FINAL TECHNICAL REPORT

R6395 The development and testing of seed priming to improve stand establishment, early growth and yield of crops in semi-arid Zimbabwe and India

EXECUTIVE SUMMARY
Based on earlier DFID-funded work in southern Africa, the concept of "on-farm" seed priming was developed and tested using a combination of *in vitro*, on-station and on-farm participatory trials. Interaction between researchers and farmers was a critical factor in the success of the project. Work was initiated in Zimbabwe and India, in marginal areas where seed soaking was a known practice but was not pursued except on a conditional basis, e.g. when was sowing was late or otherwise forced to take place under sub-optimal conditions..

Initially, the objective was to improve crop establishment under marginal conditions, on the grounds that optimal, uniform stands would be able to utilise light, water and nutrients most effectively. This objective was achieved early in the project but it became clear that rapid, vigorous establishment conferred benefits in addition to good stands. From 1995-1999, farmer-managed participatory (FAMPAR) trials in India with maize and upland rice (*kharif* season) and maize, chickpea and wheat (*rabi* season) were conducted. These showed that primed crops emerged earlier, flowered sooner, required fewer cultivations and less weeding, produced grain and pods faster and became mature earlier than the same crop sown at the same time using dry seeds. Farmers reported better drought tolerance and higher yields using primed seed.

Secondary, system-level effects were also reported: reduced labour demand for weeding; greater incentive to apply fertiliser to good stands; earlier harvest of *kharif* crops allowed *rabi* crops to be sown sooner, thus avoiding the yield penalties of late sowing; earlier harvest of *rabi* crops allowed earlier migration in search of paid work. Farmers' choice of cropping sequence was increased, allowing two short duration *rabi* crops, e.g. chickpea/mung bean to take advantage of high seasonal prices. Priming characteristics of wheat were determined in response to farmers who wished to take advantage of extra water made available as a result of KRIBP(W) soil and water conservation activities.

The impact of on-farm seed priming has not been confined to marginal areas. FAMPAR trials with wheat by farmers in a high potential area in India over two years also improved establishment. Over 90% of the farmers reported a 1-2 day acceleration in emergence and average yields were increased by 5%.

Surveys in Musikavanhu communal area in Zimbabwe established a link between crop establishment and varietal diversity. On-station trials over four seasons in Zimbabwe confirmed that a major constraint to good establishment and seedling vigour in sorghum and maize is the weather following sowing. Rate of emergence was positively correlated with seedling vigour in both crops. Seed priming, by increasing the rate of emergence, improved seedling vigour. FAMPAR trials in Zimbabwe during the 1997/98 and 1998/99 seasons confirmed that priming was effective in maize and sorghum and was popular with farmers.

Feedback from farmers in both countries and *in vitro* work identified other areas in which seed priming could be useful and additional collaborative work was undertaken in a number of countries. A large body of research was completed in collaboration with ICRISAT on the effect of priming on the establishment of pearl millet, particularly in relation to performance in crusting soils, where priming was found to

be worthwhile. Physiologists at ICRISAT also investigated in detail the effect of priming chickpea and on-farm trials in the Barind area of Bangladesh, where land is usually left fallow after the rice harvest, showed that priming chickpea seed was very effective in improving crop establishment and raising yields by 47%.

Preliminary screening of upland rice cultivars from West Africa led to more detailed research (R7189, funded by the Crop Protection Programme) on the interaction between rice genotypes and priming in relation to competitivity with weeds, which are the principal constraint on upland rice production in W. Africa. Similar research on maize/weeds competition was initiated in Zimbabwe.

Establishment of wheat in saline soils was found to be accelerated by seed priming in *in vitro* experiments and collaboration began in 1998 on FAMPAR trials to test seed priming in salt-affected areas of Pakistan.

The sense of ownership engendered by FAMPAR trials and community/group evaluation has ensured that adaptation and uptake of on-farm seed priming technology has been swift.

BACKGROUND

Good crop stand establishment is considered to be essential for the efficient use of resources like water and light (Monteith and Elston, 1983). This is true in temperate regions or under irrigation or in the humid tropics where, within broad limits, yields are often proportional to plant population density. In the rainfed semi-arid tropics, however, the balance between water supply and demand is critical and more conservative population densities are often required (Jones, 1987). Nevertheless, uniform stand establishment is still a pre-requisite for cropping success because, under adverse conditions, crowding should be avoided in order to allow each plant maximum access to limited soil water. Good germination and emergence are the key to controlling stand establishment. Similarly, vigorous early growth is often associated with better yields (Okonwo and Vanderlip, 1985; Austin, 1989; Carter et al., 1992). In general, healthy plants with well-developed root systems can withstand adverse conditions better than plants whose development and growth have been interrupted at an early stage.

Observations of crops in farmers' fields in Botswana between 1987 and 1991 suggested that crop establishment is often poor (L&WMP, 1989;1990;1991) and Harris (1991) showed that a major reason for this is the poor access to timely draught by resource-poor farmers. Crops must be sown when "windows of opportunity" present themselves after a rainstorm. Depending on the waterholding characteristics of the soils and the weather following the storm, these planting "windows" can be as short as two days or as long as a week. Crops are often sown too late after suitable rainfall, when the soil has become too dry (and hot) to support good germination and emergence. Support for these observations is provided by the results of a survey of the opinions of 92 farmers in 8 villages in Botswana between 1985 and 1987 (DAR, 1988). Thirty-two percent of farmers cited poor plant establishment as a serious constraint to crop production, with more mentioning "drought' effects in general. A further review, of the results of 146 researcher-managed trials grown in Botswana since 1979, showed that 40% did not establish properly (Harris, 1992).

Harris (1992) demonstrated how important it is for germination and emergence to be completed quickly in a semi-arid environment. In 9 sowings, made under optimal conditions of soil moisture throughout the 1990-91 season, final emergence and seedling dry weight 25 days after sowing (DAS) varied widely with no discernible relation with date of sowing. The weather after each sowing was different, however, and establishment success varied with the degree of drought stress encountered during the post-sowing period, with 4 out of 9 sowings resulting in poor establishment. Both final emergence and seedling dry matter 25 DAS were highly correlated with the rate of emergence (r=0.96 and r=0.93, respectively).

Seeds which germinate quickly produce viable seedlings with functional root systems which are not dependent on the rapidly-declining moisture in the soil surface layers. Similarly, fast emergence reduces the risk of seedlings being affected by soil capping or crusting, or soil-borne pests and diseases (Harris et al., 1987). There are 3 ways to improve the rate of germination and emergence in rainfed agriculture. Genotypes can be selected for these characteristics although the range of genetic variation for these traits in sorghum is unlikely to be large (Harris et al., 1987). In any case the development of fast-emerging genotypes with other desirable characteristics would be a long, complicated and expensive process. An alternative approach is to try to reduce the rate at which the soil surface dries out by using mulches. However, there are numerous practical problems to be overcome in using mulches in semi-arid areas, not the least of which is the large amount of material eg. stover required relative to the amount produced. Moreover, a better economic return often ensues from feeding stover to livestock (Carter et al., 1992).

A third approach to speeding up germination is to enhance the genetic potential of the seed by treating it in some way before sowing. Various seed treatments are well established, particularly in the horticultural industry and some techniques are quite complicated (Heydecker and Coolbear, 1977). However, the simplest technique, that of soaking seed in water for a short period of time prior to sowing seems not to have been tested systematically for small-grained cereals, although the practice is often used with maize (eg. in Malawi and Zimbabwe, although usually only when farmers have delayed sowing and are trying to "catch up").

In a series of controlled environment experiments Harris (1992) showed that the time taken for sorghum seeds to germinate at 30°C decreased as the soaking time increased from 0 to 10-12 hours, a treatment in which a 50% saving in time could be achieved. Germination of seeds soaked for 16 hours or more was found to continue even after soaking ceased and seed was surface-dried, suggesting that they would be susceptible to damage in the event of any delays in sowing. Emergence from soil at 30°C was significantly hastened by 23% when seeds were pre-soaked for 6 hours or longer. In four sowings in the field, soaking sorghum seed for twelve hours before sowing resulted in over 80% better emergence and plants 25 days after sowing were nearly 60% larger with more highly developed root systems (Harris *et al*., 1992).

Crop establishment is often poor in other areas of the semi-arid tropics. Olver (1988) and Chiduza et al. (1995) confirmed erratic crop establishment in Zimbabwe as a major constraint on yield. Similarly, PRAs in the area of western India served by the DFID/KRIBHCO Western India Rainfed Farming Project highlighted unreliable crop establishment as a major problem (CDS, 1990). This project was designed to build upon the preliminary work done in Botswana , and to refine and test seed priming in crops of interest to resource-poor farmers in India and Zimbabwe.

