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Sparsholt 6-11 June 1997

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Impact of the DFID
Plant Sciences Research Programme

A PRESENTATION FOR THE DFID NATURAL RESOURCES ADVISERS' CONFERENCE
Sparsholt 6-11 June 1997

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SUMMARY

The Plant Sciences Research Programme (PSP) funds projects ranging from fundamental, enabling research through to on-farm, participatory development and evaluation of technology. The impact of the PSP is considered, using a few selected projects as examples, from the viewpoint of the farmer; intermediate users; and longer-term technology development. Three examples are given of projects that have produced outputs used by farmers. **R6395** *Seed priming to improve crop establishment in Zimbabwe and India* has developed and tested, in collaboration with farmers, a simple method of improving crop establishment, growth and yield. It has been taken up enthusiastically in India and farmers in more than 30 villages will be using the technology for maize and upland rice this year. The current and future expansion of collaborative linkages with this project is discussed. **R6748** *Participatory crop improvement in high potential production systems in India and Nepal,* co-funded with the NRSP High Potential Production System, is adapting participatory methods developed for marginal areas to high potential production systems. Farmers have grown trials of varieties of wheat and rice that they had not previously encountered. Results, so far, indicate that the methods are easily adapted to high potential production systems. Farmer-managed trials and participatory evaluation have identified better varieties than those grown currently in the project area. The reasons as to why these two projects have succeeded in having an impact with farmers are discussed. **R6348** *On-farm assessment of salinity tolerance in wheat* is collaborating with farmers to test salt-tolerant varieties of wheat, bred using novel techniques developed in earlier PSP and DFID-funded research. It is clear that tolerant germplasm will be a key element in any Integrated Salinity Management (ISM) approach. Impact with farmers is at an early stage, and future research needs to be directed at optimising uptake pathways. The value of research continuity and research serendipity is discussed in relation to this project.

A project involving molecular marker technology is highlighted as an example of impact on intermediate users. **R6454** *Use of molecular markers to enhance the management of rice germplasm collections and their utilisation for rice improvement.* This powerful technology is being used by IRRI to organise and manage their rice collection to better effect. Benefits include the identification and elimination of duplicate accessions, the formation of a 'core' collection, diversity estimates for samples of wild species and prediction of performance of rice germplasm. Molecular markers are also being used in **R6667** *Marker-assisted selection, QTLs and contiguous substitution lines for improving downy mildew resistance of pearl millet hybrids* to produce, in collaboration with ICRISAT and private sector seed companies, pearl millet hybrids resistant to a devastating disease, downy mildew. These hybrids should be available to farmers in India by 2001.

Further upstream, PSP is supporting longer-term research to produce transgenic crops resistant to a range of biotic constraints. This research has already produced rice plants having potential resistance to nematodes, Tungro virus and Rice Yellow Mottle Virus. Trials under containment are in progress, and field trials of these plants are scheduled to begin in 1999. Finally, PSP-funded research

has produced fundamental, generic technology to enable the production of transgenic cassava. This technology has been adopted by laboratories in the UK, continental Europe and the USA.

INTRODUCTION

This paper examines the impact of the PSP at farmer level, at the level of intermediate users, and from the viewpoint of longer-term technology development.

It uses three case-study projects to examine some reasons why projects can produce a successful impact with farmers. Two of them are very recently started projects in response to the new RNRRS plan. (Prior to the current plan, all of the PSP research was strategic and long term.) In less than two years, they are already producing farmer-relevant results that are beginning to have an impact. However, it is inevitable that a wider-scale impact has to take longer. We argue that the uptake pathways for this larger impact are in place as a result of good project design and implementation.

In the third case study, the lesson emerges that long-term continuity of research can be valuable. Also, a frequently encountered argument that long-term strategic research can produce very useful but unintended outputs is vindicated. An example is given of PSP-funded research producing originally unintended outputs that have great practical implications for the breeding of new, superior wheat varieties to improve farmers' livelihoods.

We first review the seed priming project and the participatory crop improvement project before examining the reasons for their success. We then discuss the different lessons that emerge from the project on wheat salinity. Impact on intermediate users is illustrated by the example of enhancing the utility of rice germplasm collections by using molecular markers. The paper ends with a brief review of achievements in longer-term research.

IMPACT ON FARMERS

Case-Study 1: The adoption of seed priming by farmers: *R6395 Seed priming to improve crop establishment in Zimbabwe and India*

Background

Good crop stand establishment is a prerequisite for the efficient use of resources such as water and light, hence plant stand is a major determinant of yield. This is particularly true in the semi-arid tropics where there is a delicate balance between the water supply and demand. High and rapid germination and emergence determine good stand establishment, and the related vigorous early growth of seedlings often produces higher yields. Observations and surveys in semi-arid areas suggested that stand establishment in many crops is often extremely poor. Patchy stands and the need to replant commonly occur for many reasons, both physical and socio-economic.

Only seeds which germinate rapidly and emerge before soil surface conditions deteriorate too far will be able to emerge and form viable root systems with access to moisture deeper in the soil. Intra-specific variation in germination and emergence rates exists in many crops but previous DFID-funded work (Harris, 1996) has suggested that priming seeds i.e., soaking them in water before sowing can speed up emergence and improve early growth.

Poor crop establishment was identified as a major constraint to rainfed crop production by farmers in the tribal villages of Rajasthan, Gujarat and Madhya Pradesh served by the KRIBHCO Indo-British Rainfed Farming Project (KRIBP) and by the farmers of the Musikavanhu Communal Area in Natural Region V of Zimbabwe. *In vitro* screening of the effects of priming on the germination of seeds of local and improved varieties of maize, upland rice and chickpea (India) and maize, sorghum and pearl millet (Zimbabwe) provided 'safe limits' —the maximum length of time for which farmers should prime seeds and which, if exceeded, could lead to seed or seedling damage.

