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ON-FARM SEED PRIMING IN SEMI-ARID AGRICULTURE: DEVELOPMENT AND EVALUATION IN MAIZE, RICE AND CHICKPEA IN INDIA USING PARTICIPATORY METHODS

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SUMMARY

Poor crop establishment was identified as a major constraint on rainfed crop production by farmers in the tribal villages of Rajasthan, Gujarat and Madhya Pradesh served by the Krishak Bharati Cooperative (KRIBHCO) Indo-British Rainfed Farming Project (KRIBP). On-farm seed priming with water was chosen as a low cost, low risk intervention appropriate to the farmers' needs. *In vitro* screening of the effects of priming on the germination of seeds of local and improved varieties of maize, upland rice and chickpea 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 were 24 h for maize and rice and 10 h for chickpea, with only minor varietal differences. These recommendations were then tested in on-station trials in Dahod, Gujarat. Farmer-managed trials were conducted for chickpea in three villages in the *rabi* (post-monsoon) season in 1995–96; for maize and upland rice in eight villages in the *kharif* (monsoon) season in 1996; and for maize and chickpea in 15 villages in the 1996–97 *rabi* season. Farmers modified these recommendations to 'overnight' for all three crops. Evaluation of the technology by farmers involved focus group discussions, matrix ranking exercises and two workshops.

Direct benefits in all three crops included faster emergence, better stands and a lower incidence of re-sowing, more vigorous plants, better drought tolerance, earlier flowering, earlier harvest and higher grain yield. Indirect benefits reported were earlier sowing of *rabi* crops because of the shorter duration of the preceding *kharif* crop, earlier harvesting of *rabi* crops that allowed earlier migration from the area, with better chance of obtaining off-season work, and increased willingness to use fertilizers because of reduced risk of crop failure. In matrix ranking exercises in four villages in the *kharif* 1996, 95% of farmers indicated that, even after only one exposure to the technology, they would prime seed in the following season. Similar exercises in four villages in *rabi* 1996–97 revealed that 100% of collaborating farmers intended to continue seed priming. From 21 villages, 246 farmers attended two workshops to share their experiences of seed priming and resolved to continue with the technology.

INTRODUCTION

There is a growing realization that poor stand establishment is a major constraint on crop production in semi-arid areas. Fields without a reasonable number of

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well-spaced, vigorous plants cannot be expected to produce good yields. Farmers recognize this when they choose to re-sow poor stands, often at considerable cost in labour, materials and delayed sowing. There are many reasons for poor stand establishment in tropical crops: inadequate seedbed preparation (Joshi, 1987), low quality seed, untimely sowing (Oosterom *et al.*, 1996), poor sowing technique (Radford, 1983), inadequate soil moisture (Gurmu and Naylor, 1991; Ferraris, 1992; Harris, 1996), adverse soil properties such as a propensity to form surface crusts (Grant and Buckle, 1974; Soman *et al.*, 1992) and high temperatures (Grant and Buckle, 1974; Ougham *et al.*, 1988; Peacock *et al.*, 1993).

The constraints listed above can be addressed but at a cost. Some, like poor seedbed preparation and untimely sowing, are often themselves the consequence of socio-economic factors such as poverty or scarcity of resources such as labour or draft power (Harris, 1992). Particularly intractable, however, is the weather after sowing. Harris (1996) showed that conditions after sowing had a large influence on emergence and seedling vigour in sorghum and argued that speed of germination and emergence was an important determinant of successful establishment. Rapidly germinating seedlings could emerge and produce deep root systems before the upper layers of the soil dried out, hardened or became dangerously hot. Harris (1996) proposed a low cost, low risk intervention termed 'on-farm seed priming' that would be appropriate for all farmers, irrespective of their socio-economic status. For a large proportion of the time that seeds spend in the soil they are simply imbibing water, often very slowly, and frequently as a consequence of the use of low-precision sowing methods that do not promote good seed-soil contact. Meanwhile, the soil may be drying, hardening, crusting and heating up. By soaking the seeds for carefully determined lengths of time before sowing, valuable time is saved. This approach is termed 'on-farm seed priming' to distinguish it from the energy-intensive, high technology seed priming, seed hardening or seed conditioning processes available to farmers in high input temperate agriculture and horticulture (Parera and Cantliffe, 1994).