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PROJECT PURPOSE

The original project purpose was *Expanded knowledge of plant physiology incorporated into improved agronomic practices and promoted* (PSP Output 2.1).

More specifically, the project was to provide crop- and cultivar-specific parameters for seed-soaking (safe limits etc.) of sorghum, pearl millet, maize, upland rice, cotton and other relevant crops and to test the practicability of the technique in on-station trials and in farmers' fields in Zimbabwe and India. Close links with extension workers and farmers in the project areas would lead to the early development of technology transfer packages. More detailed measurements would provide data for modelling the processes involved and allow the impact of the technology in other semi-arid areas to be assessed.

RESEARCH ACTIVITIES

A full list of research activities is in Annex 1. Each activity is classified as either *in vitro* (incubator, growth cabinet or glasshouse studies), on station or on farm.

Materials and Methods

In vitro experiments were generally of two types:

1. Germination experiments were all conducted in incubators at the temperature indicated in Annex 1. Seeds were soaked for various times, surface-dried and either "sown" immediately on moist filter paper or kept dry for various periods of time to simulate a delay before "sowing". Germinated seeds were counted every four or six hours and removed. Time for 50% of the seeds to germinate was calculated by linear interpolation between counts taken before and after 50% had germinated. All experiments were randomised complete block designs with at least four replicates.

2. Emergence experiments in growth cabinets or heated glasshouses were performed in identical fashion, but emergence above the soil surface was counted rather than germination. Additional measurements, such as plant height, number of leaves and root axes and fresh and dry weight were sometimes taken 25 days after sowing (DAS).

On station

All experiments were randomised complete block designs or derivatives thereof.

On farm

On-farm activities took two forms:

1. Paired plot trials implemented by individual farmers and evaluated jointly by groups of farmers and researchers using a range of participatory exercises, such as farm walks, focus group discussions, matrix ranking and household level questionnaires.

2. Questionnaire-based surveys to quantify farmers' practices and attitudes, and to measure rates of adoption following exposure to seed priming.

OUTPUTS

Data collection continued right up to the end date of the project and analysis is not yet complete. Shown below are the main results of the study, together with as much synthesis as has been possible so far.

It is difficult in the light of the interactive nature of the project to report results in a definitive order, but we will begin with the farmers' results and introduce backup data (safe limits for soaking etc.) in subsequent sections. On-farm work followed a simple model, that of identification of demand, discussion of a possible solution with farmers, provisions of recommendations on safe limits, implementation of paired plot trials, group evaluation, feedback, modification and re-testing. Crops investigated reflected farmers' priorities.

On-farm trials - KRIBP(W), India

The semi-arid area of western India served by the DFID/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 22^o 30' and 23^o 48' N and between 73^o and 74^o 45' E. Rainfall varies both spatially and temporally from over 1300 mm per year to less than 800 mm per year. Droughts and years with exceptionally high rainfall are common in the area and farmers report a crop failure 3 years in 10 and a serious shortfall in 4 to 5 years in 10. Ninety percent of rain 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 livelihoods are based on rainfed agriculture, with most households being owner-cultivators. The most important *kharif* crop is maize (*Zea mays* L.), 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 e.g. fertilisers is poor and fertiliser 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 and this was confirmed by later, more detailed Participatory Rural Appraisals (PRA). Between 1995 and 1998, paired-plot FAMPAR trials were implemented in *rabi* seasons for chickpea, maize and wheat and in *kharif* seasons for upland rice and maize (see Table 1 and Annex 1, OF1-OF11 for details).

Table 1. Number of on-farm farmer-participatory trials of seed priming implemented between *rabi* 1995/96 and *kharif* 1998.

Crop	Number of trials
Maize - total, of which:	475
(*kharif*)	(431)
(*rabi*)	(44)
Upland rice (*kharif* only)	351
Chickpea (*rabi* only)	417
Wheat (*rabi* only) - total, of which:	172
(marginal areas)	(47)
(high potential area)	(125)

According to farmers, direct benefits in maize, rice and chickpea 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 (Figures ** and ** and Table **). 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; increased willingness to use fertilisers because of reduced risk of crop failure (Table **). In matrix ranking exercises in four villages in *kharif* 1996, 95% of farmers indicated that, even after only one exposure to the technology, they would prime seed the following season. Similar exercises in four villages in *rabi* 1996-97 revealed that 100% of collaborating farmers intended to continue seed priming.

Farmers also reported a range of indirect benefits due to priming (Table ***).

Table 2. Indirect "system" effects of seed priming.

- Less seed required per unit area, e.g. 19 kg ha^{-1} maize rather than 25 kg ha^{-1}.
- Can sow *rabi* crops earlier
- Early harvest of *rabi* crops allows earlier migration to obtain off-season work - more cash.
- Maize or wheat can be grown in *rabi* instead of chickpea
- Increased willingness to risk the purchase and use of fertiliser
- Fewer irrigations required for *rabi* crops, with consequent savings in water, labour and other costs (minimum Rs 250 per irrigation).
- Some farmers are able to take a third crop, usually mung bean or a second chickpea crop, in the time (and water) saved by priming the two previous crops
- Lower 'costs' of production and reduced risk

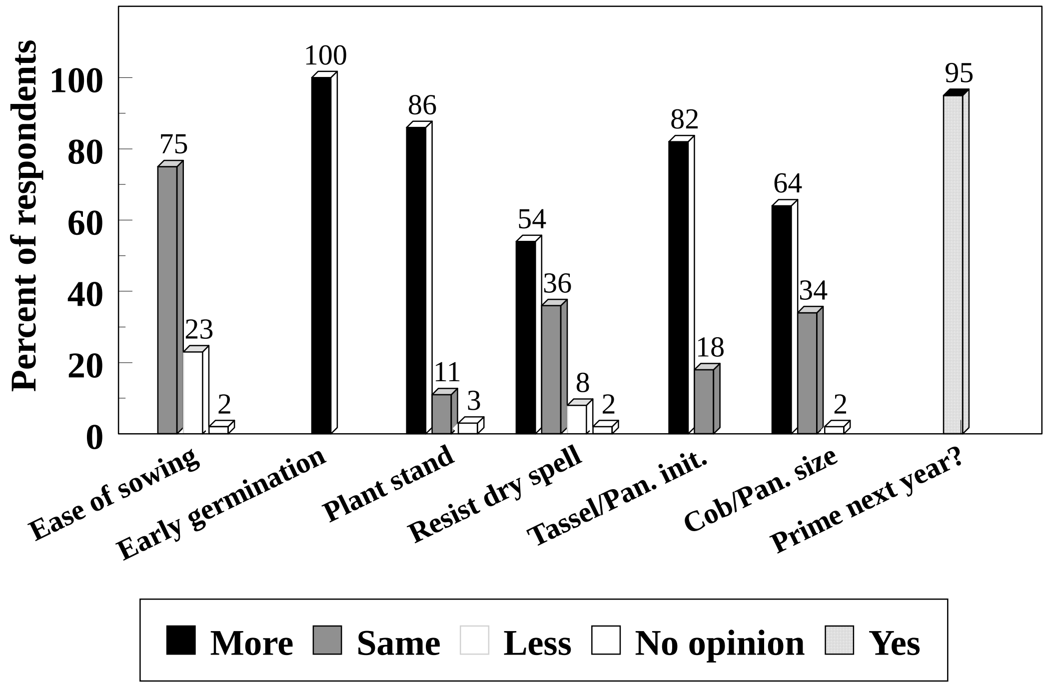

Figure 1. Summary of farmers' perceptions of seed priming in maize and upland rice during *kharif* 1996. Fifty-six farmers in four villages in Gujarat, Rajasthan and Madhya Pradesh.