Recommended safe limits can be made irrespective of variety, and varied from 24 h in rice to 8 h in chickpea and pearl millet, with maize and sorghum having intermediate values. Recommendations were then tested in on-station trials in India and Zimbabwe, and in farmer-managed participatory trials in India.

Results in India

Seed priming was evaluated in 239 farmer-managed participatory research trials in 15 villages for maize, upland rice and chickpea during three consecutive seasons from 1995 to 1997. Farmers modified recommendations for priming times to 'overnight' for all three crops. Evaluation of the technology by farmers involved focus group discussions (see Box 1) and matrix ranking exercises (Fig. 1).

Box 1. Farmers' perceptions of the direct and indirect benefits of on-farm seed priming.

Stand establishment
- Faster emergence
- Better, more uniform stands
- More vigorous early growth
- Less re-sowing

Growth & yield
- Fewer cultivations required
- Improved competition with weeds
- Better drought tolerance
- Earlier flowering
- Earlier maturity and harvest
- Higher yield

System effects
- Can sow *rabi* crops earlier Early harvest of *rabi* crops allows earlier migration to obtain off-season work
- Increased willingness to risk the purchase and use of fertiliser

In matrix ranking exercises in 4 villages in *kharif* 1996, 95% of farmers indicated that, even after only one exposure to the technology, they would prime seed the following season (Fig. 1).

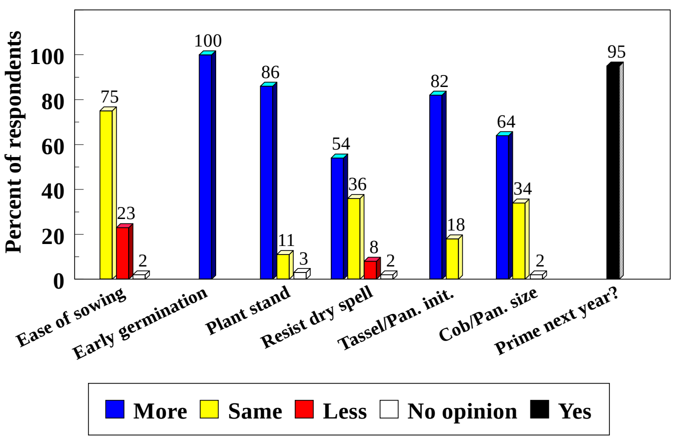

Fig. 1. Summary of farmers' perceptions of seed priming during *kharif* 1996. Total of 56 farmers in four villages located in Gujarat, Rajasthan and Madhya Pradesh.

These on-farm trials have been a revelation. Previously, primed crops had not been grown through to harvest. Benefits related to stand establishment and seedling vigour had been demonstrated on-station but the more wide-ranging effects had not been proven. The data provided by farmers were overwhelming—on-farm seed priming has shown an advantage over sowing dry seed in just about every aspect of crop growth and development. Crops were earlier, healthier, sometimes involved less work and gave bigger yields, and all this from an intervention that costs nothing and requires no special equipment. Earliness, in particular, is prized by farmers because more cropping options become available to them and crops can often escape drought. A simple cost:benefit analysis, using highly conservative assumptions, gives a projected internal rate of return of 22.5% (Henderson and Martin, 1997).

In future research, the number of villages in which farmers will take part in seed priming trials will be increased to over 30 with self- and group evaluation. In addition, selected *jankars* (village-level specialists) will be trained to record crop phenological and growth data on a sub-set of trials in 14 villages. Complementary on-station research will be conducted by other Indian institutions, i.e., the Indian Agricultural Research Institute, New Delhi; JNKVV, Madhya Pradesh; Gujarat Agricultural University; Rajasthan Agricultural University; and ICRISAT.

The importance of choice of partner in collaborative research is discussed later, and the advantages for uptake in India can be readily seen (Box 2).

Box 2. Examples of uptake promotion activities within the project

Promotion of on-farm seed priming within the KRIBP/W area continues as part of the community-focused activities of village-based project staff. This farmer-level dissemination is enhanced by workshops, presentations (by the farmers themselves) at farmers' fairs and, recently, by the use of mass media. In May 1997 the latest in a series of workshops was attended by over 150 farmers from 21 villages from within the project area. A video, produced by project staff in collaboration with farmers, was used to present farmers' views on seed priming to the other farmers. The use of video in extension has been recommended (World Bank, 1995) and the evidence from this workshop suggests that expressing the views of fellow farmers who had tested the technology for themselves through the medium of video is highly effective, and is particularly useful when most of the participants are illiterate.

Also participating in the workshop were another 40 farmers from villages collaborating with four other NGOs active in the area - Sadguru Water & Development Foundation, Prakruti Foundation, World Vision (Dahod) and NCHSE (Jhabua) together with officials from those organisations and scientists from local State Agricultural Universities (SAUs). It is hard to overestimate the potential for network building through these types of workshop. The SAUs are all planning to investigate seed priming in the coming *kharif* and *rabi* seasons using a "core" experiment designed to answer key questions about the technology in a wide range of environments. All interested NGOs have been supplied with documents that summarise project experiences with seed priming to date and the project stands ready to facilitate the implementation of on-farm trials if required.

