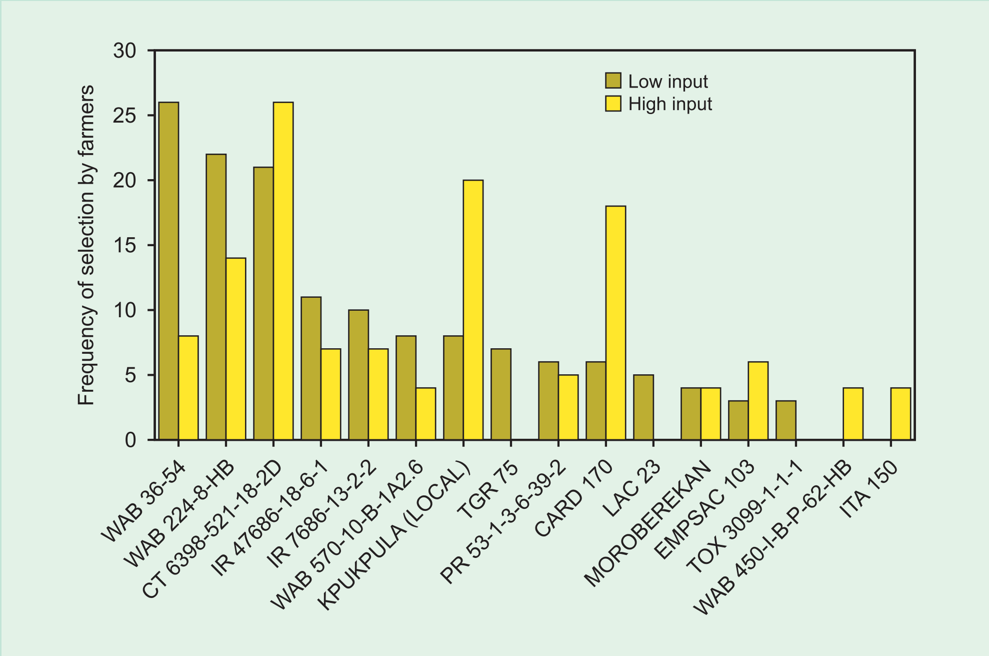
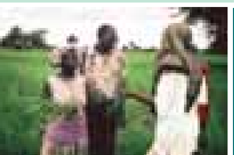


Figure 2. Farmer evaluation (combined data from male and female farmers) of rice varieties grown under high (clean weeding and fertiliser) and low (one weeding and no fertiliser) input conditions at Nyankpala in the savanna zone of Ghana.

Upland rice field near Todzi, Volta Region, Ghana.

For example, under low-input conditions the two most frequently chosen varieties were the improved varieties WAB 36-54 and WAB 224-8-HB. Under high-input conditions the local landrace Kpukpula and variety CARD 170 were amongst those selected most often. This belies the often-held belief that improved varieties need more inputs. Farmers were clearly able to discriminate among a large number of varieties and identify varieties suitable for the different conditions that exist on their farms.

Six other varieties from the same PVS programme have also been adopted in the Hohoe region and one variety (IR12979-24-1) has been formally released through SARI (Savanna Agricultural Research Institute) for northern Ghana.



PVS trials on upland rice in Ghana gave farmers more choice than they had ever had. Farmers selected a wide range of varieties and a few proved consistently popular, because of their market value, seed quality and yield.

PVS uses farmers' knowledge to identify useful varietal characteristics

PVS can provide valuable information to breeding programmes. It can identify general traits for adaptation to environmental conditions or to cropping systems. PVS can also identify specific traits or characteristics wanted by farmers in particular areas.

Varietal testing and release programmes are dominated by the need to increase yield by selecting varieties that perform well across many different environments. Hence breeding programmes traditionally concentrate on the traits most important for wide adaptation, e.g., stable grain yield and resistance to major pests and diseases. Farmers are rarely consulted about varietal characteristics and their 'ideal' plant type.

Individual farmers judge varieties by considering a wider range of traits. For example, farmers often want varieties that produce a lot of fodder, as well as grain, and that are easy to thresh.

PVS can identify general traits that give adaptation to environmental conditions or to cropping systems (such as how long it takes for the crop to mature). In addition, PVS can identify specific traits or characteristics wanted by farmers in particular areas. Some of these important characteristics (e.g., ease of threshing) are reflected by the local names given to acceptable varieties in PVS trials (Table 2). Indeed, ease of threshing was found to be of great importance to the Nepalese and Ghanaian farmers, but this trait has never been measured in conventional breeding programmes.

Threshing rice by hand in Nepal. The number of beats needed to remove grain from the bundle is a direct measure of ease of threshing.

Table 2. Sample of some of the local names given by farmers in Todzi, near Hohoe, to cultivars selected from PVS on upland rice in Ghana.

Cultivar name	Local name	Translation
IDSA 85	Idana	You'll not be tired (threshes easily)
Iguane Cateto	Levawor	I will not perish
WAB 340-B-B-9-13-4-B	Kaeme	Remember me
WAB 209-5-H-HB	Elebode	Is good to eat
WAB 160-24-H-HB	Adime	Saviour

During our PVS trials with upland rice in Ghana, the local farmers identified traits during crop growth and post-harvest that they considered important (Table 3).

Throughout the growing season, farmers selected for traits that contribute to greater weed tolerance such as broad leaves, plenty of tillers and vigorous early growth – an important constraint for upland and intermittently flooded rice in West Africa. At the post-flowering stage, farmers thought plant height, panicle traits and grain length were important as they considered them to be linked to yield.

At harvest, grain shape and size were very important. Farmers preferred long, plump or bold grains, as they believe this grain occupies a larger volume, and commands a higher market price. After cooking, taste, aroma, expansion ability, stickiness and hardness are traits that farmers thought are important.

Regional and local preferences are also important in influencing the acceptability of new varieties. We found from surveys that in villages close to urban markets farmers and traders identified grain type (long, slender grain, similar to that of imported rice) as the most important trait. Away from the urban markets, local preferences were more important. In western Ghana, cooked rice that is sticky is highly desirable, while in northern Ghana high expansion ability is preferred as rice is predominantly par-boiled[2] in this region.

Table 3. Selection criteria used by farmers to evaluate rice varieties in Ghana.

Selection criteria during crop growth		
Yield	Panicle size	Plant architecture
Plant height	Maturity period	Canopy density
Tillering ability	Lodging	Tiller density
Leaf shape/width	Plant vigour/speed of growth	Leafiness
Leaf serration	Panicle excision	
Uniformity of maturity		
Selection criteria at harvest		
Grain length	Grain size	Grain colour
Grain taste	Grain hardness	Boldness
Milling recovery	Market value	
Sensory traits		
Aroma	Taste	Stickiness
Expansion ability	Hardness	

[2] Refers to the process of soaking paddy (i.e., seed plus husk), then steaming it and finally re-drying before milling.

Together with yield and post-harvest characteristics, regional and local preferences have to be considered before a variety can become accepted and adopted.

Reaching out to the poorest farmers

PVS and PPB put seed directly in the hands of participating farmers and our studies show that given access to seed, poor farmers will adopt new varieties as rapidly as wealthier ones.

The wealth of a farmer can be a very important factor in the adoption of varieties. Resource-poor farmers may have restricted access to new varieties and may be less willing to invest in, or risk, growing new varieties. However, our studies in high potential production systems (HPPSs) in India show that, given choice and access to seed, resource-poor farmers will adopt new varieties of rice as rapidly as do better-off farmers (Figure 3).

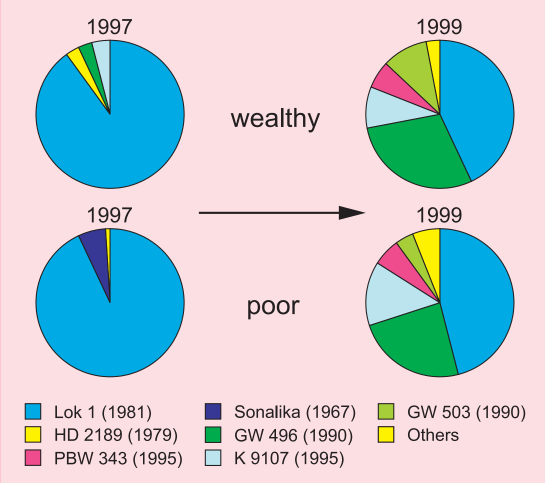


Figure 3. Uptake by participating farmers of wheat varieties by area (%) and by wealth category in Lunawada, India, following a PVS programme in 1997. Lok 1 is the traditional variety grown in the area. The year of each variety's release is given in parentheses.