The semi-arid area of western India served by the KRIBHCO Indo-British Rainfed Farming Project (KRIBP) comprises the contiguous districts of Panchmahals (Gujarat), Jhabua (Madhya Pradesh) and Banswada (Rajasthan). The three districts occupy a total area of 21 450 km^2 between lat 22°30′ and 23°48′N and between long 73° and 74°45′E. Rainfall varies both spatially and temporally from over 1300 mm a^{-1} to less than 800 mm a^{-1}. Droughts and years with exceptionally high rainfall are common in the area and farmers report a crop failure in three of every ten years and a serious shortfall in four to five years in ten (CDS, 1990). Of the total rainfall 90% falls in the *kharif* season (approximately June to September).

The project focuses on tribal (Bhils, Rathwas, Bhilalis and Minas) villages which are usually concentrated in the lower rainfall, marginal areas. These villagers have poor access to infrastructure and services and their livelihoods are based on rainfed agriculture, most households being owner-cultivators (CDS, 1990). The most important *kharif* crop is maize (*Zea mays*), although upland rice

(*Oryza sativa*) is also grown, especially where project-related soil and water conservation activities have improved soil moisture levels. Maize and chickpea (*Cicer arietinum*) are the main crops grown on residual soil moisture or with limited irrigation in the *rabi* season. Access to timely, affordable credit and agricultural inputs such as fertilizers is poor and so fertilizer use is not widespread. Without irrigation a third season (*zaid*) crop is not possible and levels of out-migration to surrounding agricultural areas and towns and cities at this time are high.

Initial Rapid Rural Appraisal (RRA) exercises identified poor crop establishment as a serious constraint in the project area (CDS, 1990) and this was confirmed by later, more detailed Participatory Rural Appraisals (PRA). This paper describes the combination of laboratory, on-station and on-farm development and testing used to evaluate on-farm seed priming for the major crops of the area, maize and upland rice in the *kharif* (monsoon) season and maize and chickpea in the *rabi* (post-monsoon) season.

MATERIALS AND METHODS

Information on responses to seed priming of the crops and varieties used in the project villages was required before recommendations could be made to farmers involved in on-farm trials. A number of experiments were conducted and these are summarized in Table 1. Methods are described below.

In vitro *screening*

The germination rate (that is, time to 50% germination) and final percentage germination of seeds of maize, upland rice and chickpea were measured on moist filter paper at constant temperature in an incubator. The performance of dry seeds was compared with that of seeds soaked for various lengths of time in water, surface-dried and stored dry for various lengths of time before ‘sowing’ (Fig. 1).

On-station crop establishment trials

Emergence of primed seed of maize and chickpea was measured in trials conducted at the KRIBP research farm, Dahod, India. Seeds were sown using the technique used by farmers, that is, seeds were dribbled into the furrow behind a bullock-drawn wooden plough and then covered with a separate pass with a bullock-drawn plank. Numbers of emerged seedlings were counted at regular intervals (4 or 6 h) and the time to 50% emergence was calculated, together with final stand counts (Fig. 2). Results from these and the *in vitro* germination tests were then used to recommend soaking times to farmers.

On-farm trials

The numbers of farmers and villages participating in testing seed priming are summarized in Table 1. Farmers were given a quantity of seed (2 kg maize, 5 kg rice, 5 kg chickpea) and asked to prime half of them in water, then surface-dry them and sow them using normal practices adjacent to a patch using non-primed

Table 1. Number of farmers participating in on-farm trials for each crop and in each village in Rajasthan, Gujarat and Madhya Pradesh.

State	Village	Crop			Total farmers
		Chickpea	Maize	Rice	
		Rabi 1995–96			
Rajasthan	Khumpura†	5	—	—	5
	Samlaser†	3	—	—	3
Gujarat	Kataranipalli†	6	—	—	6
Total for season					14
		Kharif 1996			
Rajasthan	Umarjhonka‡	—	6	6	12
	Mathurakali†‡	—	4	4	8
	Sodaliya	—	6	3	9
	Kunda‡	—	6	0	6
Gujarat	Mounala†‡	—	8	15	23
	Bar	—	11	20	31
Madhya Pradesh	Kushalpura‡	—	6	6	12
	Dhawdapada	—	6	6	12
Total for season					113
		Rabi 1996–97			
Rajasthan	Umarjhonka	4	0	—	4
	Mathurakali‡	4	0	—	4
	Pandwa Lunja	4	0	—	4
	Kunda	4	4	—	8
Gujarat	Mounala†‡	6	15	—	21
	Bar†‡§	8	4	—	12
	Umariya	15	4	—	19
	Kataranipalli†‡	6	9	—	15
	Jaliyapada	7	4	—	11
Madhya Pradesh	Kushalpura	4	0	—	4
	Amli	4	0	—	4
	Navatapara	4	4	—	8
	Kikalberi	3	0	—	3
	Naganvat Choti	6	0	—	6
	Bihar†§	8	0	—	8
Total for season					131