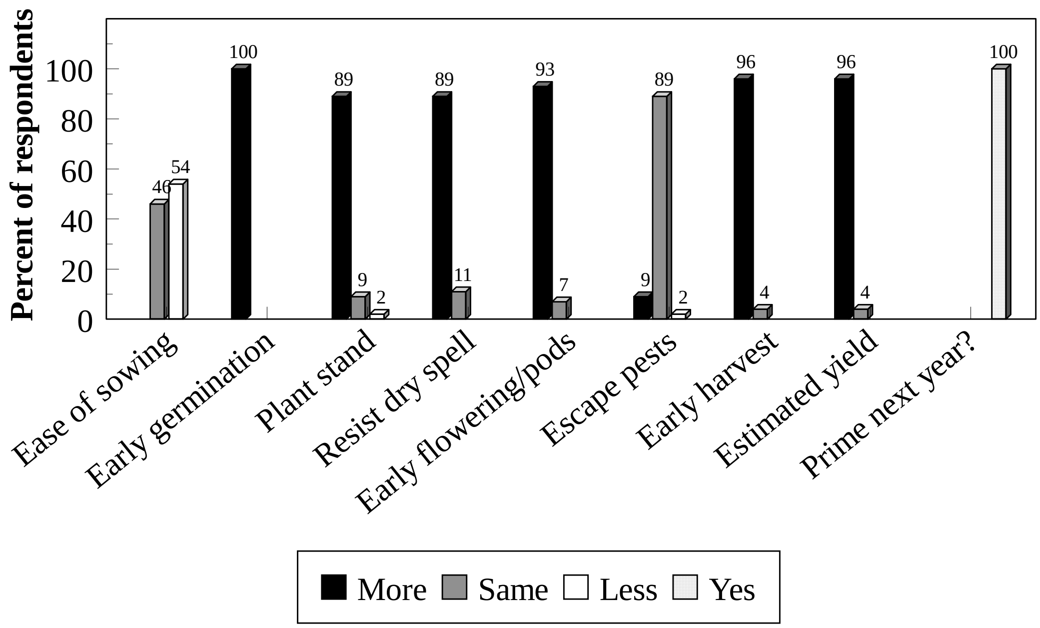

Figure 2. Summary of farmers' perceptions of seed priming in maize and chickpea during *rabi* 1996/97. Forty-six farmers in four villages in Gujarat, Rajasthan and Madhya Pradesh.

Table 3. 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	Comments
Khumpura[1]	7-14.12.96 (post-sowing)	*rabi chickpea (ICCV-88202)* • faster emergence (2-3 days)
Samlaser[2]	7-14.12.96 (post-sowing)	*rabi chickpea (ICCV 88202)* • faster emergence (2-3 days)
Kataranipalli[3]	7-14.12.96 (post-sowing)	*rabi chickpea (ICCV-88202)* • faster emergence (2-3 days)
Mathurakhali[4]	16.10.96 (pre-harvest)	*kharif maize (Shweta), rice (Kalinga III)* • earlier emergence (2-3 days) • better & more uniform crop establishment • tolerates dry spells better • fast growth compensates for sowing delays • earliness led to stout and healthy seedlings • bad year but priming could compensate • earlier tasseling, cob setting and maturity • faster growing crop escapes caterpillar attack
Mounala[5]	05.09.96 (pre-harvest)	*kharif maize (Shweta), rice (Kalinga III)* • earlier & more uniform emergence (2-3 days) • re-sown and late-sown crops can 'catch up' • more uniform sowing in ponded rice • no need for post-sowing puddling in rice • more vigorous early growth smothers weeds • earlier flowering (typically 7-10 days) • earlier sowing of *rabi* crops possible
Mounala[6]	25.01.97 (post-harvest)	*kharif maize (Shweta), rice (Kalinga III)* • earlier maturity (8-10 days) • more timely sowing of *rabi* crops • priming compensated for drought effects • better emergence and stand (95% vs 60%) • 2 farmers used fertiliser - good yield • most will prime seeds again • further trials unnecessary - priming beneficial

Table 3 continued

Village	Date	Comments

[1] 5 farmers
[2] 3 farmers
[3] 6 farmers
[4] 11 farmers - 8 male, 3 female.
[5] 16 farmers - 11 male, 4 female.
[6] 13 farmers - 11 male, 2 female.

Mounala[7]	25.1.97 post-sowing	*rabi chickpea and maize* • faster emergence (2-3 days)
Kataranipalli[8]	4.3.97 pre-harvest	*rabi chickpea and maize* • no problems mixing seed with DAP if seed dried properly • primed seed swells. Not a problem. • faster emergence (2-3 days) • better drought tolerance • chickpea flowered 7 days earlier and produced more pods per plant • pest avoidance in maize but not in chickpea • more mature by 7-10 days and higher yields expected
Kataranipalli[9]	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[10]	28.3.97 post-harvest	*rabi chickpea and maize* • priming caused problems in sowing with hollow bamboo *pora*. Not a problem if used with care. • earlier emergence (3-4 days) • better & more uniform crop establishment (estimated 95-98% vs. 70-75%) • tolerates dry spells better due to deeper rooting • earlier flowering (8-10 days) with one report of 15 days • in chickpea, infestation by pests is the same but pods in primed crops are more mature with harder coats, so damage is less. • crops matured 8-10 days earlier (with one report of 15 days) and farmers thought yields were higher (not quantified). • will all prime seeds next year

[7] 13 farmers - 11 male, 2 female
[8] 22 farmers - 16 male, 6 female
[9] 12 farmers - 10 male, 2 female
[10] 14 farmers - all male

Researcher-managed measurement of yields in chickpea (Table ***) and maize (Table ***) showed marked priming-related benefits.

Table 4. Estimated chickpea yield differences due to seed priming in trials conducted in Bar (10 farmers) and Bihar (8 farmers) villages.

	Bar			Bihar		
	mean	SD	range	mean	SD	range
Difference in maturity, d	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

Table 5. Yield of four cultivars of maize grown in Bar village, *kharif* 1997, in response to on-farm seed priming. Values are tonnes cobs ha^{-1}.

Cultivar	No. of trials	t ha^{-1} not primed	t ha^{-1} primed	SE of difference	Significance of priming
Desi (local)	13	3.49	3.69	0.065	**
Shweta	16	3.69	4.01	0.034	***

DISCUSSION / SUMMARY

On-farm trials - KRIBP(E), India

The DFID/KRIBHCO EIRFP also focuses on tribal farmers and operates in villages in the Eastern Plateau of India comprising southern Bihar, northern Orissa and the western fringe of West Bengal. The project area has a high proportion of sloping upland soils that are prone to runoff and erosion, of poor fertility, shallow and acidic with low water holding capacity. Rainfall averages 1200-1400 mm $year^{-1}$ but is erratically distributed within a short growing season (100-110 days). In common with the WIRFP, project activities to improve soil and water conservation and access to irrigation have provided opportunities to grow wheat in the post-monsoon (*rabi*) season.
(OF 12, Annex 1)

INSERT data
development and yield data - wheat

Table 6. Yields of on-farm paired plot trials of wheat seed priming in EIRFP, India, during *rabi* 1998/99 from a, two village clusters in Bihar and b, two village clusters in West Bengal.

Village cluster	No. of trials	Mean yield of non-primed plots (kg ha^{-1})	Mean yield difference (primed minus unprimed), kg ha^{-1}	Mean yield increase due to seed priming, %	Proportion of trials in which seed priming yield > non-primed yield (%)
a. Bihar					
Mehru (3 cvs)	9	1372	172	12.7	100
Nehalu (4 cvs)	12	1087	137	12.8	100
b. West Bengal					
Medni	8	1480	275	18.6	100
Pasro	12	1054	87	8.3	100

incomplete data for chickpea

trials in progress

On-farm trials - Lunawada sub-district (taluka)*, Gujarat, India.*

This *taluka* has 54,000 ha of arable land, half of which is irrigated and highly productive. Transplanted rice in the monsoon season (*kharif*) is usually followed by wheat, or sometimes chickpea, in the *rabi* season. A Participatory Crop Improvement project for these crops is working in nine villages.
(OF13-OF14; survey OF15)

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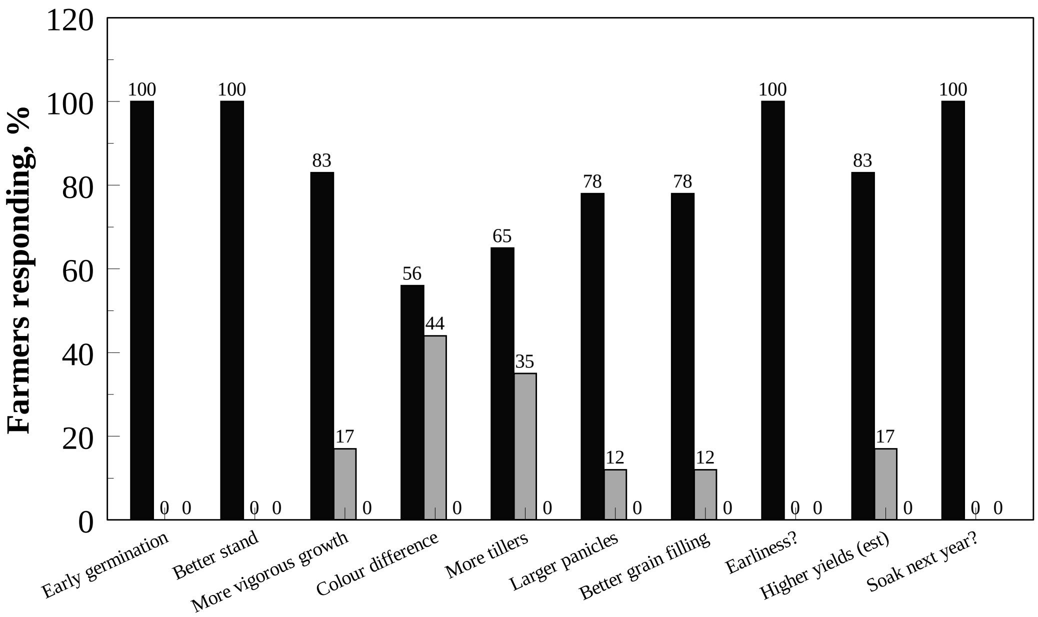