Wider promotion of the technology

'On-farm seed priming'—called 'on-farm' to distinguish the technology from more 'high-tech' interventions common in the developed world—seems likely to be a useful technique for other crops in other production systems. As a consequence the number of linkages continues to grow. For example:

- KRIBP(W) is actively pursuing links with NGOs in India to promote seed priming (see Box 2).
- The technology is to be tested and, if found to be suitable, promoted in the KRIBP(East) project area.
- Universities in Madhya Pradesh, Rajasthan and Gujarat are all planning to run on-station trials to test the technology. This is an important step in gaining acceptance of the technology as an official recommendation.
- Scientists at WARDA plan to begin on-farm trials with rice in West Africa this year.
- Collaboration with ICRISAT continues with experiments to screen sorghum and pearl millet germplasm in relation to seed priming characteristics and to look in detail at establishment of chickpea.
- In India in **R6748** *Participatory crop improvement in high potential production systems in India and Nepal,* farmers are keenly aware that late planting of *rabi* wheat after *kharif* rice reduces yields. They have also reported poor crop establishment. The new wheat varieties tested by farmers in rabi 1996-97 were tested *in vitro* to see if they respond to seed priming, and they responded very well (see Fig. 2). Farmers will test seed priming of wheat on-farm in *rabi* 1997-98. Similarly, farmers working with the same project in the Nepalese *terai* will test seed priming for *chaite* (spring) rice next year to try to reduce the high cost of seed and crop establishment using current practices.
- Dr I.P. Abrol, Facilitator for the IRRI/CIMMYT Rice-Wheat Consortium for the Indo-Gangetic Plains, has circulated in his newsletter to consortium partners details of the research outputs in seed priming rice and wheat with a view to a broader experimental and farmer adoption of the technique.

The choice of partners can increase uptake. However, the impact with secondary partners i.e., those other than the project collaborators, can be much greater as they are neither limited in number nor restricted to specified production systems or countries. The success of the uptake by secondary partners listed above can, using the seed priming project as an example, be succinctly described as 'who we know' and 'what we know'. The Plant Sciences Research Programme has frequent contact with scientists from many centres such as WARDA and ICRISAT either in the day-to-day running of the programme or at international conferences. Many have immediately appreciated the potential of seed priming. They have been quick to place that potential in the context of their local situation, e.g., weed competition in upland rice or earlier maturity of wheat in the rice wheat production system, and have 'signed up' to participate in the research.

In India, yields of wheat are reduced by 100 kg ha^{-1} for every day's delay in sowing after mid-November. Preliminary *in vitro* work with a range of varieties of Indian wheat (Fig. 2) suggests that this crop should benefit from this simple intervention in the same way as the crops noted above. In the rice-wheat production system seed priming and varietal choice - as provided by the next case study project described below - can interact favourably to enhance the overall productivity of the system (Fig. 3). It means that farmers can grow a more productive but somewhat later maturing wheat and still plant it on time. Considerably higher wheat yield can be obtained without a loss in yield of the rice crop.

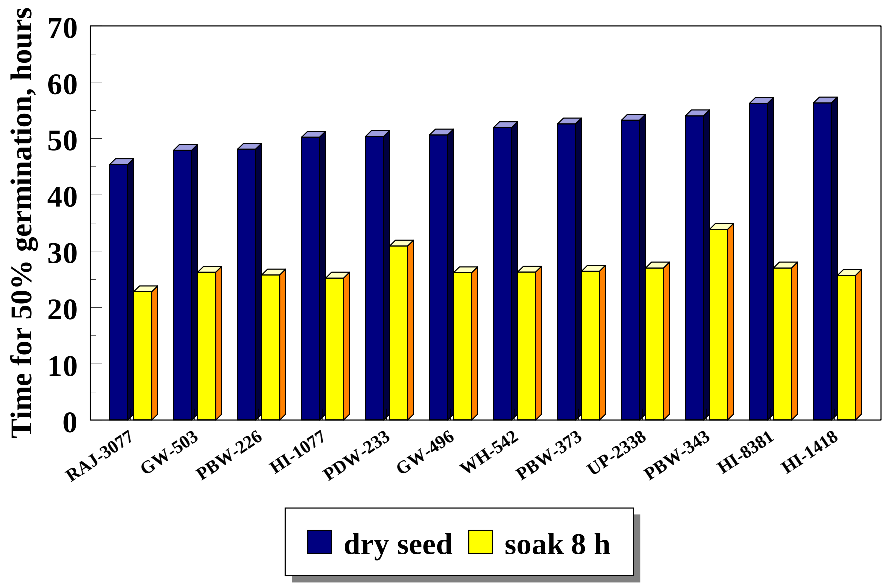

Fig. 2. **Germination of 12 wheat varieties at 20°C after priming with water for 8 hours at 20°C.**

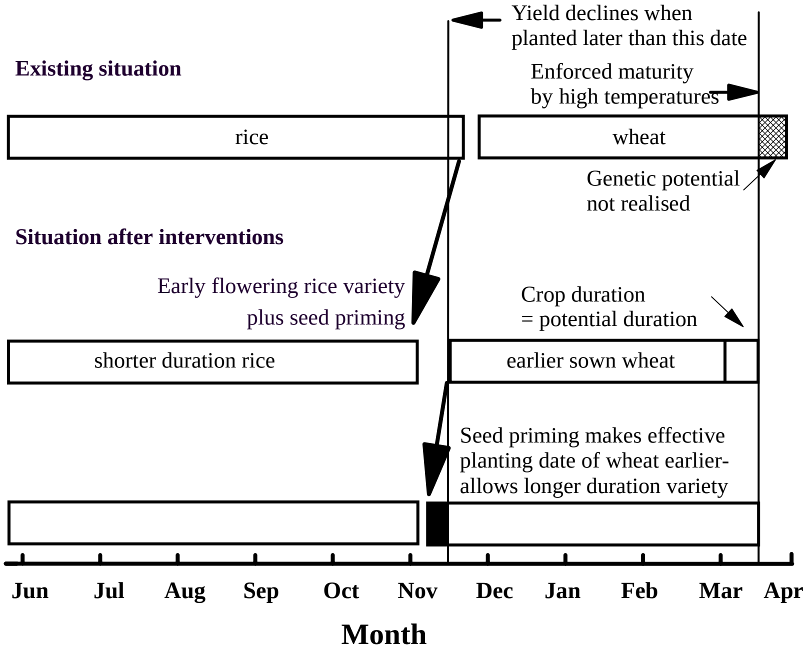

Fig. 3. **Interactions between varietal choice and seed priming to enhance productivity in rice wheat production systems.**

Germination studies on a range of upland rice varieties from West Africa have shown that rainfed rice is very responsive to seed priming. WARDA is keen to pursue on-farm trials of priming in upland environments where farmers use little preparatory cultivation and rainfed yields are limited severely by poor crop establishment and inadequate ability to compete with weeds.