†Focus group discussions; ‡matrix ranking; §yield data collected by project community organiser.

seed. It was recommended that farmers soaked chickpea overnight and maize and rice for up to 24 h. In practice, farmers generally soaked all three crops overnight before sowing.

A number of methods, based on CARE (1989), were used to facilitate evaluation of the trials by the farmers themselves and to elicit constructive feedback. Village-based community organizers (COs) conducted farm walks several times during each season to promote discussions amongst farmers about the advantages and disadvantages of the technique. These walks allowed

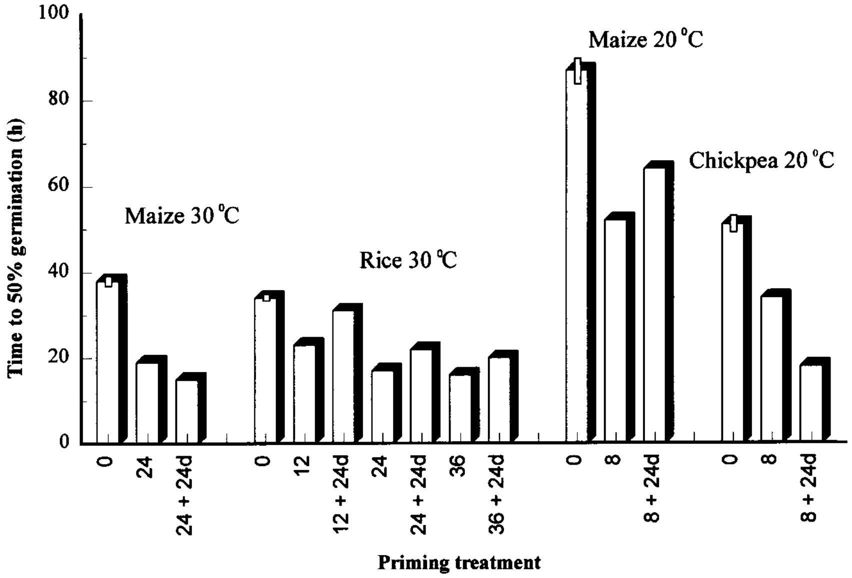

Fig. 1. Time to 50% germination of seeds of maize cv. Shweta and Sameri at 30 °C, rice cv. Kalinga III at 30 °C, maize cv. Shweta and Sameri at 20 °C and chickpea cv. ICCV 2, ICCV 10, ICCV 88202, GL 769 and L 551 at 20 °C. Priming treatment is the number of hours seeds were soaked in water before sowing; 0 represents unsoaked seed; treatments marked +24d were surface-dried and kept dry for 24 h before sowing; vertical bars represent the least significant difference between treatments for each crop/temperature combination.