Fig 3

Yield data, two seasons, different farmers

Table 7. Yields of on-farm paired plot trials of wheat (15 varieties) seed priming in Lunawada *taluka*, Gujarat, India, from a, four villages during *rabi* 1997/98 and b, six villages (different farmers) during *rabi* 1998/99.

Village	No. of trials	Mean yield of non-primed plots (kg ha^{-1})	Mean yield difference (primed minus unprimed), kg ha^{-1}	Mean yield increase due to seed priming, %	Proportion of trials in which seed priming yield > non-primed yield (%)
a. 1997/98					
Dalvai Savli	33	4323	210	4.9	85
Chapatiya	33	4260	252	5.9	88
Kothamba	26	4253	278	6.3	88
Vardhary	16	4354	143	3.3	81
Mean	108	4298	221	5.1	86
b. 1998/99					
Dalvai Savli	17	4051	156	3.93	70
Chapatiya	20	4005	252	6.27	85
Kothamba	24	4440	258	6.12	83
Vardhary	8	3935	109	2.88	75
Thana Savli	12	4253	98	2.59	75
Ladwel	16	4519	249	5.89	81

Mean (97 trials)	97	4200	187	4.61	78

Persistence questionnaire

Table 8. Persistence with seed priming in wheat. Farmers who tested seed priming in Lunawada *taluka* in *rabi* 1997/98 were surveyed during *rabi* 1998/99.

	Dalvai Savli	Kothamba	Chapatiya	Vardhary	All villages
a. Did you prime your own seed this year?					
Total no. of farmers	19	18	18	8	63
No. of farmers priming wheat seed	14	9	14	4	41
No. of farmers NOT priming wheat seed	5	9	4	4	22
b. If you did not prime seed, give reasons					
Did not grow wheat	0	2	0	2	4
Do not like seed priming	0	*3	0	0	3
Rely on hired tractor for sowing	2	1	3	0	6
Could not prime seed for large areas	2	0	1	0	3
Growing seed on contract	0	3	0	2	5
No comment	1	0	0	0	1

*includes one farmer who decided not to prime seeds because his field was flooded at time of sowing.

Table 9. Amounts of wheat seed primed per farmer as averages over all farmers priming seed. Figures in parentheses are ranges, i.e. minimum and maximum values quoted.

	Dalvai Savlai	Kothamba	Chapatiya	Vardhary	All villages
Amount of seed primed, kg	38.9 (20-50)	33.3 (20-50)	34.3 (15-50)	37.5 (20-50)	36.0 (20-50)
Priming time, hours	8.2 (8-13)	11.2 (9-12)	10.4 (6-13)	10.7 (10-12)	10.1 (6-13)
Proportion of total land sown with primed wheat seed	25% (8-40%)	--	26% 10-40%)	19.5% (18-20%)	23.5% (8-40%)

On-farm trials - Chitwan and Nawalparasi Districts, Nepal.
Chitwan and Nawalparasi districts are in the southern part of Nepal, in the region known as the *Terai*, between 83°35′ to 85°55′ E and 27°21′ to 27°52′ N. With a sub-tropical climate and widespread access to irrigation, much of the area has great agricultural potential. In Chitwan, there are estimated to be 11,904 ha of irrigated land, of which 7,826 ha can be irrigated perennially and the rest irrigated only during the monsoon season. Nawalparasi district has 23,235 ha of irrigated land. More than 2000 households in 18 villages are working with the NGO Local Initiatives for Biodiversity, Research and Development (LI-BIRD) in a Participatory Crop Improvement project for transplanted rice (main season and spring-sown), spring maize, lentil and wheat.

Nine on-farm trials of the effects of priming wheat seeds were implemented during rabi 1998/99, together with 12 trials using lentil. Priming trials were also implemented with spring-sown maize (OF17-OF19).

Farmers reported that primed lentil seed emerged 2-3 days earlier than non-primed seed, but all trials (and adjacent lentil stands) were seriously affected by Fusarium wilt and fruit and flower drop. No harvest data were collected. We are still awaiting data from the maize trials.

Data from the wheat trials are shown in Table**. Priming increased yield in seven of the nine trials and overall average yield increase was 16.6%

Table 10. Yields of on-farm paired plot trials of wheat (cv. NL 297) seed priming in East Chitwan, Nepal, during *rabi* 1998/99.

Village	No. of trials	Mean yield of non-primed plots (kg ha^{-1})	Mean yield difference (primed minus unprimed), kg ha^{-1}	Mean yield increase due to seed priming, %	Proportion of trials in which seed priming yield > non-primed yield (%)
Chainpur	4	2172	380	18.8	100
Six Group	5	2354	388	14.8	60

On-farm trials - Musikavanhu communal area, S.E. Zimbabwe.
Zimbabwe is classified into five Natural Regions (NR I-V) and the agricultural potential of the country declines from NR I which represents the high altitude wet areas to NR V which receives low and erratic rainfall averaging 500 mm or less per annum. Natural Region V covers 27 % of the geographical area of Zimbabwe and 29 % of that area is settled by communal farmers. Communal farmers are smallholders with small farms (0.5 -5.0 ha) operated by one or a few householders. The head of the farm is usually the head

of the household. He/she is sometimes the owner of the farm but is in most cases a tenant because there are no title deeds. Most communal farmers in Zimbabwe operate under rainfed conditions.

Surveys (OF23-OF24) were conducted of rainfed crops growing in farmers' fields in the Musikavanhu Communal Area. The major crops were sorghum, maize and sunflower grown by 94, 36 and 15% of the farmers, respectively, and occupied 82, 12 and 7% of the land. There were important differences in cultivation methods between crops (Table **). Eleven sorghum cultivars were grown in the area during the 1995/96 season, although only four were grown by more than 10% of the farmers. The most popular maize variety was grown by 28% of farmers on 10% of the land, but had been distributed as part of a drought relief package. On-farm seed priming was fairly common in maize and transplanting, using thinnings, was almost universal in sorghum (Table **). Stand establishment was identified as a major crop production constraint in this area (Table **).

Table 11. Common land preparation and planting methods used by farmers in Musikavanhu Communal Area, Zimbabwe

	% Positive respondents		
Practices	Maize	Sorghum	Sunflower
1 Plough beforehand	26	23	24
2 Broadcast plough	15	55	28
3 Plough plant (rows)	72	30	56
4 Dig planting hole	37	42	36
5 Broadcast and weed	7	27	4
6 Thinning	64	100	92
7 Dry planting	0	100	0

More than 50% of the farmers gap-filled at least once and there was a good correlation (R^2 = 0.728) between frequency of re-sowing of sorghum and the number of varieties present in fields because seed of the initial, preferred variety was not available for later sowings (Fig **).