Case-Study 2: Participatory Crop Improvement: *R6748 Participatory crop improvement in high potential production systems in India and Nepal*

Background

This project is an example of a productive interaction between an ODA bilateral project and the PSP. In the KRIBHCO Indo-British Rainfed Farming Project/West (KRIBP/W) participatory methods have been developed for farmers to select appropriate varieties for their marginal environments (Joshi and Witcombe, 1997; Witcombe *et al.*, 1997; Witcombe, 1997). Using these methods of participatory varietal selection (Box 3), the project has identified many higher-yielding and/or higher value cultivars that farmers prefer and are adopting. Impact studies have shown that these new varieties are spreading rapidly from farmer to farmer without intervention from the project. On average, after the first harvest in a village the seed is distributed by farmer to farmer exchange to more than two other villages, and after the second harvest the seed is distributed to more than seven new villages. As a result, the research has generated very high internal rates of return even when the entire project costs are allocated to the cost side of the analysis. None of these preferred cultivars was recommended by the extension services.

The methods that were developed for marginal areas are being adapted to high potential production systems in an NRSP (High Potential Production System) project that is jointly funded by the PSP. This project, that only started in October 1996, has already shown that:

- a wider choice of cultivars can readily be found for High Potential Production Systems (HPPSs);
- it is easier to build rapport with farmers in HPPSs than in marginal areas—in India, within 4 weeks from entry into the project villages hundreds of participatory trials were in place;
- farmers in HPPSs can conduct participatory trials of a more complex nature to the highest standard (see Fig 4);
- of 13 wheat varieties given to farmers in Gujarat to try, most yielded significantly more and most were preferred to the recommended variety;
- of 6 rice varieties given to farmers in Nepal for February-sown rice all have been preferred by farmers;
- farmers are saving seed for resowing and are demanding more seed of these new varieties.

Normally a PVS programme starts by identifying farmers' needs and searching carefully for new varieties that meet those needs. Because of time constraints this process was shortened and varieties were not selected for being particularly adapted to the late sown conditions of the project area. Despite this, 10 of the 13 varieties yielded significantly more than Lok 1 (Fig. 5). (Variety Raj 3765 failed to yield significantly more as the sample size was small due to shortage of seed.) The experiment demonstrates that this sample of released cultivars yielded significantly more than Lok 1 that currently occupies about 90% of the wheat area, and that a much greater diversity of cultivars can be offered to farmers.

The PVS involves the adaptation of methods developed in marginal areas to high potential production systems. The adaptation of technologies from system to system, rather than development and testing of totally new technology, can lead to a more rapid impact. However**,** there is a qualitative difference in potential impact in the two systems. In marginal environments, modern varieties are replacing landraces, whereas in high potential systems new varieties are replacing old varieties. Although the percentage gain per unit area will be higher in marginal areas, this is outweighed by the higher yields and much greater cropped areas in high potential production systems.

Box 3. Participatory Varietal Selection Explained (adapted from Witcombe , 1997)

Although production had increased greatly in favourable agricultural environments, production was stagnant or had increased only slowly in marginal areas. Farmers in these areas had not adopted new cultivars in favour of their local landraces. Maybe farmers did not have access to varieties that were adapted to less favourable conditions, and perhaps recommended varieties did not have the attributes, such as high straw yield, that low-resource farmers needed.

In the 1980s, to encourage the adoption of higher yielding varieties by low-resource farmers, scientists initiated farmer participatory research in plant breeding in several countries. All of this research was devoted to the latter stage of the plant breeding process—the selection among finished, or nearly finished, varieties. These participatory varietal selection (PVS) programmes had several characteristics in common. The needs of farmers were identified by discovering what crops and varieties they grew, and what traits they considered important. New varieties were selected by scientists that had the traits that farmers desired and that matched the farmers' landraces for important characters such as maturity, plant height and seed type, or farmers visited research stations to select material from the wide range of varieties in breeders' trials. Whatever method was used to select the varieties, once selected they were given to farmers to grow alongside their local varieties with traditional management. Instead of complex trial designs, farmers were the unit of replication and each farmer grew one, or a few, of the new varieties. However, all of the many varieties would be grown by the farmers of a village.

Evaluation methods were also participatory. All of the participating farmers visited all of the plots of all of the new varieties. They could then make judgements, as a group, on the relative value of the new varieties. However, in many programmes, yield per unit area was also assessed to provide data for variety release committees and to test the agreement between farmers' perceptions of yield and quantitative yield data.

Simple, informal methods for PVS also can be used. Small quantities of seed of named varieties are distributed to farmers, but no instructions are given on how to grow them, and no attempt is made to undertake formal evaluation of their relative performance. Instead, adoption rates are monitored after several seasons to see which varieties prove to be most popular with farmers. For a more rapid evaluation, informal discussions with farmers after a single season will identify highly preferred varieties.

Participatory varietal selection programmes have been described from many countries, including Colombia, India, Namibia, Nepal, and Rwanda, in grain legumes, rice, pearl millet and maize. They have proved to be very effective—all have succeeded in identifying new varieties that farmers prefer and have adopted. Yield increases attributable to the adoption of new cultivars have been substantial. Farmers adopted more varieties than they are offered in the formal extension system and the varieties they preferred were rarely those that were officially recommended.

Fig. 4. Farmer managed trials in Gujarat.