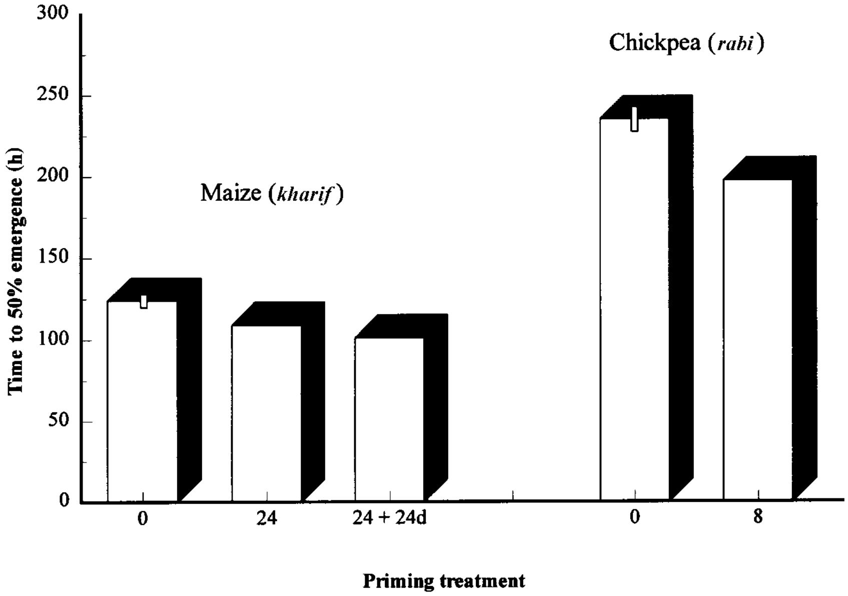

Fig. 2. Time to 50% emergence of seeds of maize cv. Shweta and Sameri in *kharif* 1996 and chickpea cv. ICCV 10 and Dahod Yellow in *rabi* 1996–97. Priming treatment is the number of hours seeds were soaked in water before sowing; 0 represents unsoaked seed; treatments marked +24d were surface-dried and kept dry for 24 h before sowing; vertical bars represent the least significant difference between treatments for each crop.

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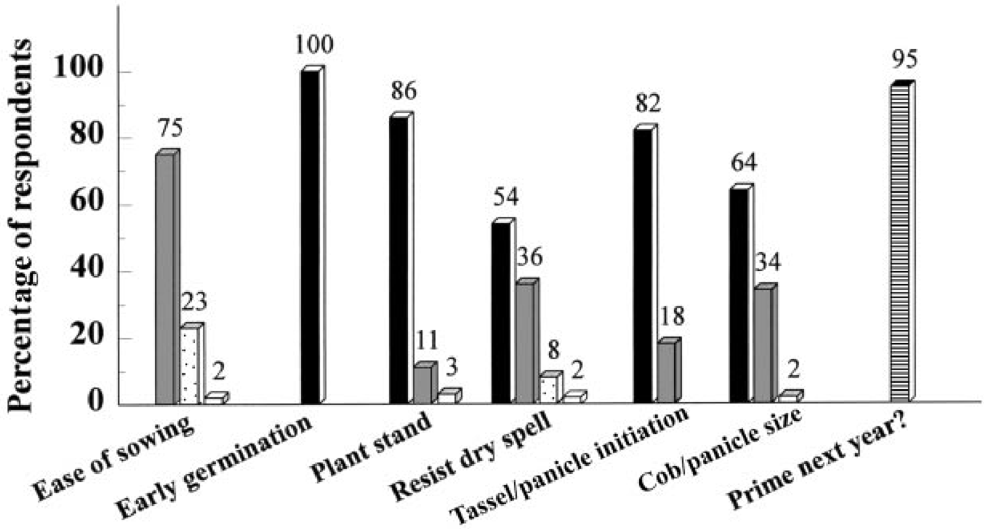

Fig. 3. Summary of farmers' perceptions of seed priming in maize and upland rice during *kharif* 1996. Fifty-six farmers in four villages in Gujarat, Rajasthan and Madhya Pradesh (Table 1) were asked about crop characteristics shown on the horizontal axis. Shading of bars represents improvement (■), no change (■), or deterioration (⁙) in the characteristic, no opinion (□) or yes to the question (⊟).

individual farmers to assess the technology at different stages of crop development and over the wide range of sowing dates, soil types and levels of management represented in that village. Farm walks were usually followed by semi-structured focus group discussions (FGDs) and, in four villages in *kharif* 1996 and in four villages in *rabi* 1996–97, these FGDs were concluded with a formal matrix ranking exercise (Table 2). In these, farmers were asked to make decisions on the merits of seed priming relative to their normal practice in a number of researcher-defined,