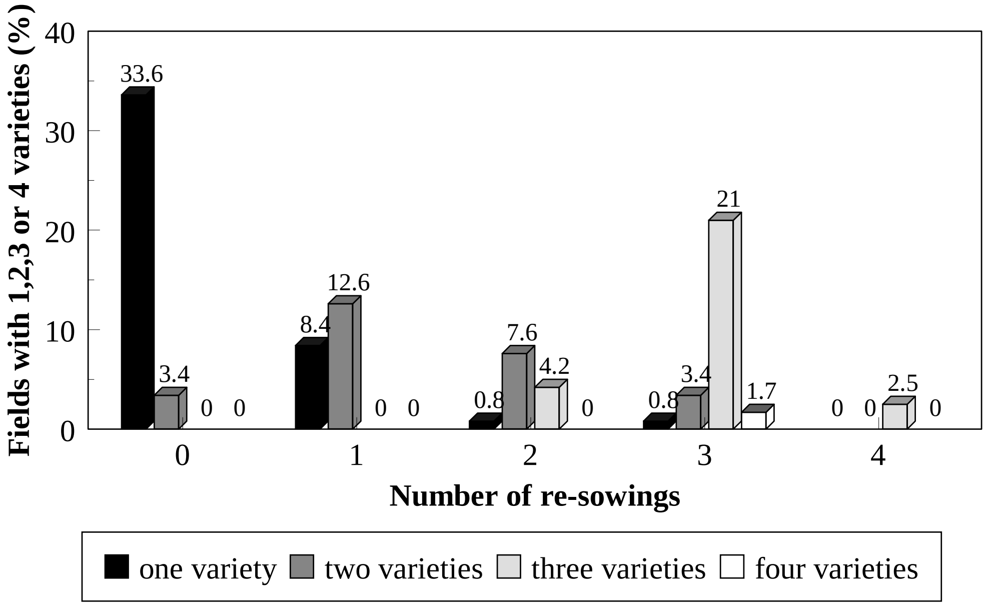

Figure 4. Relation between the number of sorghum varieties field^{-1} and the number of times the field was re-sown. Total sample was 119 fields with either Short Mutode, Chihumani or Muchayeni as the initial variety sown.

Table 11. Incidence of poor stand establishment, b) reasons for it, c) use of methods for improving it.

	% of Respondents answering yes		
Question	Maize	Sorghum	Sunflower
a). Poor stands?	93	95	87
b). Reasons?			
Low moisture	65	73	74
Bad seed	13	18	22
Pests (*Hodotermes* spp.)	50	42	17
c). Use improvements?			
Seed Soaking	37	2	4
Transplanting	15	97	13

On-farm, paired plot trials of seed priming in maize and sorghum were implemented and evaluated by farmers in four villages (Kondo, Maronga, Musapingura and Mwacheta) in Musikavanhu communal area (OF26-OF27) during two seasons, 1997/98 and 1998/99.

Preliminary trials planned in two villages (OF25) in 1996/97 were not implemented sucessfully.

In 1997/98, fifty-one farmers implemented trials with maize and forty farmers sowed sorghum trials. Planting rains were very late (January rather than November / December) hence few farmers planted at all. The rains ceased at the usual time; consequently even fewer crops reached maturity. Figure ** shows the results of Focus Group Discussions held after emergence and immediately before harvest.

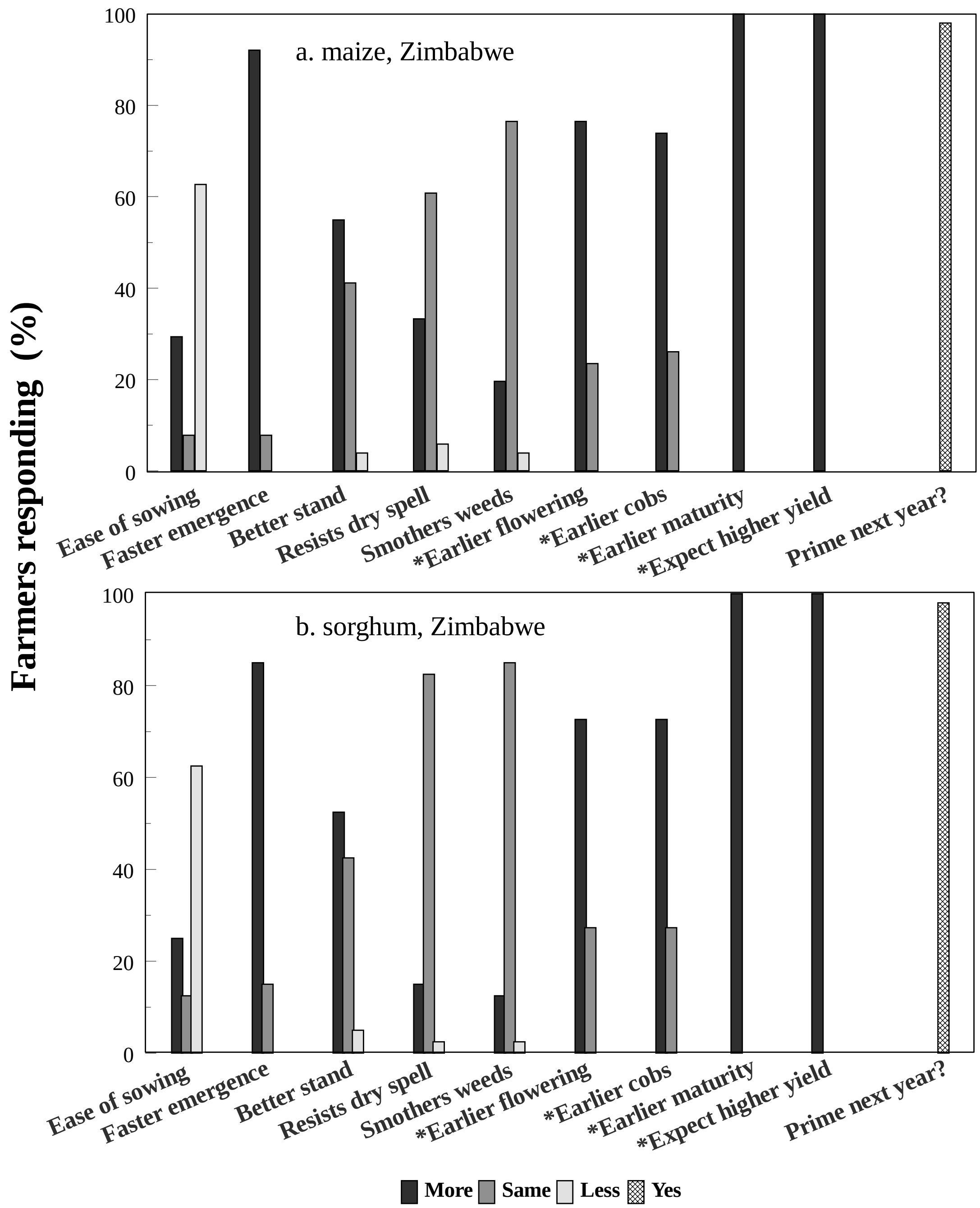

Figure 5. Summary of farmers' perceptions of seed priming in four villages in Musikavanhu communal area, Zimbabwe, during the 1997/98 season. Fifty-one farmers for maize (a) and forty farmers for sorghum (b). Note that only those farmers whose crops flowered and approached maturity expressed opinions on those criteria marked *.

Table 12. Number of farmers participating in on-farm trials in respective villages during 1998/99 season.

Village	Number of farmers		
	Males	Females	Total
Kondo	29	24	53
Maronga	14	21	35
Musapingura	21	15	36
Mwacheta	13	34	47
Total			171

Table 13. Results of matrix ranking exercise held with a total of 342 (171 maize and 171 sorghum) farmers in four villages of Musikavanhu C.A during 1998/99 season.

	RESPONSE					
Parameters	More	% of tot.	Same	% of tot.	Less	% of tot.
<u>Maize</u>						
(Post-sowing)						
Ease of sowing	35	20	7	4	129	75
Earliness in emergence	167	98	4	2	0	0
Germination percentage	84	49	70	41	17	10
Plant stand	66	39	77	45	28	16
Resist dry spell	11	6	160	94	0	0
(Post-harvest)						
Earliness in flowering	158	92	13	8	0	0
Earliness in cob bearing	157	92	13	8	1	1
Earliness in maturity	154	90	17	10	0	0
Estimated yield	146	85	17	10	8	5
Smothers weeds	17	10	99	59	2	1
OVERALL RANKING -Not weighted						
Would soak seed next year?			**Yes**		**No**	
			171	100	0	0
<u>Sorghum</u>						
(Post-sowing)						
Ease of sowing	31	18	4	2	136	80
Earliness in emergence	163	95	6	4	2	1
Germination percentage	93	54	56	33	22	13
Plant stand	90	53	55	32	26	15
Resist dry spell	52	30	119	70	0	0
(Post-harvest)						
Earliness in flowering	146	86	21	12	3	2
Earliness in head bearing	154	90	15	9	2	1
Earliness in maturity	149	87	18	11	4	2
Estimated yield	129	75	32	19	10	6

Smothers weeds	4	2	70	41	0	0

OVERALL RANKING -Not weighted

Would soak seed next year?	**Yes**		**No**	
	171	100	0	0

Table 14. Farmers' comments recorded during FGDs. The comments concern primed seeds relative to nonprimed seeds and refer to both crops unless specified.