In Jharkhand, eastern India, farmers who cultivate upland rice on low-fertility, sloping soils continue to grow low-yielding landraces that are susceptible to disease and pests. As a result of our PVS and PPB projects, two new improved rice varieties (Ashoka 220F and Ashoka 228) have been produced for upland conditions.

The size of landholding is a clear reflection of wealth status, but there was no clear relation between land size and adoption of the new varieties. Poor farmers adopted the new Ashoka varieties as enthusiastically as better-off farmers (Figure 4).

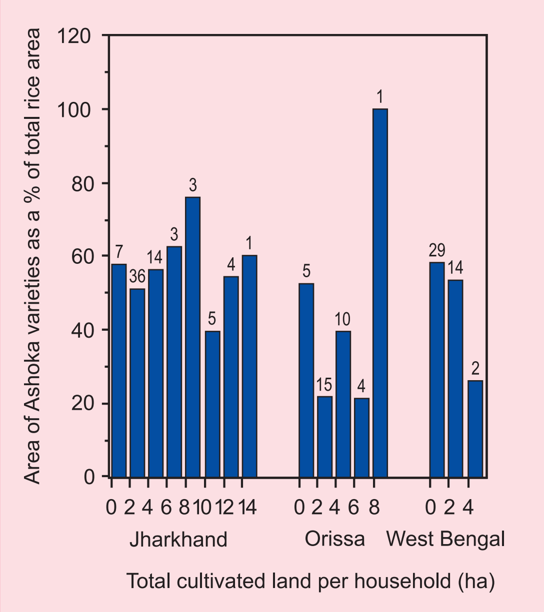


Figure 4. Percentage of area of rice land devoted to Ashoka varieties versus the average total cultivated land per household in three Indian states. Numbers above bars indicate the number of households in each category.

Farmer adoption of these new varieties has been very high. In Orissa and West Bengal, the proportion of upland area under the new varieties has exceeded 100%. This is because farmers have brought uncultivated land into cultivation or have expanded their cultivation of upland rice varieties into other rice ecosystems.

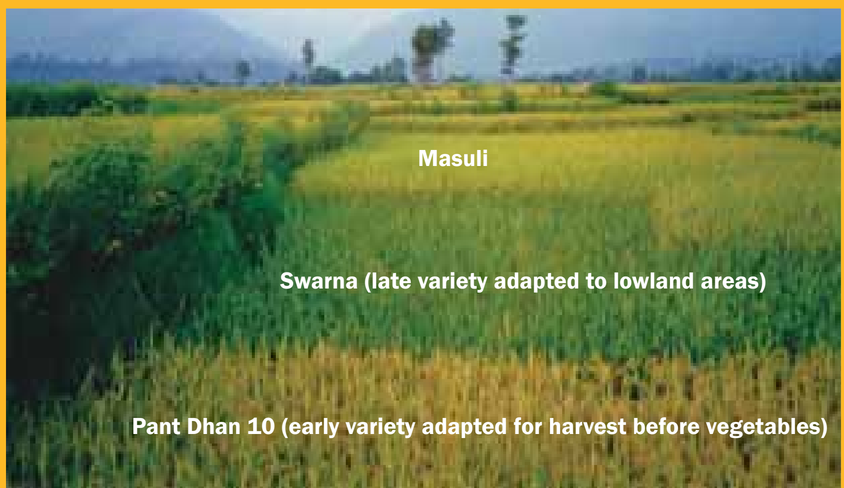
Matching varieties to local needs

The advantage of participatory research, whether PVS or PPB, is that farmers grow and assess the varieties on their farms using their own methods and input levels. They can choose varieties that are specifically adapted to their own growing conditions and needs.

Although crops in high potential production systems (HPPSs) are usually irrigated and relatively free of the environmental variation caused by erratic rainfall, we found considerable variation in the physical environment within these areas. For example, in the HPPS area of Chitwan and Nawalparasi in Nepal, our PVS programme introduced new main-season rice varieties to farmers. The farmers themselves identified and adopted different varieties for the different water and fertility conditions found on their farms. They adopted a variety called Swarna for poorly drained fields where water stands for nearly the whole growing season; they adopted three varieties (Pant Dhan 10, PNR 381 and Sarwati) for partially irrigated and medium fertility conditions. More recently Sugandha 1 and BG1442 have become more popular in partially irrigated and medium fertility conditions. In addition, the farmers found that Radha 11 was suitable for late sowing conditions and for transplanting when seedlings are more than six weeks old. This is a very important trait for areas where transplanting is dependent on unpredictable monsoon rain and where the availability of labour may prevent timely sowing and transplanting.

Some varieties, such as Pant Dhan 10, fit particular niches in the farming system. Farmers who grow vegetables prefer this variety as its early harvest allows vegetables to be sown earlier – and thus fetch a higher market price.

Varietal choice allows farmers to manage and exploit the whole cropping system. In HPPSs in particular, more than one crop is grown each year. Certain varieties may be preferred because they fit well into the system as a whole, rather than for a specific cropping niche.



A three-entry rice trial in Nepal.

Increasing crop varietal diversity

A narrow varietal or genetic base can increase crop vulnerability to pest and disease attacks. One of the greatest advantages of PVS and PPB is that they result in an increase in varietal diversity, both at the local and regional level.

In many production systems, both marginal and favourable, varietal diversity is very low and the age of varieties (i.e., the number of years since they were first introduced) is often high. During 1997, in the Lunawada district of Gujarat, we investigated varietal diversity by asking farmers which varieties of irrigated wheat and main-season (*kharif*) rice they grew. Before starting our PVS programme in this high potential production system (HPPSs), we surveyed over 100 households in three villages. In 1999, we repeated the survey in the same villages to see how our programme had affected local varietal diversity.

In the case of wheat, the age and uniformity of the varieties grown by farmers was quite extreme. We found a single variety, Lok 1 (introduced in 1981) occupied 89% of the total area sown (Figure 5). Such a lack of varietal diversity is not uncommon. After 3 years of our PVS programme, participating farmers decreased the area under Lok 1 from 89% to about 20%, as they rapidly adopted six to eight new varieties (Figure 5). The positive effect of our programme was highlighted when the varietal diversity of

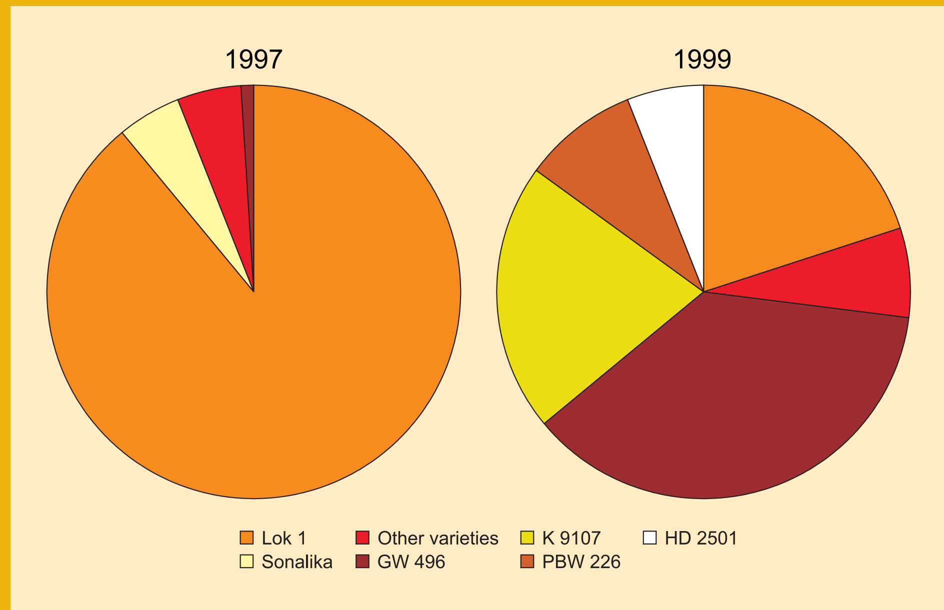


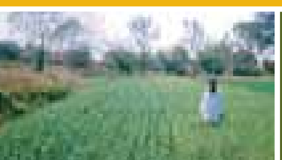
Figure 5. Increase in varietal diversity by area (%) in wheat with participating farmers in Gujarat following our PVS programme.

wheat grown by participating farmers was compared to that of the village as a whole, where Lok 1 remained the dominant variety (70% of the area).

