The status of ‘on-farm’ seed priming and related work funded by the DFID Plant Sciences Research Programme

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BACKGROUND

The PSP has always been mindful of the limited resources of our ultimate clients – poor farmers in marginal environments of developing countries. Hence we have pursued a strategy of developing ‘key’ technologies, i.e., simple, low cost, low risk interventions that can be easily adopted, without significant additional capital costs, by farmers. In agriculture, the ideal ‘key’ technology is improved seed. Farmers who adopt new varieties of existing crops can gain immediate benefits without any changes in management, although it is common to find that farmers do increase levels of inputs in response to the reduced risk and additional opportunities afforded by the new varieties. Thus the output of most of the PSP projects is either genetically improved seed (as a result of improved breeding techniques) or a wider choice and better availability of appropriate varieties (by developing participatory varietal selection – PVS – and novel seed supply systems) for resource-poor farmers.

In contrast to the seed based technologies described above, low-cost, low-risk agronomic interventions are less common. Historically, although agronomic improvements in developed countries have contributed substantially to increased crop yields, they have relied on substantial financial investment in machinery, chemical fertilisers and crop protection compounds. Such investments are seldom possible, or even appropriate, for poor farmers in high-risk, rainfed environments. Nevertheless, PSP identified one area – poor crop establishment – where farmers could make improvements without incurring additional costs.

ON-FARM SEED PRIMING

Harris (1996) highlighted just how difficult it was for farmers in marginal areas to get their crops established effectively but he demonstrated that simply soaking seeds in water before sowing could increase the speed of germination and emergence, leading to better crop stands, and make seedlings grow much more vigorously. These observations were the basis for PSP efforts from 1997 to test, develop and eventually promote seed priming for a wide range of tropical and sub-tropical crops in many developing countries.

Agronomic benefits

Initially, two projects (R6395 and R7438) used a combination of *in vitro*, on-station and on-farm work to test the germination and emergence characteristics of many crops and varieties in response to seed priming. These two projects had several overall objectives: to test the effects of on-farm seed priming for crops important for resource-poor farmers in marginal areas; to develop, using participatory approaches with farmers, practical methods of priming seeds to best effect; to promote seed priming with resource-poor farmers and organisations (GOs, universities, NGOs) working with such farmers.

The concept of the ‘safe limit’ was found to be important – the maximum length of time for which seeds can be soaked and which, if exceeded, could lead to seed or seedling damage. Once safe limits were determined from *in vitro* studies, participatory work with farmers was used to test and develop through feedback practical methods of priming seeds. Farmers’ trials were also used to assess the effects of priming on a large scale, while further *in vitro* studies

(R7440) and studies on research stations were used to gain insights into possible mechanisms for the effects of priming.

Results quickly began to accumulate that showed that, not only was seed priming effective in improving crop stands (e.g. Fig. 1), but that there were many positive 'knock-on' effects of faster emergence and more vigorous early growth. Priming was seen to promote earlier tillering in cereals, earlier flowering (e.g. Fig. 2) and maturity and higher yields (e.g. Fig. 3). These effects were noted in many crops and countries (see Table 1).

Figure 1. **Better stand and more vigorous growth of chickpea after priming the seeds in Bangladesh.**

Table 1. **Crops in which seed priming has increased yields, the countries involved and the references where the methods used and the results obtained can be found.**

Crop	Countries	References
Wheat	India, Nepal, Pakistan	Harris *et al*. (2001b); Rashid *et al*. (2002)
Upland rice	India, Nigeria, Sierra Leone, Gambia, Ghana, Cameroon	Harris *et al*. (1999); (2002); Harris (2003)
Maize	India, Nepal, Pakistan, Zimbabwe	Harris *et al*. (1999); (2001a); (2001c)
Sorghum	Pakistan, Botswana, Zimbabwe	Harris (1996); Chivasa *et a*l. (1998); (2001); Rashid *et al*. (2002)
Pearl millet	Pakistan, India	Harris and Mottram (2004)
Finger millet	India	Kumar *et al*. (2002)
Chickpea	Bangladesh, India, Nepal, Pakistan	Harris *et al*. (1999); Musa *et al*. (2001); Rashid *et al*. (2002)
Mungbean	Pakistan	Rashid *et al*. (2004b)
Cowpea	Senegal	Braconnier and Bouru (2004)