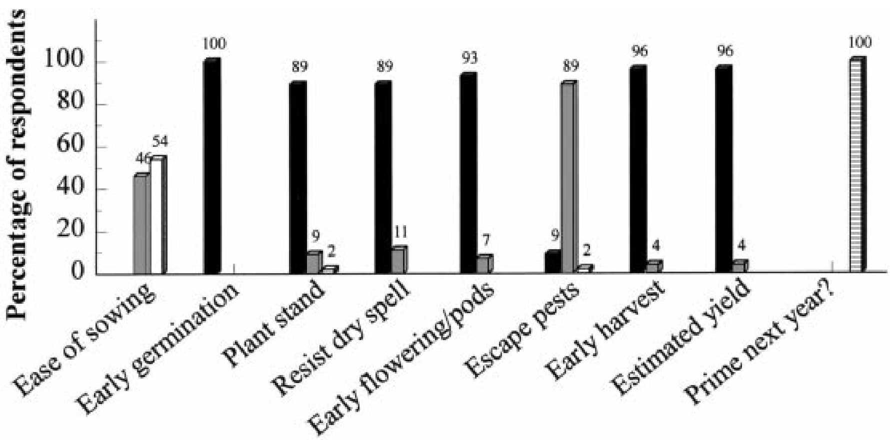

Fig. 4. Summary of farmers' perceptions of seed priming in maize and chickpea during *rabi* 1996–97. Forty-six farmers in four villages in Gujarat, Rajasthan and Madhya Pradesh (Table 1) were asked about crop characteristics shown on the horizontal axis. Shading of bars represents improvement (■), no change (■), or deterioration (□) in the characteristic or yes to the question (⊟).

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Table 2. Farmers' comments recorded during focus group discussions. All comments concern primed crops relative to non-primed and refer to all crops tested unless specified.

Village	Date	Crop and comments
Khumpura (5 farmers)	7–14.12.96 (post-sowing)	*rabi* chickpea (ICCV-88202) ● faster emergence (2–3 d)
Samlaser (3 farmers)	7–14.12.96 (post-sowing)	*rabi* chickpea (ICCV-88202) ● faster emergence (2–3 d)
Kataranipalli (6 farmers)	7–14.12.96 (post-sowing)	*rabi* chickpea (ICCV-88202) ● faster emergence (2–3 d)
Mathurakhali (11 farmers, 8 male, 3 female)	16.10.96 (pre-harvest)	*kharif* maize cv. Shweta and rice cv. Kalinga III ● earlier emergence (2–3 d) ● better and more uniform crop establishment ● tolerated dry spells better ● fast growth compensated for sowing delays ● earliness led to stout and healthy seedlings ● bad year but priming could compensate ● earlier tasselling, cob setting and maturity ● faster growing crop escaped caterpillar attack
Mounala (16 farmers, 11 male, 4 female)	05.09.96 (pre-harvest)	*kharif* maize cv. Shweta and rice cv. Kalinga III ● earlier and more uniform emergence (2–3 d) ● re-sown and late-sown crops could 'catch up' ● more uniform sowing in ponded rice ● no need for post-sowing puddling in rice ● more vigorous early growth smothered weeds ● earlier flowering (typically 7–10 d) ● earlier sowing of *rabi* crops possible
Mounala (13 farmers, 11 male, 2 female)	25.01.97 (post-harvest)	*kharif* maize cv. Shweta and rice cv. Kalinga III ● earlier maturity (8–10 d) ● more timely sowing of *rabi* crops ● priming compensated for drought effects ● better emergence and stand (95% *vs*. 60%) ● 2 farmers used fertilizer – good yield ● most will prime seeds again ● further trials unnecessary – priming beneficial
Mounala (13 farmers, 11 male, 2 female)	25.1.97 (post-sowing)	*rabi* chickpea and maize ● faster emergence (2–3 d)
Kataranipalli (22 farmers, 16 male, 6 female)	4.3.97 (pre-harvest)	*rabi* chickpea and maize ● no problems mixing seed with diammonium phosphate if seed dried properly ● primed seed swelled, but not a problem ● faster emergence (2–3 d) ● better drought tolerance ● chickpea flowered 7 d earlier and produced more pods per plant ● pest avoidance in maize but not in chickpea ● more mature by 7–10 d and higher yields expected

(*Continued*)

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Table 2. *Continued.*

Village	Date	Crop and comments
Kataranipalli (12 farmers, 10 male, 2 female)	28.3.97 (post-harvest)	*rabi* chickpea and maize • confirmed pre-harvest perceptions • better yields reported (but not quantified) • no taste differences due to priming • will all prime seeds next year
Bar (14 farmers)	28.3.97 (post-harvest)	*rabi* chickpea and maize • priming caused problems in sowing with hollow bamboo *pora*, but not a problem if used with care • earlier emergence (3–4 d) • better and more uniform crop establishment (estimated 95–98% *vs*. 70–75%) • tolerated dry spells better due to deeper rooting • earlier flowering (8–10 d) with one report of 15 d • in chickpea, infestation by pests was the same but pods in primed crops were more mature with harder coats, so damage was less • crops matured 8–10 d earlier (one report of 15 d earlier) and farmers thought yields were higher (not quantified) • will all prime seeds next year

but mutually agreed, categories relating to agronomy, crop development and yield (see Fig. 3 and 4 for details of the categories used).