An increase in the number of varieties grown is one way to measure an increase in diversity. However, if many of the varieties are related (have common parents), then the increase in genetic diversity is not so great as it first appears, and the varieties may have the same resistance genes. This may increase the risk of disease epidemics or severe pest outbreaks in the crop.

The increases we found in varietal diversity were accompanied by increases in genetic diversity. In the example on rice diversity in Gujarat, Gurjari was a valuable addition to varietal diversity because it was unrelated to other varieties. When new varieties have little or no relationship to the other varieties currently grown in the region, they play a significant role in increasing biodiversity. This illustrates an important consideration when planning any PVS programme: the need to include genetically diverse varieties to increase both genetic and varietal diversity.

Wheat PVS trials in a farmer's field in the Lunawada district of Gujarat.



In Gujarat, India a single variety, Lok 1, occupied 89% of the total wheat area. After 3 years of our PVS programme, farmers decreased the area under Lok 1 to about 20% as they adopted six to eight new varieties.

In Nepal, the National Programme has released relatively few varieties for the Terai, particularly in view of its importance in area, and only four varieties have been released in the last 10 years (the most recent in 1998). A minority of the varieties that have been released have been popular with farmers. Instead, many of the most popular varieties are farmers' introductions, such as Kanchi Masuli and Radha 17, most of which are from India.

Participatory surveys in the project villages of Chitwan and Nawalparasi in Nepal revealed that farmers were growing old varieties of rice, in some cases as much as 40 years old. Varietal diversity was often extremely low in main season rice, with the most-popular, very-old variety, Masuli, usually occupying the majority of the rice area and sometimes over 90% (Figure 6).

Our PVS and PPB programmes in Nepal have identified an increasing number of rice varieties that farmers wish to adopt. In recent years, these new varieties are mostly the products of PPB. Fifteen varieties have been identified that are suited to poor farmers who cultivate the less-productive medium upland and upland conditions in the main season i.e., most of the area of the Terai. These varieties were first tested in Chitwan and Nawalparasi where rates of adoption by both men and women farmers have been high (Figure 6). Adoption of project varieties was already over 40% of the rice area in many of the 34 villages surveyed in Chitwan and Nawalparasi in 2002.

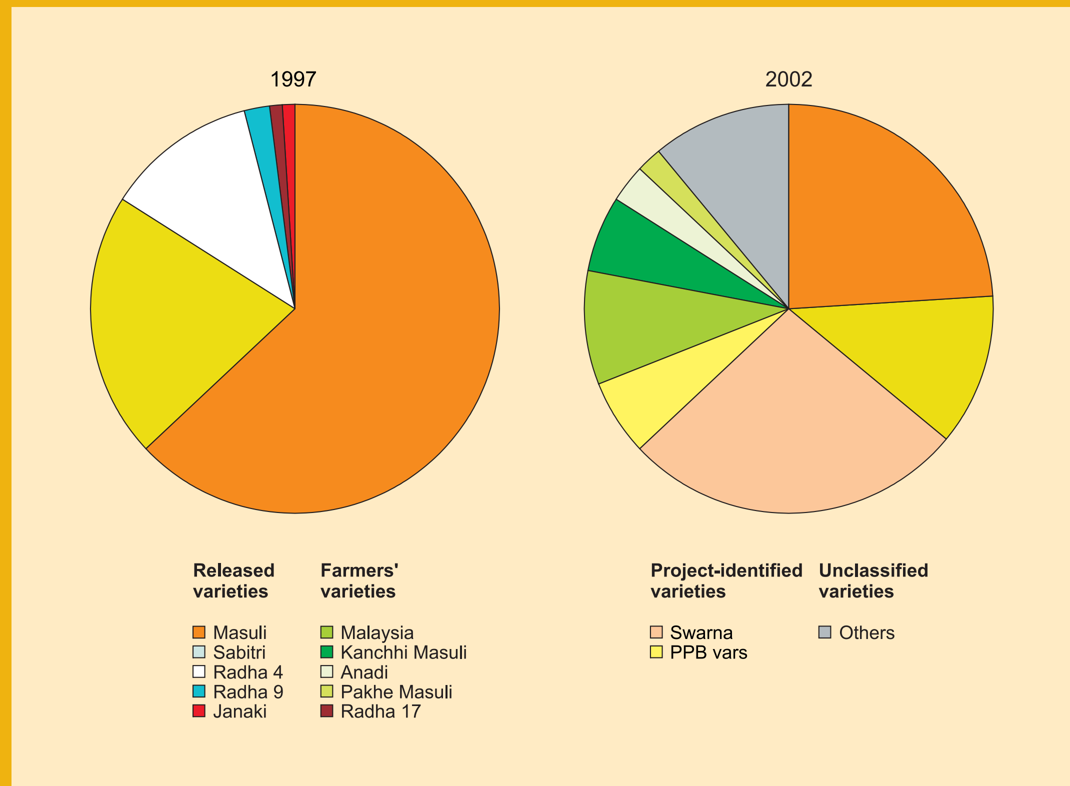
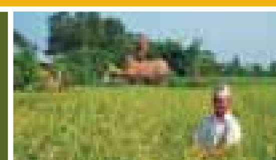


Figure 6. An example of the effect of adoption of project varieties on varietal diversity. Changes in varietal adoption in Nawalparasi village cluster from the baseline survey (1997) to the 2002 main season. By 2002, the adoption of project varieties was 33% of the total rice area in the village cluster.

Our PVS and PPB projects on low-altitude rice in the Terai of Nepal have addressed the problem of lack of varietal diversity by identifying a wide range of new varieties that farmers wish to adopt.



In Nepal, we have monitored the effects on varietal diversity of widespread adoption of two cold-tolerant PPB rice varieties, Machhapuchhre-3 (M-3) and Machhapuchhre-9 (M-9). Farmers were considered adopters if they had grown the variety for at least two seasons, or had actively obtained the seeds from another farmer in order to grown the variety.

A survey of adoption trends between 1996 and 1999 revealed an increase in both the area and the number of households growing the new rice varieties (Figure 7). Despite the marked increase in adoption of M-3 and M-9, there was little affect on the number of households growing other local landraces (Figure 7). Interestingly, the largest decline in area since 1996 was for the most common landraces (Chhomrong Dhan, Kathe and Kalopatle), whilst the least common landraces experienced little or no change. It was clear that farmers preferentially retained rare landraces that had specific adaptations and uses. Indeed, M-3 and M-9 added to the genetic diversity as they had inherited alleles from a genetically distinct, exotic parent.

Farmers' management of on-farm biodiversity is a very dynamic process. Farmers rarely use new varieties to completely replace their existing crop genetic resources, particularly in risky marginal areas. Instead, they prefer to add new materials to their existing varietal portfolio.

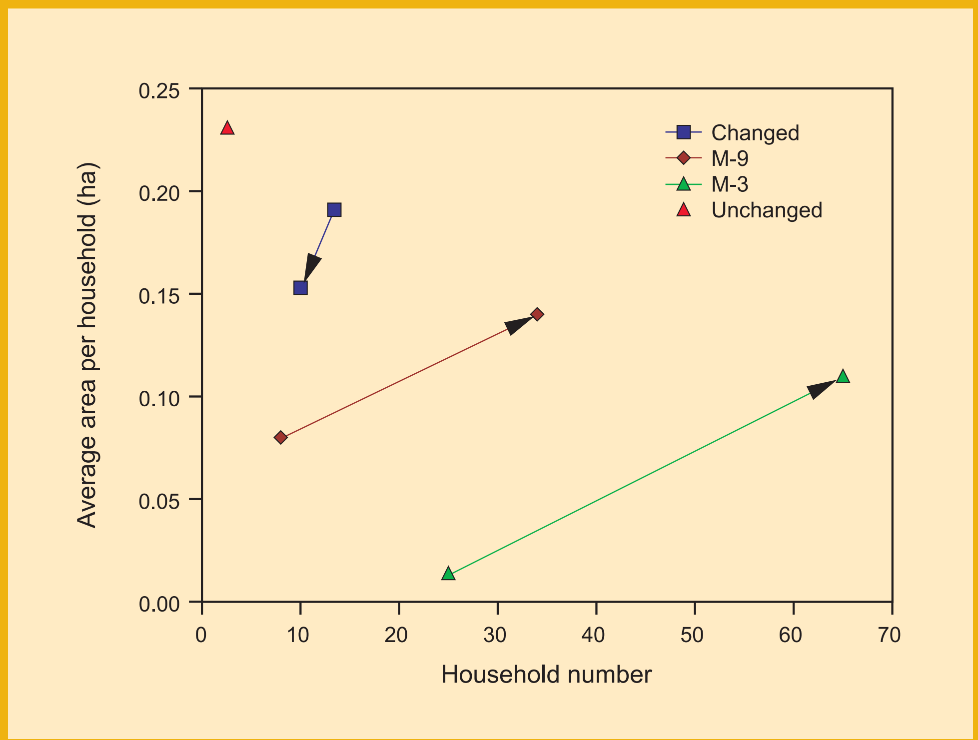
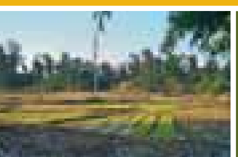


Figure 7. Area and household adoption of two PPB rice varieties, M-3 and M-9 in seven villages in Nepal. The arrows indicate those landraces and varieties that changed significantly in terms of the average area of adoption from 1996–1999. The landraces that did not change were the least commonly grown.