Figure 2. **Earlier flowering (left) in maize plants in Zimbabwe from seed primed with water.**

Seed priming is demonstrably effective for a wide range of crops and environments (Table 1), yet its promotion as a stand-alone technology has limitations, particularly for inclusion in government extension programmes. Consequently, more emphasis was placed on using seed priming as one of a set of tools to address more fundamental shortcomings in cropping systems. Other PSP-funded work (R7541) had identified and quantified the huge area of land left fallow in South Asia after the harvest of rainfed rice (Subbarao *et al*., 2001). Preliminary research (R8098) showed that poor crop establishment was a major constraint on the adoption of a second crop after rice. Projects R7540, R8269 in Bangladesh and R8221 in Eastern India demonstrated that early, rapid, minimum tillage and sowing primed seeds of a short-duration legume such as chickpea was effective in raising yields in these rice fallows (Musa *et al*., 1999; Musa *et al*., 2001) to levels where the technology was adopted widely by farmers (Saha, 2002 and this volume).

Figure 3. **Yield of mungbean pods from same-size plots with seeds primed for (L-R) 0, 4, 6 and 8 hours.**

In addition to the acknowledged yield benefits from priming with water alone, PSP research has identified a number of opportunities for priming to be used as a vehicle to introduce fertilising *rhizobia*, additional micronutrients or crop protection agents into seeds.

Nutrient supplementation

Many legumes are relatively unproductive in acid soils because nodulation is limited by poor availability of molybdenum (Mo). In particular, chickpea is known to respond to added Mo but soil application is problematic for resource-poor farmers because of the relatively high rates of application required (at least 0.5 kg/ha) and because uniform application is difficult to achieve. On the other hand, alkaline soils are often deficient in micronutrients such as zinc (Zn). Recent work (R8221 and R8269) in India and Bangladesh has shown that large yield increases in chickpea are possible in farmers' conditions following priming with tiny amounts of molybdenum (Fig. 4; Kumar Rao *et al*., 2004; Johansen *et al.*, 2004). Similarly, Harris *et al.* (2004b) in R7438 demonstrated large, highly cost-effective yield increases in chickpea and wheat in Pakistan in response to priming with zinc sulphate. Harris *et al.* (2004a) have also shown that seeds can be effectively inoculated with *rhizobium* (to enable fixation of nitrogen) during normal priming operations. Preliminary data (unpublished) also suggest that it is possible for farmers to prime seeds with small amounts of phosphate (P) to good effect in that early root growth is stimulated allowing more effective uptake of available P in the soil. There are huge areas of rice fallows in S. Asia (around 16 million hectares) and many of the soils are deficient in N, P and Mo so the domain for this technology is very large.

Figure 4. **Provision of molybdenum by priming chickpea seed (background) results in better fixation of nitrogen and higher yields in Bangladesh.**

Disease resistance

Musa *et al*. (2001) reported that seed priming in chickpea significantly reduced the damage caused by collar rot (*Sclerotium rolfsii*) in Bangladesh in two contrasting seasons. Recent work in Pakistan (R7438) has demonstrated that mungbean (*Vigna radiata*) grown from seed primed in water for 8 hours before sowing showed significantly fewer serious symptoms of infection by Mungbean Yellow Mosaic Virus (MYMV) than a crop established without priming (Fig. 5). The large differences in virus-related damage were associated with significant increases in pod weight (threefold) and grain weight (fivefold) due to priming (Rashid *et al*., 2004a). Rashid *et al*. (2004b) also observed similar differences in MYMV infection in other mungbean priming trials.