Seed condition	Stand establishment	Growth & yield
- heavier seed, not blown by wind & easier to direct - better spacing & number of seed per station control; - seed increase in size (swell) & easier to handle; - seed stick to hand if not properly surface dried; - poor quality seed float and was discarded.	- earlier emergence (1-3 d); - better & uniform stands; - less re-sowing; - escaped pests (termites).	- faster growth; - less weeding due to faster growth; - smothers weed; - earlier flowering, cob/head bearing & maturity (1-3 days); - higher yield.

Farmers' yield estimates were obtained after farmers had harvested plots separately and recorded yields in local units - usually standard bucketsful of grain. These were later converted to kilograms using a derived conversion factor. Data are shown in Table ** as kg farmer^{-1} as plot sizes, although assumed to be equal or at least sown with the same number of seeds, were not measured.

Table 15. Average yields (kg farmer^{-1}) recorded by farmers during 1998/99 season in four villages of Musikavanhu C.A.

Village	crop	unprimed	Stdev	primed	stdev	n
Kondo	maize	92.97	62.82	118.75	59.12	32
	sorghum	73.76	58.04	103.10	67.94	29
Maronga	maize	90.53	55.53	116.84	68.70	19
	sorghum	43.71	24.31	56.94	41.81	17
Musapingura	maize	77.92	46.67	91.67	57.21	24
	sorghum	38.92	36.04	50.28	36.84	25
Mwacheta	maize	106.49	67.74	118.83	72.17	47
	sorghum	78.55	45.99	90.26	47.37	47

The data seem to confirm farmers' impressions of the trials (in Table **). Interestingly, 85% of farmers estimated that yields of primed maize would be higher than that of non-primed plots, whereas only 72% of farmers who measured yield reported an advantage due to priming. For sorghum, 75% of farmers were expecting larger yields from primed plots and 71% reported that this was the case. However, yield estimates from a sub-sample of 30 trials each for maize and sorghum were obtained by field assistants using three randomly-located 2m x 1m quadrats per plot which, in retrospect, was not a large enough sample. Comparison of mean yields showed no significant difference between primed and non-primed crops for either crop.

It is possible that

On-farm trials - Barind area of Bangladesh
In the High Barind Tract (HBT) of Bangladesh more than 160,000 hectares of land remain fallow during the winter season following the harvest of the rainfed rice crop. The total long term mean annual rainfall is 1285 mm (SD ± 311 mm) at Godagari in the south and 1402 mm (SD ± 295 mm) at Nithpur in the north. The maximum temperature can reach 45^0C in May and the minimum can fall to 6^0C in January. More than 90% of the rainfall occurs from June to September. Although residual moisture is present at depth in these silty loam soils, their surface begins to dry rapidly from October and by December no moisture is available for crop establishment.
(OF16)

There is scope for growing chickpea in this area if appropriate management techniques are followed. Chickpea *(Cicer arietinum L.)* is the third most important pulse crop in Bangladesh and has a high yield potential (4.5 t/ha) under favorable environmental conditions, although it is probably the most unstable among pulses due to its sensitivity to micro-environmental conditions. The acceptance of this crop by farmers has been increasing in the HBT but currently yields average only 765 kg ha^{-1}.

Timely (early) sowing is essential.
INSERT

INSERT data
establishment

development

yields

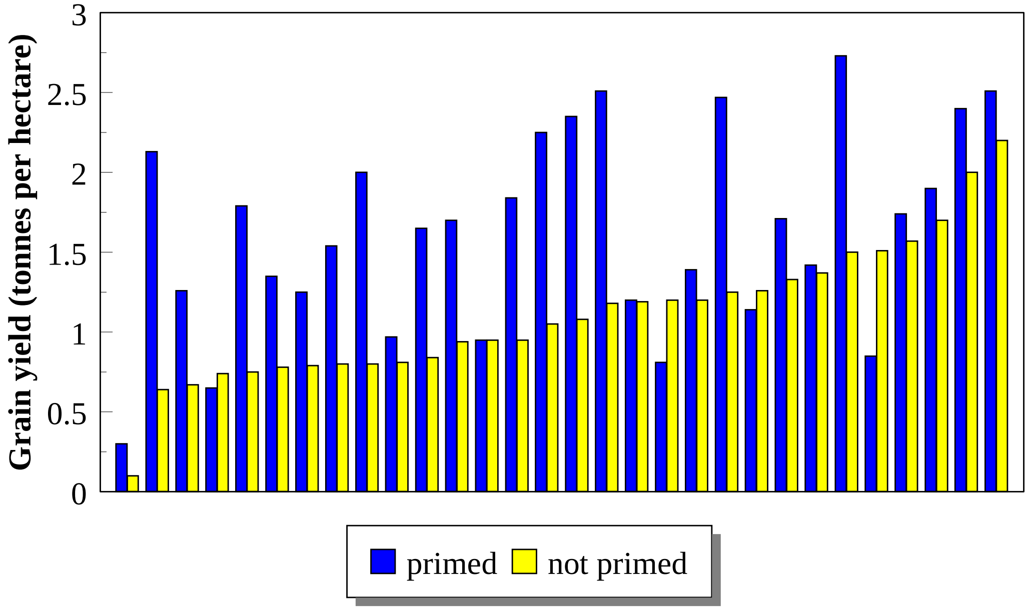

Fig 5

Table 13. Summary of data from Barind chickpea, *rabi* 1998/99

Variable	Primed	Non-primed	Increase %	Probability (Paired t-test, 2-tailed)	Significance
Emergence m^{-2}	36.7	30.2	21	1.51E-08	***
Early growth, cm	10.5	8.6	22	1.47E-12	***
Height at harvest, cm	36.4	33	10	1.17E-07	***
No. diseased plants m^{-2}	1.1	2.0	45	2.87E-05	***
Pod borer damage m^{-2}	3.6	4.1	13	0.366	ns
No. unfilled pods $plant^{-1}$	3.4	4.4	21	0.1287	ns
No. plants at harvest m^{-2}	30.6	25.0	22	2.56E-07	***

No. pods m^{-2}	1493	1074	39	4.09E-05	***
1000 grain wt., g	117.7	111.3	6	0.0734	ns
Grain yield, t ha^{-1}	1.63	1.11	47	1.96E-05	***
Residue yield, t ha^{-1}	2.0	1.53	31	2.94E-05	***

risk analysis

economics

On-farm trials - Pakistan
A body of research into seed priming was initiated in collaboration with Professor A. Rashid of the North West Frontier Province Agricultural University, Peshawar, Pakistan. Results of field trials of seed priming (OF20) are reported in '*Introduction, incorporation and assessment of genes for salt tolerance in India and Pakistani wheat cultivars'*, Final Technical Report of DFID PSP project R6438, together with data from on-station experiments (OS32) at that university. The potential, identified in IV21-IV23, of seed priming to contribute to improved production in saline areas was confirmed. Work on the performance of primed crops in saline areas continues at NWFPAU in PSP project R7438 '*Participatory promotion of 'on-farm' seed priming'*.

On-farm trials - Nigeria (OF22)
Preliminary work on seed priming in upland rice during 1998 was initiated in Nigeria by a team led by Dr O.A. Fademi and Mrs V.E.T. Ojehomon.

Surveys in two states (Benue and Nassarawa) showed that seed priming was known by farmers for rice and, to a certain extent in other crops, notably maize but highlighted differences in attitudes to seed priming in the two states. The general picture was very similar to that found elsewhere e.g. for maize in Zimbabwe and for maize, chickpea and rice in India - seed priming is only pursued as a "conditional" practice when conditions for sowing are considered poor and farmers are trying to "catch up". This is very encouraging, because farmers in those countries have adopted seed priming enthusiastically once they have appreciated the benefits from priming as a matter of course. If farmers in Nigeria follow a similar pattern, then prospects for rapid adoption there are good.

Some on-station work at Badeggi was linked to ongoing trials (using cv FARO 46) focused on pest management, notably nematodes and gall midge, and weed control. There were generally consistent trends of seed priming superiority with all variables, including gall midge infestation, sheath blight, general chlorosis and weed infestation, with consistent yield differences for seed priming related to numbers of productive tillers and plant height. However, only the latter difference was significant. Primed seeds produced seedlings that emerged significantly faster but final emergence was not affected.