PPB rice varieties developed for high altitude villages in western Nepal impacted most on the more commonly grown landraces and had little effect on rare landraces that had specific adaptations and uses.

Participatory evaluation of post-harvest traits

Post-harvest traits are very important in determining whether an agronomically suitable variety is adopted or not. We have developed participatory techniques to evaluate these traits in rice, early in the breeding process. By avoiding expensive field evaluations of rice lines that will only be later rejected by farmers in the kitchen, major savings in resources can be made.

Traditionally, such post-harvest traits as milling characteristics and organoleptic qualities have been tested in the laboratory during the later stages of the breeding process. We have developed a protocol to incorporate farmers' preferences in the evaluation of post-harvest traits of rice lines prior to testing for yield performance in the field.

Farmers in Madhya Pradesh, India participating in a post-harvest evaluation of rice lines.
Photo: M.Billore, JNKVV.

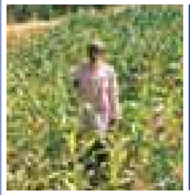
In our post-harvest assessments, we asked farmers to evaluate a selection of promising rice lines in terms of milling characteristics and organoleptic qualities (Table 4).

Table 4. Traits that farmers in Chitwan, Nepal consider important when assessing rice post-harvest quality.

Milling and visual traits
- Milling recovery percentage
- Size of grain
- Shape of grain
- Colour of grain
- Chalkiness
- Translucence

Organoleptic qualities
- Softness
- Taste of cooked rice
- Water absorption capacity
- Aroma

The micromilling test of grain quality, and the organoleptic taste assessment, have been found efficient in screening out poor rice lines before the field testing phase. For example, in Nepal in 2000, out of 57 rice lines evaluated for post-harvest traits more than half could be rejected: 16 for poor micromilling and 11 for unacceptable quality in organoleptic assessment (colour, cooking and eating qualities).



Farmers with plant breeders: Maize

Our PPB programmes for maize and upland rice have targeted resource-poor farmers on marginal lands where farmers favour early-maturing varieties that can escape terminal drought. PPB has proved highly successful in producing varieties that are superior to those currently available.

Maize is the most important rainy-season cereal crop in marginal, upland areas of western India that are inhabited by indigenous tribes. We gave maize farmers, in Gujarat, Rajasthan and Madhya Pradesh, new varieties to try in a PVS programme. These included white and yellow endosperm types. The farmers did not markedly prefer any of our varieties to their local ones. However, some of the varieties had specific traits that the farmers wanted, so in a PPB programme we crossed six of them to produce a composite population. We made the initial selections from this population based on characteristics identified by farmers, and at later stages farmers selected for themselves in populations we grew. Three of the most promising white-endosperm varieties we produced from the population were then assessed in formal and participatory trials.

GM-6 was one of these three promising varieties. It was bred as an extra-early maize variety. GM-6 was very popular and high-yielding in farmers' fields in Gujarat, Madhya Pradesh and Rajasthan over two seasons (Figure 8).

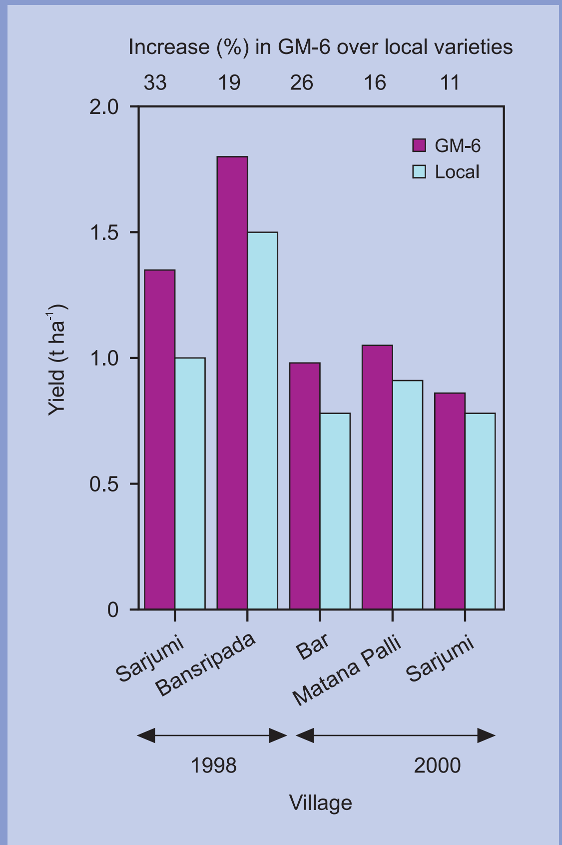


Figure 8. Performance of maize variety GM-6 compared with local varieties.

This variety matures about 7 days earlier than the local varieties. It produces fewer barren plants, larger cobs, and unlike local varieties, cobs that are filled to the tip. Farmers also noticed that the husk completely and tightly enclosed the cobs, thus reducing insect attack. Farmers greatly appreciated the grain quality of this variety. By using our PVS programme to identify suitable parents, by selecting for characteristics valued by the farmers, and by testing under farmers' own conditions, a new and improved variety acceptable to farmers was successfully and rapidly produced.

Farmers with plant breeders: Rice

Our PPB programme on upland rice used only a few crosses from which large populations were produced. Since few parents were employed, their choice was crucial. This was where PVS helped because it identified parents that had the desired traits.

In many marginal areas, such as for high altitude rice in Nepal, farmers continue to grow landraces. These have been grown in the same location over many generations and have often evolved many highly desirable traits. These may range from adaptations to specific environmental conditions, disease and pest tolerance, to cooking, storage and taste qualities. PVS can help identify varieties with desirable attributes. By crossing new varieties, perhaps containing different sources of pest or disease resistance, with landraces or varieties identified by PVS we can produce a new variety having a desirable combination of traits.

In a PPB programme for rice in India and Nepal, we crossed the variety Kalinga III with IR64. Farmers like Kalinga III, as it is extra-early maturing and has fine grain quality. However, it tends to lodge because it has weak stems, and is not drought-tolerant because it has a poorly developed root system. IR64 is high-yielding, has multiple disease and pest resistance, better straw quality and is highly resistant to lodging.

Our plant breeders made initial selections from this cross. A farmer grew the F_4 bulk in his field and he selected early maturing, tall, high-tillering, lodging-resistant, disease-free plants (Figure 9). This farmer gave some of the 5th generation seed to scientists who, after a further generation of seed multiplication and selection for trait uniformity, named it Ashoka 200F. It was tested in trials in 2000 where it yielded as much as 25% more grain than Kalinga III and even flowered earlier (by one day) than Kalinga III. Another variety Ashoka 228 was selected by farmers among lines grown by breeders on the research station. Both Ashoka 200F and Ashoka 228 yield more grain and fodder than Kalinga III. They are drought-resistant, early-maturing and highly suitable for cultivation in rainfed uplands (see page 22).

Ashoka 200F was the result of a single generation of selection by a farmer. However, farmers have selected for several generations in the same bulk to produce material that is highly uniform and well adapted to their fields (see the example of Figure 9).

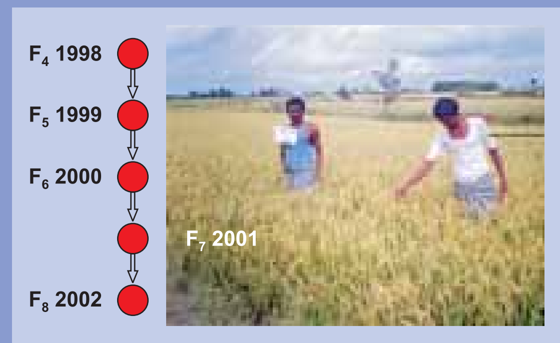


Figure 9. History of farmer's selection in a bulk from Kalinga III x IR64 cross. By 2002, the farmer, from West Bengal, had grown the bulk for 5 years (the farmer is pictured with his 2001 crop).