Two workshops were held, in Mounala in April 1997 and in Dahod in May 1997. The first was attended by 91 farmers from 11 villages while 155 farmers from 21 project villages took part in the latter, together with representatives of other local NGOs and scientists from Gujarat Agricultural University. These workshops were used to facilitate wider discussion of the issues involved in seed priming, to interact with more farmers than would be possible through individual village FGDs and to plan further on-farm trials.

At the end of the 1996–97 *rabi* season the CO in Bar (Gujarat) village was able to estimate the chickpea yields produced by ten farmers with and without seed priming. Similarly, the CO in Bihar (Madhya Pradesh) village measured the areas of the experimental plots of eight farmers and was able to quantify yields of chickpea.

RESULTS

In vitro *screening*

Germination was hastened significantly by seed priming in maize at 30 °C and 20 °C (approximating to soil temperatures in the *kharif* and *rabi* seasons respectively). Similarly, germination was significantly faster following priming in rice at

30 °C and chickpea at 20 °C (Fig. 1). Final germination percentage was not significantly affected by priming in any of the crops tested. The effect of delayed sowing following priming was more variable, however. In particular, chickpea varieties ICCV 2 and, to a lesser extent, ICCV 10 and L 5551 continued to germinate following priming for 8 h resulting in very fast mean germination rates for chickpea. For practical purposes this raised the possibility that some pre-sowing sprouting of seeds might occur if sowing of these varieties was delayed for any reason after priming. Sprouted seeds are more susceptible to physical damage during the sowing operation and their use should be avoided if possible.

On-station crop establishment trials

Observations of emergence of maize and chickpea following sowing using farmers' methods confirmed that faster germination due to seed priming led to significantly earlier seedling emergence (Fig. 2). On the basis of these and other results, some of which are shown in Fig. 1 and some other preliminary germination experiments, farmers were advised to soak maize and rice for 24 h before sowing but to soak chickpea for no more than 8 h.

On-farm trials

Ten focus group discussions were held in six villages between September 1996 and March 1997 to canvass opinions on the performance of seed priming for *kharif* and *rabi* crops. Table 2 summarizes farmers comments made at these meetings. There was a general view that priming maize and rice for 24 h was too risky (despite our evidence to the contrary) and it transpired that all farmers conducting trials had only soaked seed of these crops overnight, for approximately 10–12 h. All farmers agreed that priming led to faster emergence of all three crops and the consensus view was that the advantage was 2–3 d. This difference due to priming was considerably greater than that observed in either of the on-station trials reported above. This faster emergence was held to lead to better and more uniform crop establishment and this positive effect on stand establishment was enough in itself to justify the continued use of seed priming. However, the farmers also reported a wide range of other effects on their crops (Table 2). Primed crops grew more vigorously, tolerated dry spells better, flowered earlier (typically 7–10 d), escaped pest build-ups and matured earlier (8–10 d). Pre-harvest estimates of yield increases in primed crops were confirmed by post-harvest FGDs. Minor difficulties were reported, the most common being that primed seed swelled slightly and could stick in the hollow *pora* through which seed was channelled into the planting furrow behind the plough. Once this was realized, farmers had taken more care and had reported no further problems.

The opinions of farmers concerning seed priming are quantified for maize and upland rice grown in *kharif* 1996 in relation to six important criteria (Fig. 3). Only ease of sowing was considered to be similar using dry and soaked seed; soaked seed was generally reported to have performed better than dry seed for the other five

Table 3. Estimated difference in maturity (d) and yield advantage (%) in chickpea as a result of seed priming. Trials were conducted in the villages of Bar (10 farmers) and Bihar (8 farmers).

	Bar			Bihar		
	Mean	s.d.	Range	Mean	s.d.	Range
Difference in maturity	7.6	1.58	5–10	6.7	2.49	3–10
Yield advantage	45.0	15.5	25–67	15.4	10.8	4–35

criteria. When asked if they would prime seeds next year, 95% of all farmers replied that they would.