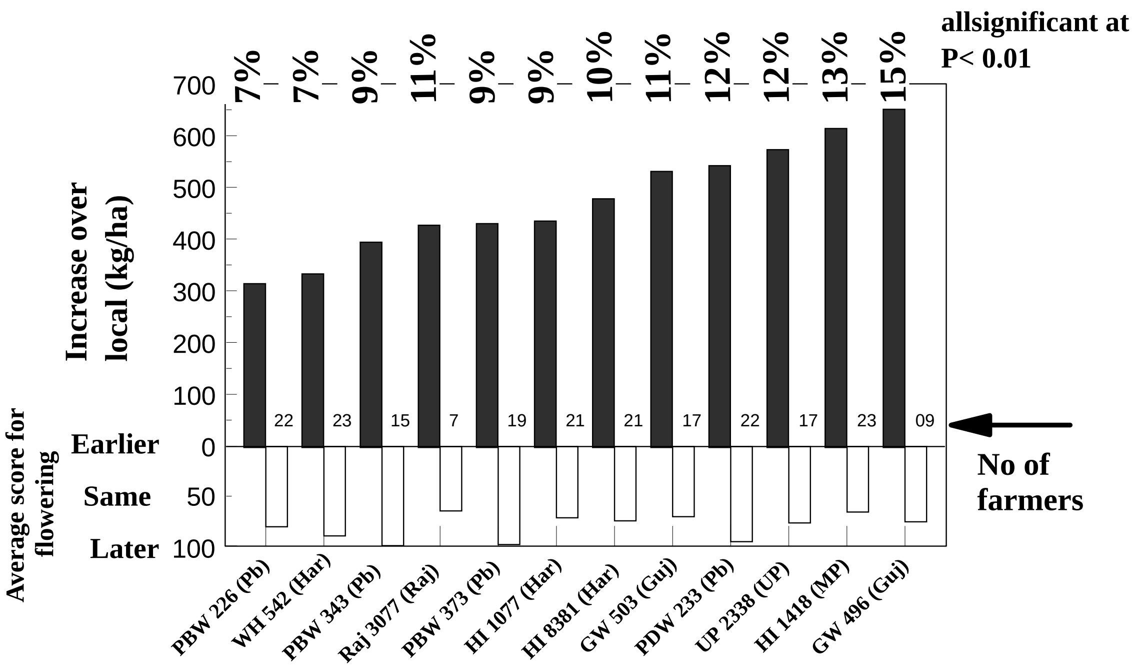

Fig. 5. The results of farmer participatory research trials, Lunawada, Gujarat, 1996-97. Ten of the 13 varieties yield more than the local variety (Lok 1). The yield data have not been adjusted for differences in time of planting. Flowering characteristics are calculated as an average of the scores given by farmers where 0 = earlier than Lok 1, 50 = same as Lok 1 and 100 = later than Lok 1. The state in which the variety is recommended is given in parentheses after the varietal name (Pb = Punjab; Har = Haryana; Raj = Rajasthan; UP = Uttar Pradesh; Guj = Gujarat; MP = Madhya Pradesh). (Source of data DS Virk *et al*. unpublished).

REASONS FOR SUCCESS IN THE SEED PRIMING AND PARTICIPATORY CROP IMPROVEMENT PROJECTS

Although both projects have identified a constraint, thus satisfying the essential criterion that the research is demand led, they share common advantages in the choice of technology (Box 4). In the case of seed priming, these advantages include a rare but favourable combination of characteristics for an agronomic intervention. The uptake pathways for improved agronomy are usually more complex because, typically, improved agronomic practices require additional investment on the part of the farmer by needing one or more of purchased inputs, new equipment or additional labour. Risk is increased because of the additional investment. Often, improved agronomic practices are complex to adopt and, in comparison to seed priming, require more knowledge on the part of the farmer and are more location- and production system specific. In the case of PVS the favourable combination of characteristics described in Box 4 is typical of seed-based technology.

Both projects share a common collaborative partner that provides significant advantages (Box 5). However, the participatory crop improvement project is a special case of adapting the technology proven in one production system (marginal environments in the semi-arid production system) to another (the high potential production system). One of the advantages for seed priming, the size of the project in terms of the villages in which it is operating, can no longer be exploited since the 70 villages of the project are all in marginal areas[†].

Box 4. Common advantages of the technologies used in the seed priming and participatory crop improvement projects.

Seed priming is an agronomic intervention whereas participatory varietal selection (PVS), an important component of participatory crop improvement, is seed based. Surprisingly, both of these technologies have much in common that has contributed towards their success. They both:

- use a simple technology that involves elements of indigenous technical knowledge (ITK);
- exploit a technology that is at low, or even no, additional cost to farmers;
- exploit research outputs that require little further development before they can be put to practical use;
- provide options that either reduce risk to farmers or provide only a small increase in risk; and
- address a widespread and important constraint (poor crop establishment and its associated problems in the case of seed priming, and low-yielding, disease-and pest-susceptible varieties in the case of PVS).

[†] There are spin-offs from the NRSP/PSP project in the high potential system to the bilateral project. For example, wheat varieties selected by farmers in the HPPS are relevant to irrigated areas created by irrigation and water conservation schemes in the bilateral project.

Box 5. Advantages in project design in the seed priming and participatory crop improvement project — the wise choice of partners

Both projects link with a DFID bilaterally funded project in western India, the KRIBHCO Rainfed Indo-British Farming Project/West (KRIBP/W). This bilateral project has many advantages for developing research linkages that reflect the time and resources devoted by the bilateral programme to obtaining an excellent project design.

The advantages of KRIBP/W as a partner can be summarised for the seed priming project:

- the enthusiastic collaboration of project management;
- the use of participatory methods to understand the farming system;
- a collaborating partner that has:
  - a commitment to farmer participatory approaches,
  - a rapport with farmers and the trust of the target communities,
  - an established network with GOs and NGOs, such as Sadguru, SAUs, and IARI,
  - an innovative approach to extension, and
- a large-scale programme working in over 70 villages in three states so that any research output can quickly have a widespread impact.