Farmers with plant breeders: Cassava

Cassava is the main source of starch eaten by subsistence farmers and their families in sub-Saharan Africa. Unfortunately, most production depends on relatively low-yielding landraces that are susceptible to cassava mosaic disease (CMD). Our PPB programme[3] in Ghana aims to increase the production of cassava by developing superior cassava genotypes that are resistant to CMD.

One of the main constraints to cassava production throughout Africa is cassava mosaic disease (CMD). Whilst modern varieties exist, most production in Africa is reliant on landraces that are relatively susceptible to CMD. In Ghana, for example, none of the four varieties of cassava released in the past few decades have been widely adopted. This is despite the importance of cassava to Ghana's economy and despite three of the released varieties being high-yielding clones resistant to CMD.

We implemented a cassava breeding programme at three sites in Ghana, representing two distinct agro-ecologies; the forest and the forest-savanna transition zones (most important for cassava production). Seed stocks from a diverse range of cassava families but including resistance to pests and diseases, particularly CMD, and high storage root yields were selected by the International Institute of Tropical Agriculture. Seedling were distributed to farming communities for evaluation and selection. They were also sown at the Crop Research Institute research farm. A multi-disciplinary team consisting of a breeder, a pathologist and an agronomist evaluated the seedlings together with farmers for above-ground characteristics, pests and diseases and finally for yield at harvest.

Farmers in Ghana involved in our PPB programme on cassava.

Following the harvest in July 2002, selected clones were replanted for a further annual cycle of monitoring evaluation and reselection of clones. Correspondence between farmers in their selections was very high. Similarly, agreement between farmers and breeders was strong with 60% of seedlings selected by both groups.

From over 2000 seedlings established in year 1 at the three locations, 20% were selected at the end of year 1 and 9% by year 2. Clones have now been distributed to individual farmers. These clones are preferred by farmers over their landraces because of their higher yield and greater resistance to CMD.

[3] Funded by the DFID Crop Protection Programme and the DFID Plant Sciences Research Programme.

Impact of PVS and PPB in low-altitude rice ecosystems of Nepal

Our PVS and PPB programmes in the Terai of Nepal have created new varieties of rice that are adapted to rainfed, low-fertility conditions. They yield up to 50% more than local rice cultivars and fetch higher prices in the market because of their superior grain quality.

The Terai is the most important rice-growing region of Nepal, accounting for about 75% of the total 1.5 million ha of rice area. Approximately 70% of the main-season rice in the Terai is grown under rainfed or limited irrigation water conditions (Figure 10).

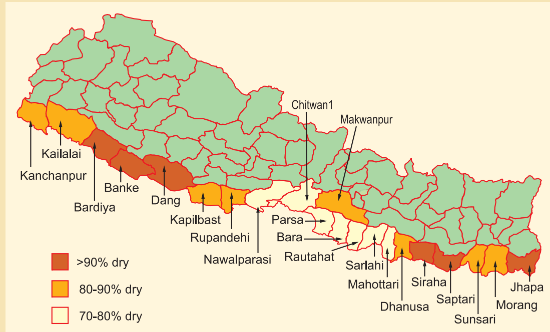


Figure 10. Percentage of land that is without perennial irrigation in the Terai. (ICMOD, 1997).

One of the main achievements of our work in the Terai of Nepal has been the identification of an increasing number of rice varieties, from both PVS and PPB, that farmers wish to adopt (Figure 11). More recently these new varieties are products from the PPB programme. Most of the new varieties are adapted to rainfed, low-fertility conditions and because they are more disease and pest resistant need less, or no, environmentally damaging pesticides. The new varieties have improved grain quality so fetch significantly higher market prices (up to 25% more), have improved drought tolerance, and yield up to 50% more grain.

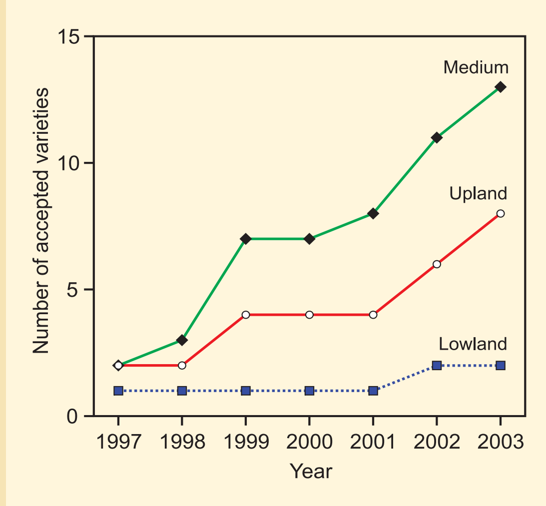


Figure 11. Increase in available rice varietal choice from our PVS and PPB project activities for farmers in the medium, upland and lowland of the Terai, Nepal.

These varieties are spreading rapidly from farmer-to-farmer in all 20 districts of the Terai and some of the low hill districts bordering the Terai.

In the PVS programme the project introduced Swarna, a variety from India. Swarna had already been introduced by farmers into Nepal, but the PVS programme greatly accelerated this process. Farmers who had received seed in the PVS programme were asked what impact Swarna had made on their lives.

Kamali and Arjun Kumar Shrestha of Agauli Village Development Committee (VDC), Sherganj village, Nawalparasi explained that they only own about one fifth of a hectare (7 *Kattha* in local units) of low-lying land where they used to grow the rice variety Masuli. It never produced more than 0.75 t on that land - just enough to sustain the six members of their family for about 6 months. They heard about Swarna 3 years ago and first tried it in a small plot. Kamala says that, to her surprise, it did extremely well even when the field had standing water where Masuli generally does very poorly. They decided the next year to plant the entire plot to the new variety and it yielded nearly twice as much as Masuli (1.3 t). Added to the harvest from their early-season rice, the household had more than enough grain. They sold nearly 500 kg of Swarna and bought corrugated iron sheets to roof their cowshed. Swarna is now contributing to the food needs of about half of the farmers in Sherganj village.

Mrs Kumar Shrestha outside her house in the village of Shergani, Nawalparasi, Nepal.

Mrs Kumari Thanet outside her house in the village of Sherganj, Nawalparasi, Nepal.

Tek Kumari Thanet, Sherganj, also owns 7 *Kattha* of land. Like most other farmers she also grew Masuli in the past. She has been growing Swarna for the last 2 years. She never had enough rice to feed her family but now, because of the higher yield of Swarna, she no longer has to buy rice.

Pitmaber Chaudhary of Agauli is a food deficient farmer with only 4.5 *Kattha* of land. Masuli rice harvested in late November only lasted until about February. She says *"Once we started growing Swarna, we could meet all our family needs from our own harvest and do not have to buy rice"*.

Farmers found the new PVS-introduced rice variety Swarna to be earlier-maturing, more resistant to pests and diseases and higher yielding than local landraces

Impact of PVS in a high potential production system of India

Our PVS work in western India has begun to demonstrate the effectiveness of participatory approaches in high potential production systems. Farmer-preferred varieties have been identified that are not only higher-yielding but are cheaper to produce than existing local cultivars.

It is commonly assumed that farmers in high potential production systems (HPPSs) have much better access to modern technologies than those in marginal environments. However, huge variation exists in the HPPSs and in many regions old varieties still dominate cultivation, suggesting that farmers are failing to benefit fully from modern plant breeding products.

Our PVS programmes in a HPPS of Gujarat, India have identified a new rice variety, Mahamaya. This variety has been released in several states of India, but not in Gujarat and is much higher yielding than the local cultivar GR 17 (Figure 10). The increase in yield is largely due to the shorter duration of Mahamaya (ca. 10 days) which reduces its vulnerability to end-of-season drought.

Farmers place great importance on early maturity as it brings many added benefits, including lower costs of production. By harvesting earlier, the next crop (usually wheat) can be sown on residual moisture, thereby saving on pre-sowing irrigation. Mahamaya is also more resistant to pests and diseases and so requires fewer chemicals. This has both financial and environmental benefits. Overall, Mahamaya resulted in a net saving of 25% compared with the recommended GR 17 cultivar (Figure 11).

Figure 10. Percentage yield gains due to the introduction of the new rice variety Mahamaya relative to the cultivar Gurjari. Data are the mean of 36 farmers in each village.