A researcher-managed trial on-farm at Tufa used 4 cvs (ITA 321, IDSA 10, WAB 35-2-Fx and FARO 46), without replication. Seedlings of all 4 cvs emerged faster when primed but there were no differences in final stand density. Growth, as measured by plant height at 21 DAS, 42 DAS and at maturity, was consistently better in the primed treatments. Final yield was also consistently higher for primed treatments for all cvs, with an average yield advantage of 40%.

Research on the performance of primed rice crops continues in Nigeria and in four other West African rice-growing countries (Cameroon, the Gambia, Ghana and Sierra Leone) in PSP project R7438 ‘*Participatory promotion of ‘on-farm’ seed priming*’.

***In vitro* experiments.**

A total of 47 *in vitro* (germination and/or emergence) studies were implemented during the project. Sorghum (IV 1-8), maize (IV 9-13), pearl millet (IV 14-16), wheat (IV 17-23), rice (IV 24-27), cowpea (IV 28-31) and chickpea (IV 32-35) were investigated in detail while other crops (cotton, sunflower, horsegram, pigeonpea, mungbean, lentil, soybean, kidneybean, finger millet, mustard, niger and various forage species) were screened to determine if seed priming was effective and, if so, to provide safe limits for soaking (IV 38-47).

Of all crop and variety combinations investigated, only pigeonpea was found to be unsuited to seed priming using “overnight” - 8 to 10 hours - as the soaking time. Otherwise, all crops responded positively to seed priming. Fig ** and Table ** summarise the germination responses to priming of the major crops tested.

The germination rate of varieties at constant temperature varied widely within each crop (Table 2/ Figs 2-??). However, priming for eight to twelve hours (“overnight”) resulted in significant reductions in $t_{50\%}$ in most varieties of all crops, with no significant differences in final percent emergence (G). The average time saved varied from only four hours in pearl millet at 40^{o}C to more than 20 hours in wheat, chickpea, cowpea and maize (Fig. *). Time saved was more than just the soaking period in most cases except the very fast germinating seeds of pearl millet, finger millet and sorghum and the special case of rice (see later).

On average, slower-germinating crops responded better to seed priming. Mean time saved by priming was linearly related to $t_{50\%}$ over all crop combinations (Fig. 1). A similar inverse relation between intrinsic germination rate and response to priming also held over a range of cultivars for some crops, e.g. wheat, maize, pearl millet, and finger millet (Table 1). In a sample of 17 maize cultivars, $t_{50\%}$ ranged from 35 h to 65 h and priming for 12 h reduced that range to 23 h to 32 h. In wheat, priming for 12 h reduced $t_{50\%}$ from 45 - 90 h down to 23 - 53 h. Slow germination of seeds in 150 mM NaCl solution was accelerated the most by priming with distilled water. For pearl millet at 30^{o}C, priming reduced the range of $t_{50\%}$ from 16 - 21 h down to 10-12 h, whereas there was no significant relationship between time saved and $t_{50\%}$ at 40^{o}C (Table *). This small-seeded crop is intrinsically fast to germinate and it seems that, for the range of cultivars chosen, almost all differences in $t_{50\%}$ are due to differences in the time required for imbibition. There was a significant relation between time saved by priming and seed weight for pearl millet at 30^{o}C but not at 40^{o}C. Larger seeds have a lower ratio of surface area to volume than that of small seeds, so rates of influx of water are slower.

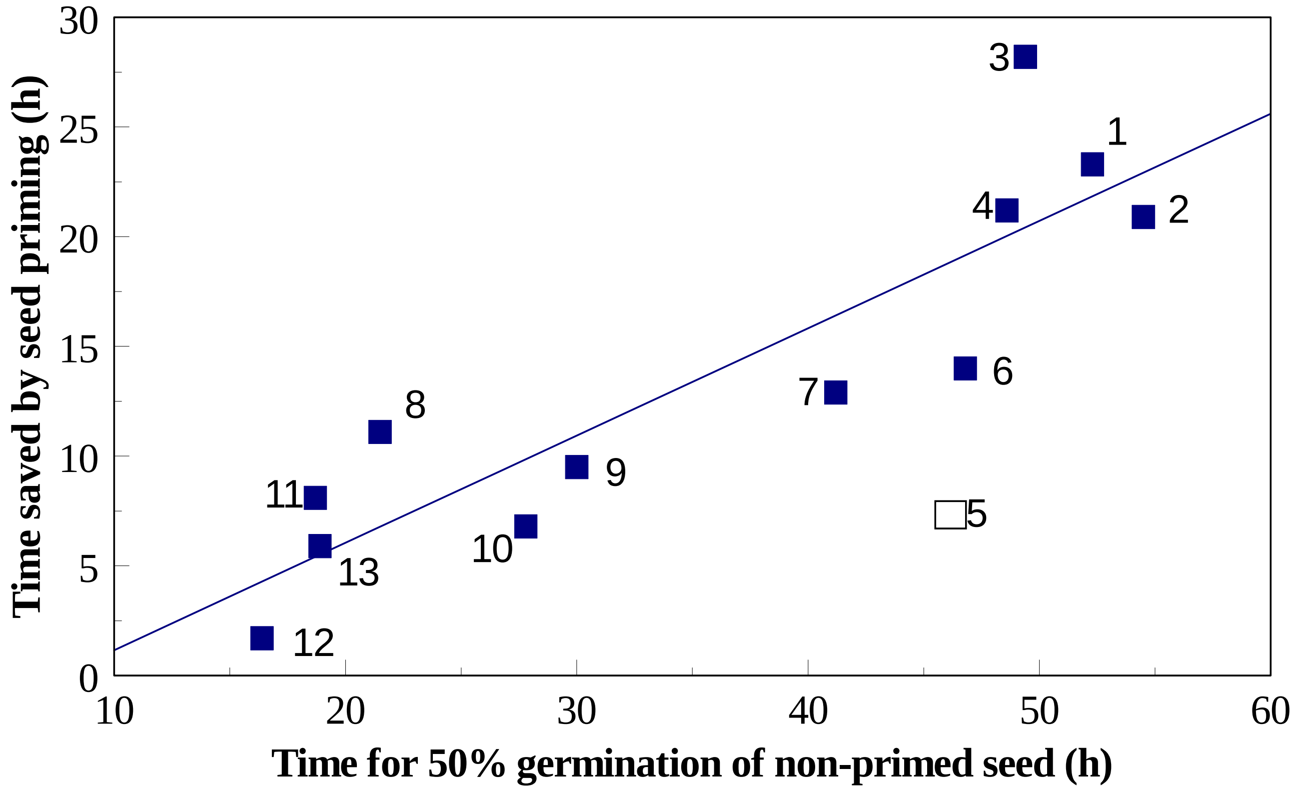

Fig. 6. Relation between time saved by priming and time for "normal" germination. Numbers refer to crop/treatment combinations listed in Table 14.

Table 14. Linear regression parameters for 13 crop x environment combinations of the relation between time saved by priming (y) and time for 50% germination of non-primed seeds (x).

No. in Fig. 1	Crop (priming time)	b	a	R^2	n	Sig.	Comments
1	Wheat @ 20°C (12 h)	0.3833	3.78	0.6133	17	0.01	Indian varieties. Includes slow germination in saline conditions.
2	Chickpea @ 20°C (8 h)	1.0734	-37.6	0.7166	4	ns	Indian varieties.
3	Cowpea @ 30°C (8 h)	0.5317	1.9	0.7239	6	0.05	Nigerian varieties.
4	Maize @ 30°C (12 h)	0.6760	-11.6	0.7321	17	0.01	Zimbabwe hybrid varieties. One variety did not respond and was not included.
5	Rice @ 30°C (12 h)	-0.0094	7.33	0.0013	10	ns	WARDA
6	Rice @ 30°C (24 h)	0.0883	9.86	0.0345	11	ns	WARDA
7	Mung bean @ 20°C (8 h)	0.8332	-21.4	0.9207	4	ns	Indian varieties.
8	Mung bean @ 30°C (8 h)	1.7081	-25.6	0.7237	5	0.10	Indian varieties
9	Mustard @ 20°C (8 h)				2		No regression - only two data points.
10	Sorghum @ 30°C (8 h)	0.0932	5.4	0.0179	12	ns	Indian varieties (ICRISAT)
11	Pearl millet @ 30°C (8 h)	0.7936	-6.8	0.7796	11	0.01	Indian varieties (ICRISAT)
12	Pearl millet @ 40°C (8 h)	0.2339	-2.13	0.2016	11	ns	Indian varieties (ICRISAT)
13	Finger millet @ 30°C (8 h)	0.6605	-6.49	0.7203	7	0.02	Indian varieties

Insert Fig 7 - sal;inity emergence

describe results.