Case-Study 3: Salinity tolerance in wheat: *R6348 On-farm assessment of salinity tolerance in wheat*

In the past, the socio-economics of research into salinity tolerance in wheat for salt-affected areas have generated much discussion. More recent information from Pakistan (Ijaz and Davidson, 1997) indicates the great economic impact of salinisation and how research on salinity has both a gender and a poverty focus. It is clear that educational attainment in salt-affected areas is lower than in non-salt affected areas, and the considerable disadvantage of women is more pronounced (Fig. 6). The proportion of people finding livelihoods outside farming is less in the saline areas, probably as a result of lower education (Fig. 7) and the disadvantage that woman have in finding off-farm employment is more pronounced in the salt-affected areas. When off-farm employment of women is analysed separately (Fig. 8) the differences between the salt-affected and the control areas are striking.

An understanding of the physiology and genetics of salinity tolerance in wheat has been gained from more than 10 years of DFID-funded research, illustrating the importance of continuity in research activity (Box 6). During the course of this research linkages have been established with developing country scientists, particularly in Pakistan and India, who have applied their training to breed salt-tolerant wheat cultivars. Farmers are adopting these varieties and are achieving higher yields in saline affected soils. In Pakistan, varieties have spread through farmer-to-farmer seed exchange and through farmers' groups. More recently, efforts have been integrated with other international development projects in Pakistan that are using trees and salt-tolerant fodder species to tackle the salinity problem. This project typifies an emerging consensus that no single solution is sufficient to solve the problems of salinisation. Total reliance on physical engineering solutions is expensive, and bio-engineering (the introduction of salt-tolerant trees to lower the water table), and salt tolerant crop species and varieties complements physical approaches. An integrated salinity management (ISM) approach is required, of which salt-tolerant cultivars are a key component.

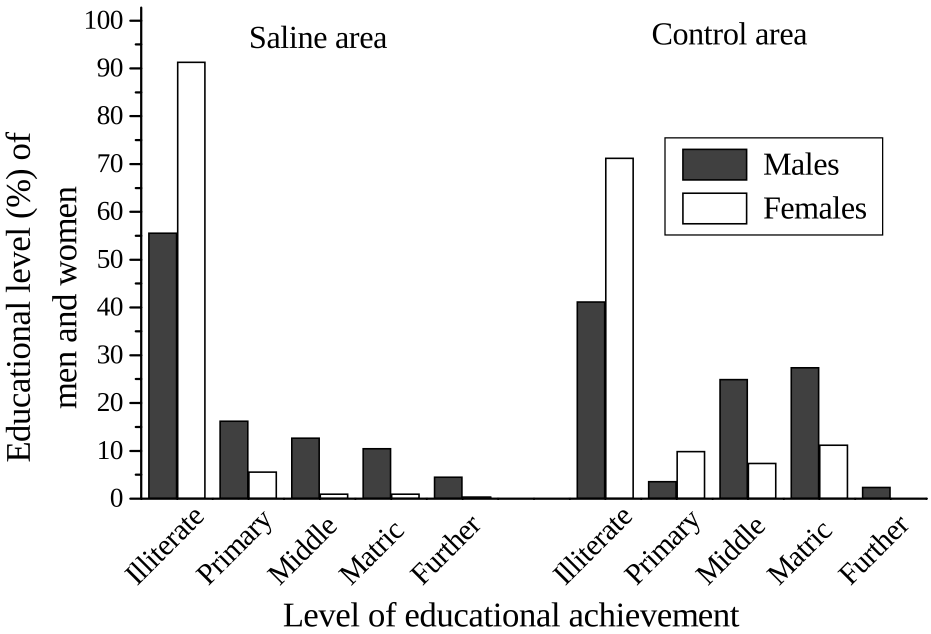

Fig 6.
Distribution of principal males and females by level of education in saline and non-saline areas, Satiana, Faisalabad.

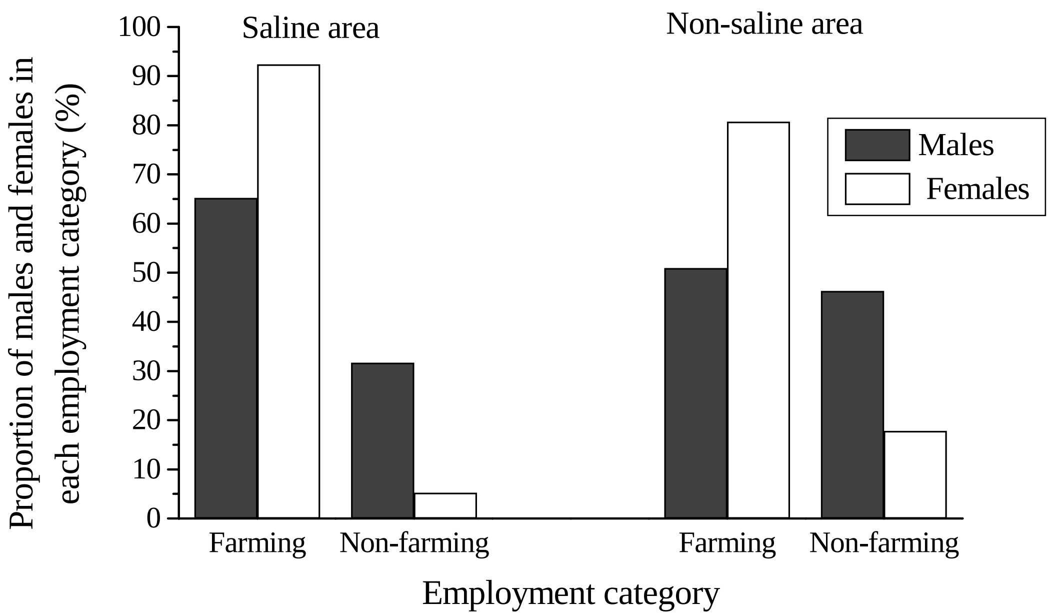

Fig 7.Men and women in farming and non-farming employment in saline and non-saline areas, Satiana, Faisalabad.