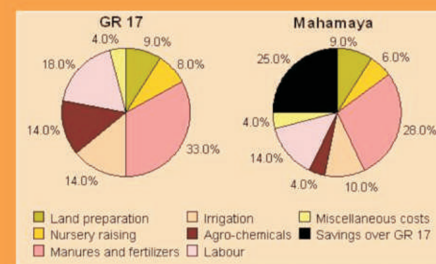


Figure 11 Percentage costs of production for GR 17 (local cultivar), and Mahamaya (PVS variety), Gujarat, India 2003.

Impact of PPB on rainfed upland rice in India

We conducted surveys in three states of eastern India to assess the acceptability of the new Ashoka rice varieties released from our PPB programme. Farmers much preferred the new varieties and 97% of those interviewed intended to grow them again the following year.

Most farmers thought the new rice varieties were earlier, higher-yielding, more resistant to drought and lodging and easier to market, fetching higher prices than the local cultivars (Figure 14).

By 2001, the year of their official release, farmers who had earlier been given seed had already adopted the varieties on significant areas (Table 5) and this had increased further in 2002. Farmers intend to increase the area still further. The adoption ceiling was very high – exceeding 100% in Orissa and West Bengal in 2003. This was because the total area under upland rice increased as farmers brought uncultivated land into cultivation or started to grow upland rice in areas where varieties suitable for medium land were previously grown.

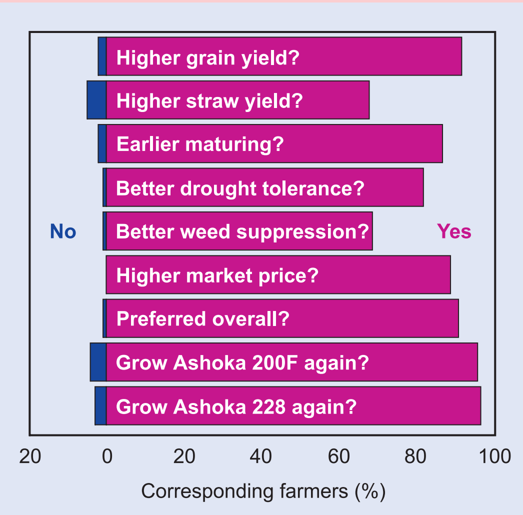


Figure 14. Farmers' perception of Ashoka 228 and Ashoka 200F rice varieties in comparison to local cultivars. Based on a survey of 159 households sampled over three states in India (Orissa, Jarkhand and West Bengal). December 2002.

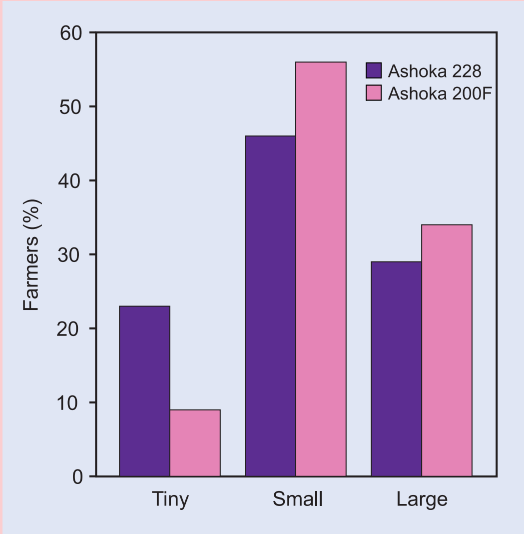


Figure 15. Impact of new rice varieties on overall income of farmers in three eastern Indian states. December 2002.

Table 5. Adoption (% of upland rice area) of new rice varieties in 159 households in three states of India.

State	2001	2002
Orissa	56	76
West Bengal	78	92
Jharkhand	46	75

The new varieties had a significant effect on income (Figure 15) and are expected to contribute significantly to the improvement of livelihoods of poor farmers in marginal upland areas.

Informal seed dissemination networks

Most farmers in marginal areas do not buy seed regularly but instead use seed saved from the previous year, or obtain seed from other farmers.

In Nepal and India, we identified farmer-to-farmer spread and informal seed dissemination networks as the most important mechanisms in the spread of new varieties to farmers. For example, around 80% of the seed requirement in the Punjab was fulfilled by farmer networks (Figure 16).

In the marginal areas of Gujarat, Madhya Pradesh and Rajasthan, India, one of our earlier PVS programmes identified the extra-early maturing, high-yielding rice variety, Kalinga III.

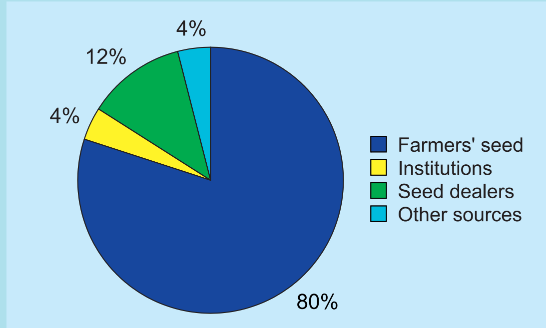


Figure 16. Results of a survey of farmers' seed sources, conducted in the Punjab, 1999.

Following the introduction of this variety, the rate of adoption by farmers within the trial villages was rapid (Figure 17). Friends and relatives carried Kalinga III initially to nearby villages (within 10 km), but sometimes to far off ones. From only three villages in 1994, Kalinga III spread to over 100 villages in an area of several thousand km^2 by 1997.

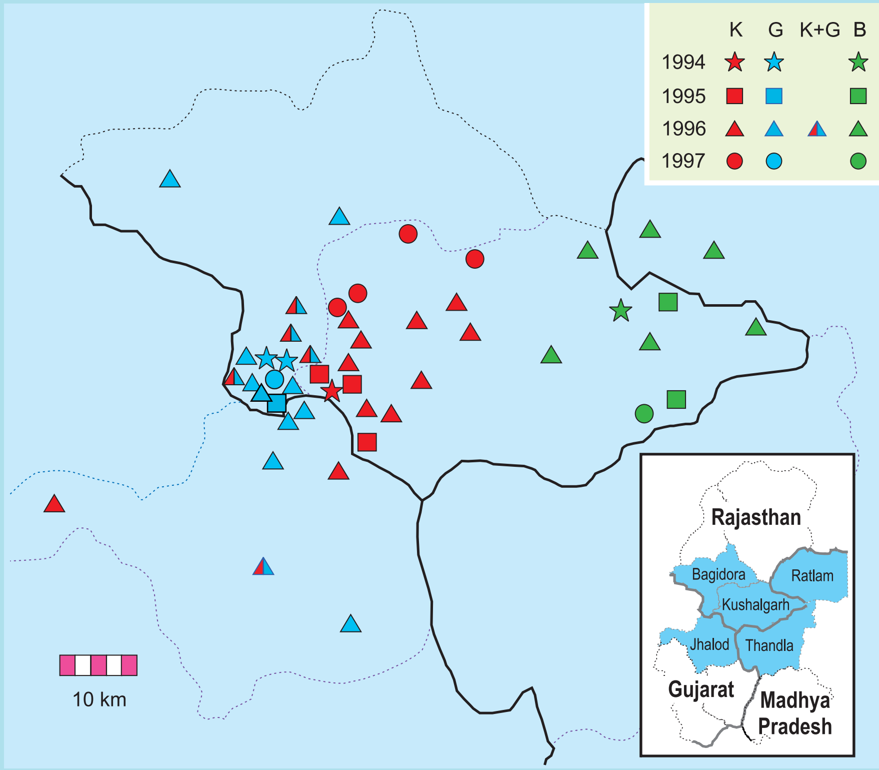


Figure 17. Documented spread of Kalinga III from three case study villages over the period 1994 to 1997 where K = Kompura, G = Gamana and B = Bijori villages.