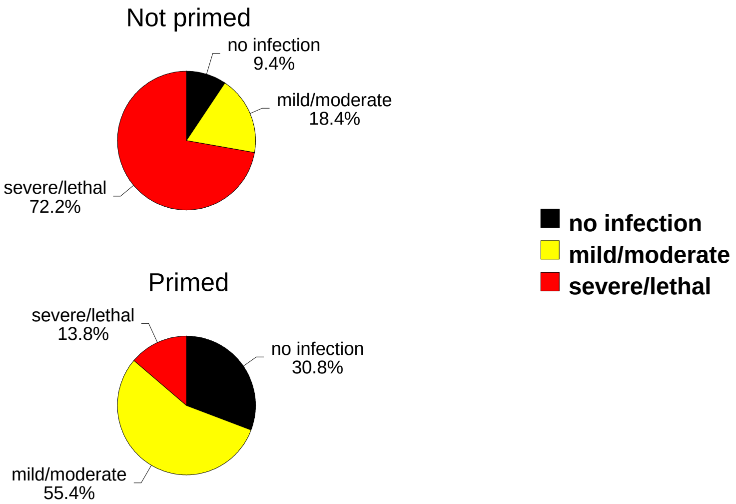

Figure 5. **Changes in incidence and severity of MYMV disease following seed priming in a mungbean crop in Pakistan.**

These observations from field trials of enhanced resistance to disease following seed priming have prompted an *in vitro* investigation of the phenomenon using a well-established plant-disease model, i.e., pearl millet and downy mildew disease. Ongoing research (R7438) has shown that priming seeds in water for eight hours before sowing significantly reduced the incidence of downy mildew disease in seedlings of a highly susceptible cultivar from about 80% to less than 60% (Table 2 and Harris *et al*., 2004a).

Table 2. Percentage of plants showing symptoms of downy mildew disease. Analysis used arcsin transformed data. Transformed means are presented (with non-transformed means in brackets). SE diff. values were calculated using transformed data.

Treatment	Disease incidence, %.
Seed not primed	63.5 (79.7)
Seed primed for 8 hours	50.3 (58.8)
Standard error of difference between means	3.42
Least significant difference (P<0.05)	7.19

These unexpected results cannot be explained without reference to biochemical changes induced by priming and further experiments are underway (R7438) to investigate this mechanism and to discover if it operates in other plant/disease systems. The practical consequences for resource-poor farmers of such a mechanism are enormous and far-reaching.

Promotion and dissemination

Information on seed priming is available on the website www.seedpriming.org and a significant proportion of project staff time is dedicated to the distribution of information related to seed priming. Staff have made presentations on various aspects of seed priming at 20 international conferences and workshops since 1997 and have published widely (Table 1 and reference list below). Almost 3000 copies of the illustrated brochure *'On-Farm' Seed*

Priming. A key technology to improve the livelihoods of resource-poor farmers in marginal environments have been distributed through various channels. In addition detailed advice, research protocols and supporting materials, e.g. publications concerning seed priming, have been provided in response to enquiries from around 150 individuals and organisations (researchers, NGOs etc) around the world who have expressed an interest in testing seed priming for themselves. Seed priming has been featured on the radio and on TV (twice).

The future

Many thousands of farmers, researchers and extensionists, many not directly linked to PSP, have been exposed to seed priming and enough time has elapsed to allow us to follow up and learn from their experiences. In addition, studies of uptake and persistence of the technology are required where seed priming work has been funded directly by PSP. An example of this is ongoing in Cameroon, Gambia, Ghana, Nigeria and Sierra Leone in the rainfed rice systems described by Harris (2003).

The simplicity and effectiveness of using seed priming to deliver Mo, Zn, P and (via *rhizobium*) N has been demonstrated on a research scale in Bangladesh, India and Pakistan and needs to be researched and disseminated at operational scales. The work so far on second cropping has demonstrated many synergies between priming-related advantages and the introduction of new varieties through PVS – a clear example of the integrated approach favoured by the PSP. The obvious focus for such work is the huge area of rice fallows in South Asia where the livelihoods of some of the world's poorest people can be transformed by growing a low-cost, low-risk second crop after rice. There are also large areas of 'maize fallows' in East Africa and preliminary experiments with chickpea (R7438) have also identified a potential impact there.

Using seed priming to deliver nutrients may need further backup research, particularly for P, in addition to the operational scale, adaptive research noted above. However, more fundamental research will certainly be necessary to understand the nature of the relation between seed priming and disease resistance. Although preliminary research (Musa *et al*., 2001; Rashid *et al*., 2004a; Harris *et al*., 2004b) has established that seed priming can, in some circumstances, increase plant resistance to disease further work is required to confirm this phenomenon to the point where it can be regarded as another of the assured benefits of priming seeds.

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(note: not all references listed below appear in the text)

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