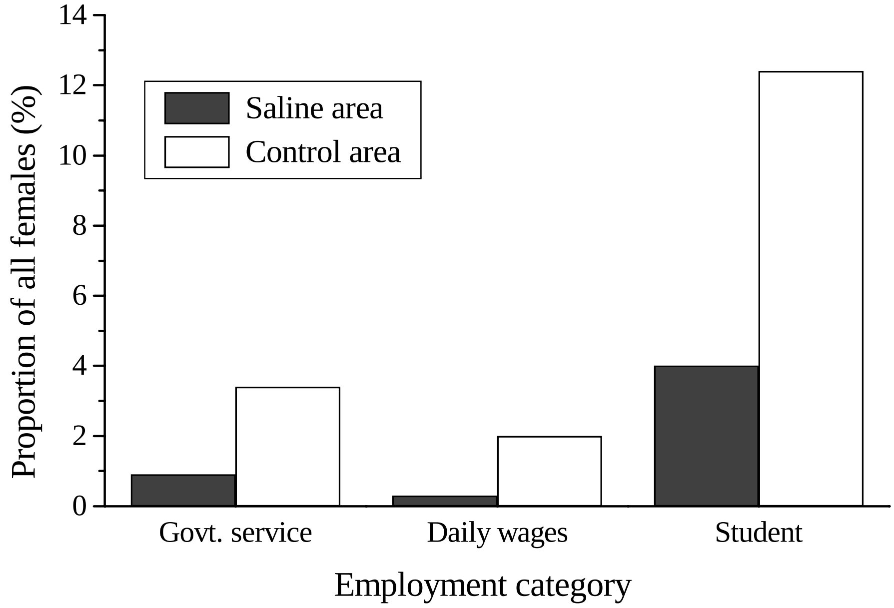

Fig 8. Women in non-farm employment in saline and non-saline areas, Satiana, Faisalabad.

This third case study in wheat has many features in common with the first two. The research provides a low-risk, appropriate technology to meet a very important constraint and, after an initial choice of partner institutions, relationships have been strengthened over a long period of time. However, this case study reveals two more important lessons — the value of continuity of research and the importance of recognising and exploiting serendipitous research outputs (Box 6). In the present project **R6348** *On-farm assessment of salinity tolerance in wheat* training has been given to several scientists from India in doubled haploid techniques developed in another DFID funded research project (Box 6). The use of doubled haploids provides a much faster system of producing potential new varieties. This year, four cultivars developed by an Indian scientist using this technique are under multiplication and will be entered into National Salinity Trials in India in the 1997/1998 season. Two of the cultivars have KTDH 19 as one of the parents — a genotype that was produced at the John Innes Centre, Norwich in follow-on research from PSP projects. A second Indian scientist has also produced many promising genotypes using this doubled haploid technique, and these are expected to enter the trials in 1998/99.

It is clear that from PSP developed technology, salt-tolerant cultivars can be bred that are accepted by farmers. Further research is underway to better quantify the impact. Amounts of primary seed distributed need to be determined, along with secondary dissemination from farmer to farmer. To package and promote these research outputs, future work should concentrate on participatory varietal selection to gain a better understanding of farmers' perceptions of the new varieties and to identify, with a high degree of certainty, those that are most acceptable.

Box 6. The need for research continuity and the important role of serendipity

Research continuity

The research on salinity tolerance has always employed the multi-disciplinary approach of physiological trait identification and genetic manipulation using wide crossing. The research has built up a body of knowledge on the physiology and genetics of salinity tolerance and on practical breeding and screening techniques. Since 1990, research has continued in collaborative projects at CAZS and the John Innes Centre with overseas partners in Pakistan and India. This has culminated in the identification of salt-tolerant cultivars that are being adopted by farmers. Without this research continuity such a positive outcome would have been unlikely.

Research continuity is an important theme in the management of the PSP where a high proportion of new projects build on the outputs of past projects. In the same way, plant breeders are said (to paraphrase Newton) always to stand on the shoulders of other plant breeders when they use their varieties as parents in a breeding programme. The salinity research is only one of many examples where this long-term approach is being taken, often using research outputs produced in other RNRRS programmes or research outputs produced by the PSP under previous managers.

Research serendipity

That rocket science has produced non-stick frying pans, or happenstance produced penicillin, are examples of unintended applications of research that have passed into scientific folklore. Although we do not have quite such remarkable examples, PSP research that was originally funded to improve maize using transfer of genes from a related genus (sorghum) is now having a huge impact in the way that wheat breeding is done using quite another technique. The research led to the now widely adopted method of rapidly producing new wheat varieties using doubled haploids created by initially crossing wheat with maize. When this cross is made, the maize chromosomes are naturally eliminated to produce a haploid embryo. These embryos are then 'rescued' and their chromosome numbers doubled to rapidly produce homozygous lines—potential new varieties. This technology is being exploited in PSP-funded wheat salinity research, and has been widely adopted by international (CIMMYT) and national wheat breeding programmes.

Much of current PSP-funded research is strategic, and since 1990 there are several cases of unintended applications of research results. The most advanced example is in the case of molecular markers in pearl millet designed to assist breeders to select for difficult characters. The technique is being used by private-sector seed companies to test more rapidly for the genetic purity of seed produced for them by contracted farmers. The seed companies benefit because they can market their seed more quickly, the seed producers benefit by earlier payment, and farmers benefit because a major constraint—an inadequate and untimely supply of quality seed of pearl millet hybrids and varieties —is removed.