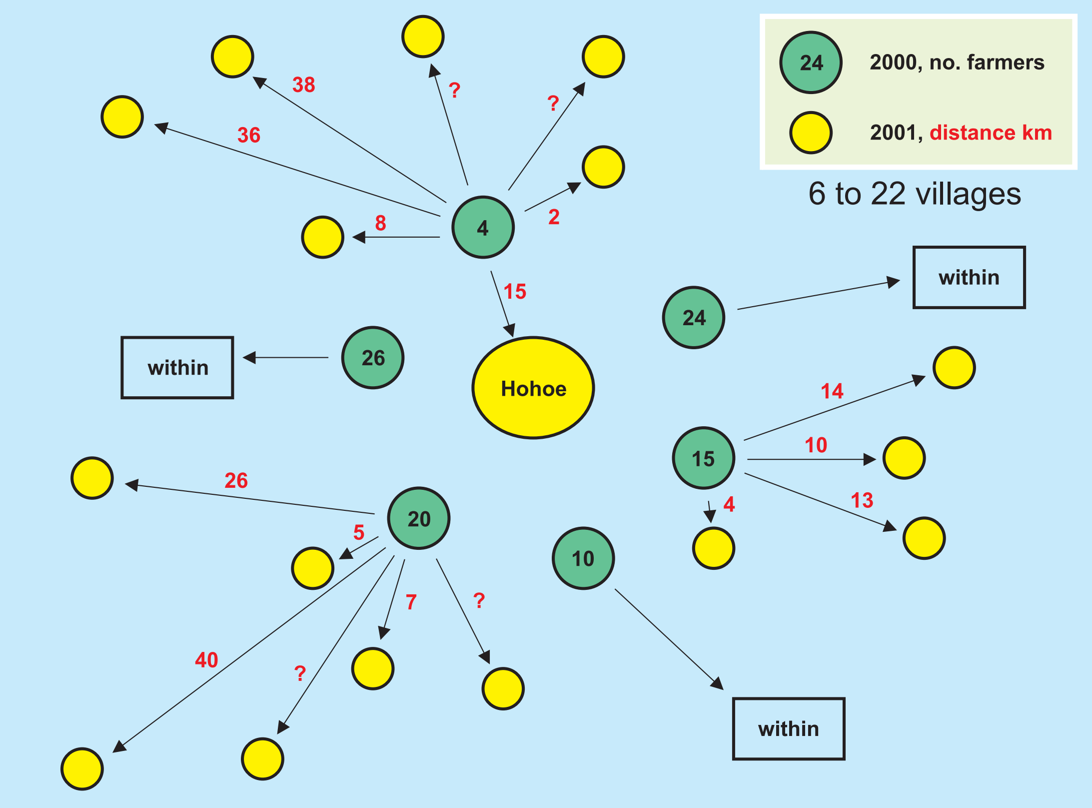
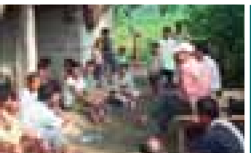


Figure 18. Seed dissemination in Hohoe District, Volta Region 2000 and spread in 2001.

Since 1997, a PVS programme on upland rice has been implemented in several communities in the forest and savanna zones of Ghana. In 2000, seed of eight upland rice varieties was distributed to farmers around Hohoe in the Volta Region. Seed was distributed through a number of different channels including: individual farmers who participated in the PVS evaluations; a seed producer group; through the chief farmer; through the 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 18). 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 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% more than the price of local seed.

The most effective 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 kg returned. After the first year, when the seed fund had grown, the original seed committee set up similar committees in neighbouring villages.

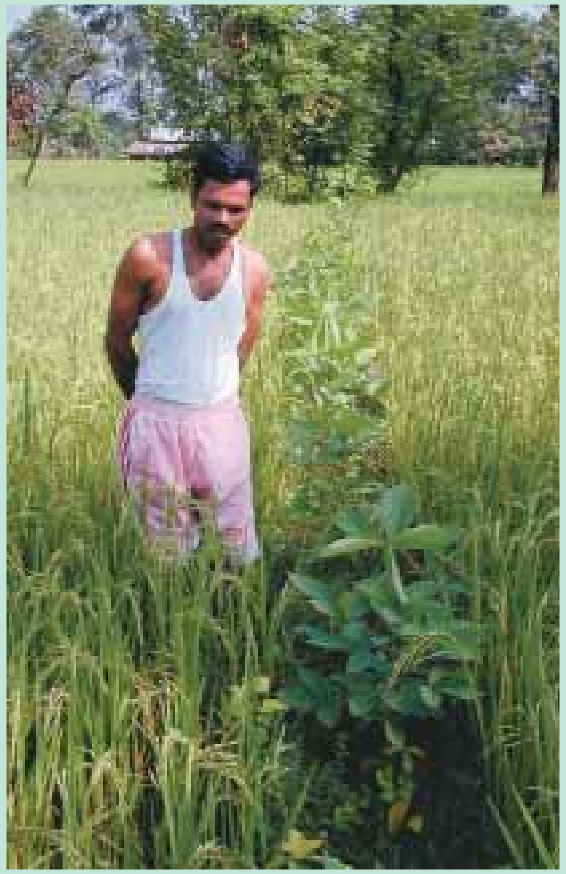


In the forest and savanna zones of Ghana, seed of PVS upland rice varieties spread rapidly, initially from kin to kin both within and between neighbouring villages and demand for seed was very high

From food to fodder

PVS is not only for annual crops. Participatory techniques can test other innovations, such as new perennial species for fodder and fuelwood. We introduced Flemingia to the Terai area of Nepal and it is now widely grown by farmers.

Flemingia [*Flemingia congesta* (syn. *macrophylla*)] is a woody, leguminous, deep-rooting shrub, that can grow to more than 2m in height. It has a wide ecological range, and is found from sea level up to 2000m asl.



A local farmer with a row of Flemingia one month after planting.

Flemingia shrub 6 months after planting. Half of the hedge has been cut for fodder and half retained for seed.

It needs at least 1100 mm of annual rainfall, but it can also thrive under equatorial rainfall conditions, e.g., in the Cameroon (2850 mm annual rainfall). Flemingia is hardy, tolerating long dry spells, and it can survive on poorly drained, occasionally waterlogged, soils.

We introduced Flemingia to the Terai area of Nepal and it is now widely grown by farmers. Its rapid production of biomass and its coppicing ability make it particularly attractive for mulching and weed control.

In addition, farmers value Flemingia as a source of fodder. Its digestibility is low (less than 40%), but this means that it satisfies animal appetites for long periods, an important attribute of fodder for stall-fed animals when feed is scarce. The palatability of young tissue is considerably better than that of mature tissue. Although much of its biomass is non-woody, farmers appreciate the fuelwood it produces.

In the Terai of Nepal, Flemingia's low shrubby habit enhances its potential. It can be grown on field bunds (small earthen banks between fields), in contrast to other perennial legumes such as the taller *Leucaena* tree species, which farmers fear will shade their crops.

Twenty farmers in the clusters of East and West Chitwan took part in trials, planting Flemingia on field bunds in August 2000. Nearly all the trees planted survived and grew well and farmers appreciate their fodder quality for goats and cattle (which eat the leaves and green stems), and also for buffalo (which only eat the leaves). Farmer Om Maya, from West Chitwan, claims there may be an increase in the quality and quantity of buffalo milk after feeding Flemingia, with no change in buffalo manure characteristics. The shrubs produce seed which many farmers have collected for additional planting on their own and their neighbours' farms.

Seeds and cuttings were distributed to other interested farmers not involved in the original trials. Demonstration plots of other, potentially suitable, leguminous species that can be grown as hedgerows were also established.

As a result of our PVS activities, more than 1100 households have adopted wide-scale planting of one or more agroforestry species in their cropping systems. *Flemingia congesta*, *Ficus roxburghii* and *Ficus semicordata* were the three most popular fodder species among the dairy and livestock farmers in Chitwan and Nawalparasi, Nepal. More than 8000 saplings were distributed during the lifespan of the project and there is increasing demand for these species by the livestock groups.

Flemingia seedlings being raised in Nepal for planting in the 2001 season.

Official release to promote wider spread

Two new rice varieties (Ashoka 200F and Ashoka 228) and two maize varieties (GM-6 and BVM-2) have been officially released as a result of our PPB work.

In 2001, the Birsa Agricultural University (Jharkhand, India), released the first-ever early-maturing, high-yielding rice varieties for rainfed uplands. The two new rice varieties Ashoka 200F and Ashoka 228 are the products of a collaborative PPB programme and on their release performed extremely well during the severe drought of 2002.

Farmer preference for the new varieties has been high with most farmers perceiving the new varieties to be earlier, higher- yielding, more resistant to drought and lodging and easier to market with higher prices than the local cultivars.

Ashoka 200F and Ashoka 228 identified from PPB and released as Birsa Vikas Dhan 109 and 110 by the Birsa Agricultural University in May 2001.

Local maize (left) compared with GM-6 (right)

In the case of maize, GDRM-187 was officially released (as GM-6) for the hill areas of eastern Gujarat in April 2001. Interestingly GDRM-186, also developed by PPB, was even higher yielding than GM-6 in research station trials and would, under a non-participatory system, have been the variety submitted for release. Although GM-6 was lower yielding, farmers overwhelmingly preferred it because it was earlier. An early variety escapes common end-of-season droughts, and produces a harvest at the hungriest time of the year before other crops mature. Also, GM-6 reaches the market first, so its grain fetches a higher price. GM-6 is spreading to other states and has now officially been recommended for cultivation in Rajasthan.