Eight criteria were used to evaluate the relative merits of using primed or dry seed of maize and chickpea in *rabi* 1996–97 (Fig. 4), with similar results to those in Fig. 3. There was a general feeling that plots established with primed seed did not escape the eventual buildup of pests, although some farmers (9%) were adamant that pest damage was less because earlier podding (in chickpea) meant that pods were harder and less easily damaged by insects. Even those farmers who had reported minor problems with the technology, usually as a result of the slight swelling of primed seed, were keen to prime seeds the next year.

Differences in maturity due to seed priming were relatively similar in Bar and Bihar villages but the mean yield advantage in Bihar was smaller (Table 3). Yields in primed plots were larger than those where dry seed was used in all 18 cases.

The pros and cons of seed priming were discussed at length during the two workshops. Great enthusiasm for seed priming was expressed by farmers at both workshops, resulting in a general consensus in favour of further trials and resulting in agreement to test the technology in 30 villages during the 1997 *kharif* season.

DISCUSSION

'On-farm' seed priming was not unknown to the farmers in the project area. Some farmers reported trying seed-priming with chickpea but they had had mixed success because of poor information on priming times leading to damage due to oversoaking. Consequently, some farmers were initially reticent about trying seed priming again because of bad experiences in the past. Also, farmers had only used priming when optimal sowing conditions had passed, in order to 'catch up'. Farmers had not applied the technique under otherwise optimal sowing conditions. Similarly, priming rice seed was found to be a common practice in some villages in Gujarat but the concept had not been extended to other crops.

This lack of exposure to, and uptake of seed priming is surprising in the light of previous research over more than 25 years in India. In on-station experiments, pre-soaking seed of a number of crops has been shown to improve germination, establishment and, in some cases, to increase yields. Most work has been done on wheat (Dhillon and Panwar, 1971; Dayanand *et al.*, 1977; Misra and Dwivedi, 1980; Sen and Misra, 1984; Bhati and Rathore, 1986) although positive responses in cotton (Wannkhede, 1975; Rao *et al*., 1978), sunflower (Kathiresan and Gnanarethinam, 1985; Naphade *et al*., 1986), maize (Kulkarni and Eshanna, 1988) and other crops have been reported. As a consequence, seed priming has been adopted in many states as a recommended practice but does not appear to have been widely adopted by farmers, even in high potential areas where rice is followed by wheat and extension advice is theoretically available (D. Harris, unpublished data, Gujarat, India, 1988).

It is essential to differentiate clearly between the on-farm seed priming described in this paper and the seed priming as pursued in temperate agriculture and horticulture. The use of this latter technique has been reviewed by Parera and Cantliffe (1994). Essentially, it entails hydration of seeds under controlled conditions to minimize osmotic shock and damage to seed membranes. Methods include the use of solid matrix materials (Taylor *et al*., 1988), a variety of osmotically active compounds (Brocklehurst *et al*., 1987) and inorganic salts (Paul and Chaudhury, 1991). This controlled hydration induces a series of changes in seed enzyme systems, the benefits of which are maintained after seeds have been dried down to their original water content and stored in normal fashion. Subsequent germination is faster and more uniform and final germination is often increased (Parera and Cantliffe, 1994), all of which are very important under the cool, damp conditions prevalent when temperate, commercial crops are grown. In contrast, tropical crops are often sown in hot, drying conditions using unsophisticated sowing techniques. Under these conditions seeds are not limited by low temperatures but imbibition can be slow. On-farm seed priming simply begins hydration of the seed before it encounters the harsh soil environment. Any adverse effects of rapid hydration are more than offset by the benefits of fast emergence and vigorous seedling growth.

It was clear that, in planning the on-farm trials, risk to farmers' enterprises should be minimized. Any recommendations made to farmers had to be robust and compatible with their perception of time, that is, soaking times should not be so precise that farmers without timepieces could not measure them. In fact, farmers' reluctance to soak seed for longer than 'overnight' solved this problem, even though 'safe limits' for soaking maize and rice were much longer (Fig. 1) and provided wide effective safety margins. Although we attempted to estimate, with *in vitro* tests, the effects of unforeseen delays in sowing this was not a problem in practice. Nevertheless, this information is important because seed is precious and may be in short supply. Although the *in vitro* and on-station work served to establish the potential of the technology, it underestimated the performance of primed seed in farmers' fields. Preliminary work on seed priming with other crops, for example, pigeonpea, cowpea and cotton, has confirmed the utility of *in vitro* germination studies, particularly in identifying adverse reactions to priming conditions (D. Harris, unpublished data, Bangor, UK, 1997).