IMPACT ON INTERMEDIATE USERS

Molecular markers make rice germplasm collections more useful to plant breeders*: R6454 Use of molecular markers to enhance the management of rice germplasm collections and their utilisation for rice improvement*†

Background

Rice is the most important cereal crop in the developing world where it provides the major food source for over half the population. Breeders are increasingly using accessions from collections of plant germplasm to improve the characteristics of cultivated varieties. The largest collection of rice germplasm is held in the Philippines at the International Rice Research Institute (IRRI). Here, over 80,000 samples of rice are conserved, and since 1973 over 740,000 packets of seed have been distributed throughout the world for use in research and breeding. This germplasm has made important contributions to improvements in many characteristics of new rice varieties although the economic value of germplasm is difficult to measure. One recent study at IRRI assigned a value of $2.5 million per released rice variety per year, and a relationship of 0.52 released varieties per year per 1000 accessions held in the IRRI gene bank. Pressure on germplasm distribution will further increase over the next 30 years as plant scientists strive to meet the demands for increased rice production. However, the management of the material is made more difficult by the sheer size of the collection.

Molecular marker techniques can increase the efficiency with which such large plant collections can be handled so that they become even more valuable resources for plant breeders. The project uses the IRRI collection as a model and the protocols developed are being adopted by the Genetic Resources Centre at that institute; they will also be transferred to the National Bureau of Plant Genetic Resources (NBPGR) in India. The collaborative studies involve workers at Birmingham University, the JIC and IRRI. Two examples of useful research outputs that are being put to use by IRRI are described below:

Duplicate accessions and core collections

The conservation of any accession is expensive. It requires periodic testing for seed viability, the regeneration of fresh seed in the field, characterisation to provide breeders with key information, and distribution to breeders who request its seed. All of this effort is wasted if the accession is a duplicate of another. Unfortunately, in a very large collection of more than 80,000 accessions, such as the one at IRRI, it is inevitable that some of the accessions are duplicates. It would be more efficient if most of the diversity present within a large germplasm collection could be represented in a much smaller (5-10% of the total) 'core collection'. Then efforts could be concentrated on the core which could be much more thoroughly characterised, would contain no duplicates, and could be generated in bulk so that seed was always quickly available on request. Both duplicate recognition and the development of core collections are made much easier by the use of molecular markers. Methods developed for the designation of duplicates are now being employed at IRRI. It has also been shown that by using molecular markers core collections can be efficiently developed using a stratified geographical sampling method (Newbury *et al.* 1997). The elimination of duplicates and the development of core collections will markedly improve the cost effectiveness of the collection for plant breeders, saving time and resources during breeding programmes.

† This section is adapted from Newbury *et al*. 1997.

Diversity estimates for samples of a wild species

The IRRI collection holds samples of a large number of rice species. The entire holding of a single wild species (*Oryza minuta*) was evaluated for one type of molecular marker (AFLP bands). *O. minuta* possesses resistance to several insect pests and fungal and bacterial pathogens. The 29 samples (accessions) were genetically extremely similar (*see* Fig. 9). Indeed, some could be considered to be duplicates. With this lack of diversity there is no point using more than a few of the accessions in crosses to transfer potentially valuable genes to cultivated rice. This finding has considerable resource saving implications for breeding programmes. Another use of such studies is to confirm the taxonomic identification of accessions. It had been suspected that one of the accessions used had been mis-identified but the data obtained indicated that it was clearly the same as other *O. minuta* material.

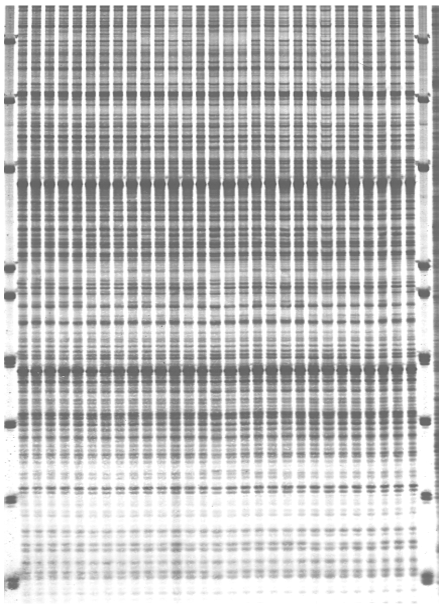

Fig. 9. A portion of the banding pattern using AFLP technology with a range of *Oryza minuta* accessions. The lack of diversity that is apparent between the accessions has important practical applications for plant breeders.

Measuring impact

Although this research has an undoubted impact on intermediate users such as IRRI , and will have an impact on plant breeding as germplasm will be used more efficiently, attribution of the impact of the research in newly-bred and adopted rice varieties is a most challenging task. The attribution of genetic resources to plant breeding is difficult enough[†], without attempting to partition the value of genetic resources according to research contribution.

IMPACT IN LONGER-TERM TECHNOLOGY DEVELOPMENT

The PSP is having great impact in the area of technology development. Important examples are:

- the creation of molecular marker maps to assist plant breeding in pearl millet;
- the production of transgenics in rice to produce virus and nematode resistant cultivars; and
- the development of reliable and reproducible methods for producing transgenic cassava.

[†] The ancestry of a single variety, when written in full, can be pages long and involve over 100 parents.

The first example, of molecular markers in pearl millet, is the nearest to market. Marker-assisted selection is at an advanced stage, and products are expected to reach farmers' fields within three years. Advanced generations of pearl millet have been produced by using marker-assisted selection for downy mildew resistance, an economically important disease in India and Africa. This technique can be applied to breed for all economically significant traits. Those currently targeted, in addition to downy mildew resistance, are:

- seedling thermotolerance
- drought tolerance
- fertility restoration
- yield
- flowering time

In the second example, transgenics have been produced for resistance to nematodes, Tungro virus, and Rice Yellow Mottle Virus. These transgenics are currently being screened against these important biotic constraints.

The final example is of the production of a technology that has been adopted by other laboratories in the UK, continental Europe, and the USA. The PSP has funded research which has produced an enabling, generic technology that will be used by all laboratories that produce cassava transgenics. Because of the exceptional difficulties of conventional plant breeding in a clonally propagated crop, the use of transgenics in the breeding of cassava resistant to biotic stresses is likely to be even more important than in sexually reproducing crop plants.

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