One month after the official release of GM-6 in Gujarat, Birsa Agricultural University also released the maize variety Birsa Vikas Makka 2 (BVM-2), another product of PPB. It is officially released for cultivation in Jharkhand, eastern India. It yields 20% more in farmers' fields than the best modern variety and even more than the local landraces.

Linking farmers to molecular biology

Our marker-assisted selection (MAS) work has shown that there are no barriers to combining modern technology with participatory approaches. We have given small-scale farmers the products of our MAS programme on rice to test in their own fields and preliminary results are very promising.

Some traits are very difficult to select using conventional field screening methods, and it is often impossible for farmers to select for them in PPB. Traits which are controlled by recessive genes, such as aroma in rice, are often masked in segregating populations. Selection for disease resistance is often not possible in seasons where there is little disease. Similarly, drought resistance is a complex trait for which many farmers would have difficulty selecting in their fields in most years.

In rice, DNA markers have been mapped to specific regions along the length of all the chromosomes. These markers, which are linked to the genes controlling a particular desired trait can be used to make selections from segregating populations. When DNA markers are used in this way it is called marker-assisted selection (MAS). Because field screening is no longer required the work can be done in a glasshouse and generations can be advanced more rapidly. Once target markers have been selected in individual lines they can be crossed to 'pyramid' all the useful genes into one line. This is particularly important if the trait is controlled by several quantitative trait loci (QTLs)[5].

The rice variety Kalinga III is popular with farmers in eastern India, but it is susceptible to lodging and its poor rooting system makes it prone to early-season drought. A MAS programme was conducted to transfer beneficial traits from the Philippine variety Azucena to Kalinga III.

Molecular markers offer a more efficient means of selecting for desired traits than conventional screening approaches

- Molecular markers rely on indirect selection of desired traits and therefore offer a quick, and ultimately cheaper, method of screening plant material.
- By selecting indirectly for associated molecular markers, rather than for the physical expression of the trait itself, offspring can be screened without the need to subject them to expensive and difficult-to-control drought stress or disease treatments.
- Molecular marker screening can be done at the seedling level in the laboratory.

[5] The genes (or segments of DNA that contain genes) influencing a quantitatitive trait are called quantitative trait loci (QTLs).

Farmers evaluation of MAS bulks

	Bulk I none	Bulk II root QTL	Bulk III root QTL	Bulk IV root QTL	Bulk V root QTL	Bulk VI root + aroma QTLs	Kalinga III
Evaluation of four farmers							
Score	19	22	15	14	12	18	7
Rank	2	1	4	5	6	3	7

Figure 19. Overall scores given by farmers during PPB evaluation of six MAS bulks alongside the Kalinga III check, rainy season 2001.

Selection was made using markers linked to a gene for aroma and four regions linked to drought resistance (longer and thicker roots). Bulks containing selected root QTLs and aroma were advanced and given to upland farmers in eastern India for further selection through PPB.

In the 2001 rainy season farmers were asked to rank the plots in their order of preference.

Four farmers responded and they ranked all six of the MAS bulks higher than Kalinga III for overall performance, including the control bulk that had no QTL (Figure 19).

In 2002, 54 farmers grew one of the MAS bulks in their fields and in 2003 this increased to 84 farmers across three Indian states. In both years, despite many of the plots experiencing severe drought, the bulks performed better than Kalinga III.

PPB with farmers in eastern India

1. **Six bulks were selected with molecular markers**
   - 4 bulks with one QTL for root traits
   - 1 bulk with one QTL for root and aroma traits
   - 1 bulk was a control—contained none of the MAS traits
2. **Farmer grew six bulks alongside Kalinga III using their usual practices**
3. **Farmer were asked to make selections**

A farmers' field in the village of Borogora, Jharkhand, India. The farmer was making selections of individual rice plants within marker-assisted selection (MAS) bulk IV (right). The rice variety Kalinga III is shown on the left.

Molecular marker technology has produced bulks that are preferred by farmers.

Another aspect of our molecular marker work involves using DNA fingerprint linkage blocks to assess whether farmer-preferred genomic regions can be identified. We have followed inheritance of markers in rice varieties selected by farmers in PPB, starting with varieties selected from the cross Kalinga III x IR64. This is a wide cross because Kalinga III is adapted to upland conditions whilst IR64 is adapted to lowlands. Farmers selected twenty diverse varieties from this cross for a range of ecosystems including uplands, medium lands and lowlands in India and Nepal and for off-season cultivation in Nepal.

We then used 28 markers to: (i) determine whether it was possible to detect shifts in marker allele frequency as a result of farmer selection, and (ii) evaluate the genomic regions with different allele frequencies in different ecosystems.

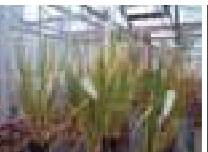
These results can be used as a basis for the development of genomic ideotypes for specific environments. New varieties could then be designed and selected to contain all the ‘best’ bits of the genome for the conditions in which the crop will be grown.

Women farmers in India selecting amongst the Kalinga III x IR64 cross.

Rice genetics and breeding are entering a new era in which we can see, explore and employ the genetic variation to the letter of the genetic code now that rice genome sequences exist. A new type of marker has been developed which picks out variation at single letters in the sequence, it is called single nucleotide polymorphism or SNPs. We are testing PPB varieties with SNPs for genome-wide evaluation of selection.

Results from molecular marker evaluation of farmer-preferred varieties

1. Genomic regions influencing important traits for adaptation to specific environments were identified without making any prior assumptions of which traits were important.
2. Genomic regions from Kalinga III were strongly selected in the upland environments and regions from IR64 in the lowland environments.



We are testing whether molecular markers can be used to identify farmer-preferred regions on the genome and regions that determine adaptation to specific environments.

Plant Sciences Research Programme’s Participatory Crop Improvement Projects

R6748 **Participatory crop improvement in high potential production systems in India and Nepal.** CAZS, GVT(W) & LI-BIRD.

R6826 **Testing drought-tolerant plant types of upland rice in Ghana using participatory methods.** PEL, CRI & WARDA.

R7080 **Assessing the feasibility of using marker assisted selection for root characteristics to aid participatory plant breeding in upland rice in India.** CAZS, BAU & KRIBP

R7122 **Participatory plant breeding for high potential production systems in the Terai and low hills of Nepal.** LI-BIRD, CAZS & GVT(E).

R7281 **Participatory crop improvement for maize–millet intercropping in the mid hills of the Himalayan region.** SAFS, PAC & HCRP.

R7323 **Participatory crop improvement in high potential production systems and salt affected areas of Patiala district of the Punjab state.** PAU(P), CAZS & PAU(L).

R7324 **Participatory plant breeding in finger millet in India. Phase 1.** UAS & CAZS.

R7409 **Participatory varietal selection (PVS) for postrainy (*rabi*) season sorghum.** NRCS & CAZS.

R7434 **Innovative methods for rice breeding – combining participatory plant breeding (PPB) with molecular marker techniques.** CAZS, LI-BIRD, GVT(E), BAU, UAS & MPUATU.

R7542 **Participatory crop improvement in high potential production systems – piloting sustainable adoption of new technologies.** CAZS, LI-BIRD & ASA.

R7565 **Participatory breeding of superior, mosaic disease resistant cassava.** NRI & CRI.

R7657 **Participatory rice improvement in Ghana II.** PEL, CRI & SARI.

R7574 **Rapid generation advance in photoperiod sensitive sorghums.** ICRISAT

R7838 **Rapid generation advancement of a chickpea population for farmer participatory selection.** ICRISAT

R8071 **Participatory plant breeding in high potential production systems – an evaluation of products and methods.** LI-BIRD, CAZS, NARC & DoA

R8099 **Participatory plant breeding in rice and maize in eastern India.** CAZS, GVT(E), BAU & IRRI

R8200 **Marker assisted selection (MAS) for participatory plant breeding (PPB) in rice.** CAZS, IRRI, University of Agricultural Sciences GKVK, NARC & GVT

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Plant Sciences Research Programme (PSP) website
[www.dfid-psp.org]

Natural Resources Information System DFID's RNR & Environment Database
[www.narsis.org]

LI-BIRD website
[www.panasia.org.sg/nepalnet/libird]

Nepal Agricultural Research Council
In situ conservation of agricultural biodiversity on-farm.
[www.narc-nepal.org]

Participatory Research and Gender Analysis
List of participatory research web-sites.
[www.prgaprogram.org]