The original premise of this work was that on-farm seed priming would result in faster germination and emergence of seedlings. This was clearly shown to be true in the laboratory (germination only, for all crops) and in on-station trials for maize and chickpea. Evaluation of the technology in farmers' own trials confirmed this but also identified a much wider range of benefits beyond the optimization of plant stand (Table 2 and 3, Fig. 3 and 4). Of particular value to farmers was the effect of priming on earliness because shorter duration crops can often avoid drought. New varieties introduced in the project area have been adopted primarily because they mature earlier than local varieties (Joshi and Witcombe, 1996). In the current work, the priming-related earliness is *in addition* to the earliness of new varieties. Farmers noted that in the *kharif* season short duration crops allow more timely planting of subsequent *rabi* crops while early varieties in the *rabi* season allow farmers to migrate earlier to find off-season work. The possible consequences of this sort of flexibility for productivity in two- and three-season farming systems have been discussed by Witcombe and Harris (1997).

KRIBP (1997) reported that the project in three case study villages had a great impact on farmers' access to resources, for example, timely availability of fertilizer and affordable credit. It is noteworthy that several farmers reported using fertilizer for the first time on primed crops because they perceived the risk of failure of the well-established stands to be low. Conversely, minor mishaps occurred. A common practice in some Rajasthan villages is to mix urea or diammonium phosphate (DAP) with seed before sowing. Residual dampness of primed seeds caused damage to seeds in several instances. Close contact between the fertilizer and the seed is not recommended by project staff but thorough drying of the seed surface minimizes risk of damage if farmers continue to follow this practice.

Farmers reported savings in labour and benefits from fast, vigorous growth and thus reduced competition from weeds. In general, women have the responsibility for seed-related issues and for much of the weeding, and any technology that minimizes re-sowing or weed growth is particularly welcome to them. Faster growth and development also offers the possibility that grains and pods could form and become mature before pest numbers build up to damaging levels. This was the most contentious issue amongst the farmers with some reporting benefits while others dismissed the issue (Table 2 and Fig. 2). These differences of opinion may have been related to differences in pest pressure between fields that were not adequately represented during brief farm walks.

An unusual benefit was reported for seed priming in rice which is often broadcast on to the surface of water ponded behind bunds. If the wind is blowing, dry seeds tend to drift to one end of the plot before they sink, whereas soaked seed sinks promptly and a more uniform stand is obtained. According to farmers' perceptions, such factors add up to higher yields or at least a greater benefit relative to the cost of the seed. Seed soaking of rice is found in other systems. For instance, in the *terai* of Nepal farmers use the *lewa* system in which rice seed is soaked for 24 h before sowing (Hobbs *et al.*, 1996). If it is not possible to sow immediately, seed is dried in the shade for one day then in the sun for one further day, after which it can be stored for up to one month. Seed is re-moistened before sowing into nurseries unless the rains are late in which case it is direct seeded.

Acceptance of on-farm seed priming by farmers is very good (Fig. 3 and 4). Almost all of the farmers who tested seed priming in *kharif* 1996 in four villages said that they would prime seed next season, while all participating farmers in *rabi* trials indicated that they would prime seeds again. Observations in *kharif* 1997 suggest that they have done so and that farmers in the same villages who had not previously tested the technology were also priming their seed to good effect. In fact, in some villages, for example, Mounala, farmers were unwilling to participate in further trials, stating that they would not use dry seed again (Table 2). Studies are planned to quantify the level of uptake by farmers and persistence of the technology in the absence of project staff. Further, more detailed studies of the effects of seed priming on competition with weeds and the relationship between earliness and damage by pests are also warranted. Harris and Jones (1997) have demonstrated variation in response to priming amongst rice varieties and have postulated that priming upland rice seed could be beneficial in West African and other environments where weed growth is an important constraint to yield.

On-farm seed priming is a good example of a 'key technology' — a simple, low cost intervention, the impact of which is large enough to induce farmers to make other, perhaps more risky or more costly, changes in agronomic practices in order to make yet further gains. Usually these key technologies are new varieties but since the benefits from on-farm seed priming are in addition to those from new varieties, we have a powerful combination with which farmers can improve their farming system. Participatory on-farm trials using paired plots have allowed farmers to evaluate the potential benefits of a 'recommended' practice for themselves. Future work in the KRIBP area will be to expose many more farmers to this low-risk, low cost technology and to quantify more fully the impact on farmers' livelihoods.

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