On-station verification of effects

Ten experiments using maize and sorghum were implemented on the DR&SS Research Station at Save valley in Zimbabwe (OS 1-10). In India, three trials involving maize, chickpea and rice were sown on leased land in Dahod by WIRFP (OS 11-13); 10 experiments with pearl millet were conducted in collaboration with ICRISAT in Rajasthan at Fatehpur Shekavati and at Mandore (OS 14-23) and two, with sorghum, pearl millet and chickpea, at ICRISAT Asia Centre in Hyderabad (OS 24-25); two rice trials, with RAU Borwat, and two maize trials, with GAU Godhra, involved collaboration with State Agricultural Universities (OS 26-27 and OS 29-30); the Indian Agricultural Research Institute, New Delhi ran abortive trials with maize and rice (OS 31). Preliminary on-station trials with maize and wheat were implemented at North West Frontier Province Agricultural University in Peshawar, Pakistan (OS 32) and with rice in Nigeria (OS 28).

Reasons for on-station trials were various (see Annex 1). For new collaborators who had not seen seed priming tested before, on-station trials almost always seemed to be necessary before they would take the technology to farmers. Other trials were implemented to test further the *in vitro*-derived safe limits. Some on-station trials were designed to gather information on the possible mechanisms involved in the crop response to seed priming.

In upland rice trial OS 26, in collaboration with WIRFP and Dr Tripathi at RAU, Borwat, showed that priming affected not only crop establishment but all components of yield (Table **).

Table 15. Response of rainfed rice to seed priming. Trial conducted at RAU, Borwat, Rajasthan, *kharif* 1997. Values are means of 10 pre-release cultivars.

Variable	Dry seed	Primed (water)	Primed (2%NaCl)
Emergence, % (3 DAS)	12.6	72.0	63.5
Emergence, % (18 DAS)	60.7	90.8	72.7
Time to 50% flowering, DAS	74.7	71.0	72.1
Plant height, cm	94.1	108.0	91.9
Panicle length, cm	20.3	22.4	18.5
No. of panicles $plant^{-1}$	4.9	5.7	5.2
Grain yield, kg ha^{-1}	1.73	2.43	1.96
Yield increase, % of dry seed	**---**	**40**	**13**

An experiment to confirm these findings was conducted during kharif 1999, beyond the end date for this project. Data are not yet available.

The two series of trials, on pearl millet (OS 14-23) and on maize and sorghum (OS 1-10) were designed to look in more detail at the interaction between crop responses to priming and the physical environment. These experiments generated a huge amount of data, the analysis of which is still ongoing. Final results will be submitted when available as an addendum to this report.

Discussion and Conclusions

Forty-seven in vitro experiments were conducted to generate information on the priming characteristics of 23 crop and forage species. This information was supplemented by 30 on-station experiments in India and Zimbabwe, plus two further sets of trials in Nigeria and Pakistan. Twenty-six programmes of on-farm trials were implemented in India (15), Zimbabwe (5), Nepal (3), Pakistan (1), Bangladesh (1) and Nigeria (1).

The utility of ‘on-farm’ seed priming was confirmed, and the technology was found to be very popular with farmers who were able to test it for themselves. Seed priming leads to faster, more complete establishment of crops, a lower risk of crop failure and the need to re-plant, more vigorous growth, earlier flowering and maturity and higher yields. Yield increases between 10-30% are regularly reported by farmers and trials with chickpea in Bangladesh have shown a 47% advantage over non-primed seeds. Secondary effects on the farming system have been reported from India, e.g. a lower seed requirement, savings in water and time that allow a third crop to be grown, less weeding required etc. This latter effect has led to a CPP-funded project R7189 Cultivar competitiveness and interactions with on-farm seed priming for integrated weed management. This wide range of benefits has consistently persuaded collaborating farmers to adopt seed priming as a regular practice.

Contribution of Outputs to Project Goal.

On-farm seed priming has been shown to be a viable ‘key technology’ - low cost, low risk with immediate benefits that can persuade farmers to adopt further improvements. Lower risk of crop failure, higher yields from minimal investment and more cropping options have convinced farmers that seed priming is good insurance. Farmers who have adopted seed priming have stabilised and increased their returns from crop production. Seed priming has contributed substantially to the livelihoods of poor farmers who have adopted it. Adoption is very high amongst farmers who have tested it for themselves. Participatory research has been essential for the successful promotion of the technology.

The main output of the project has been delivered (Robust and farmer-acceptable technologies, based on seed priming, for improving crop establishment, growth and yield under rainfed conditions produced and promoted). Seed priming was so successful in a range of crops and farming systems that the two minor outputs (related to modelling) were de-emphasised. Issues relating to the detailed physiological mechanisms responsible for the effects of priming, and modelling of recommendation domains, are being explored in a further PSP-funded project.

Seed priming proved to be such a robust technology that results disseminated from the project led to widespread testing and evaluation by farmers in a number of additional countries, e.g. Bangladesh, Pakistan, Nepal, Nigeria, Malawi, Namibia. Such testing is to be supported in these and other countries by another PSP-funded project.

Follow-up indicated / planned:

Participatory promotion of on-farm seed priming will be pursued in a range of crops and countries, together with widespread dissemination of results via research networks, with support from PSP, who will also fund a project to investigate the detailed physiological mechanisms responsible for the effects of seed priming. The DFID Crop Protection Programme currently funds a project to evaluate the effects of seed priming on the ability of maize and upland rice to compete successfully with weeds. Seed priming will continue to be promoted in PSP-funded Participatory Crop Improvement projects in India (Gujarat and Punjab), Nepal and Bangladesh.

A proposal has been submitted to DFID India to ‘mainstream’ seed priming in all of DFID’s ongoing and pipeline rural development projects in that country. Collaboration will continue with the Kribhco WIRFP project to monitor uptake and impact and to produce and distribute a Hindi translation of some of the dissemination literature noted above. Attempts will be made to promote seed priming with development agencies worldwide.

Dissemination Outputs

Publications:

Musa, A.M., Johansen, C., Kumar, J. and Harris, D. (1999). Response of chickpea to seed priming in the High Barind Tract of Bangladesh. *International Chickpea and Pigeonpea Newsletter* 6: 20-22.

Harris, D., Khan, P.A., Gothkar,P., Joshi, A., Chivasa, W. and Nyamudeza, P. (1999). On-farm seed priming: using participatory methods to revive and refine a key technology. *Agricultural Systems* in press.

Chivasa, W., Chiduza, C., Harris, D., Mashingaidze. A.B. and Nyamudeza, P. (1999). Biodiversity on-farm in semi-arid agriculture: case study from Zimbabwe smallholder farming system. *Zimbabwe Science News* (submitted).

Chivasa, W., Harris, D., Chiduza, C., Mashingaidze, A.B. and Nyamudeza, P. (1999). Evaluation of on-farm sorghum (*Sorghum bicolor* L.[Moench]) and maize (*Zea mays* L.) seed priming in semi-arid agriculture. *Tanzanian Journal of Agricultural Science* (submitted).

Chivasa, W., Chiduza, C., Harris, D. and Mashingaidze, A. B. (1999). Crop stand establishment and seed priming: their importance and research needs in the semi-arid smallholder farming systems of Zimbabwe. *Transactions of the Zimbabwe Scientific Association* in press.

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- Save Valley
    - conditions after sowing
        - sorghum x 10
        - maize x 6
    - dry sowing
        - sorghum x 1
        - maize x 1
    - seed predation in soil
        - sorghum x 2
        - maize x 2
    - soil moisture at sowing
        - sorghum x 2
        - maize x 2
    - population density effects
- Dahod
    - emergence of maize (x 2), chickpea (x 2) and rice (?)
    - yield of chickpea (x 1)
- Pakistan
    - salinity
    - quality of priming water
    - effect of gypsum
- ICRISAT Hyderabad
    - sowing method in chickpea (x 1)
    - population density effects in chickpea (x 1)
    - interaction with soil moisture in chickpea (??)
    - emergence of sorghum (x 1) and pearl millet (x 1) through crusts
- ICRISAT Fatehpur
    - emergence and survival of pearl millet (x 2)
    - soil crusting (x 3)
- ICRISAT Jodhpur
    - emergence and survival of pearl millet (?)
    - soil crusting (?)
    - sowing method (seed/soil contact) (?)
- GAU Godhra
    - maize (*kharif*) emergence, development and yield x 2
- RAU Borwat
    - rainfed rice emergence, development and yield x 2
- IARI, New Delhi
    - emergence, development an yield of *kharif* maize x 1
    - emergence, development an yield of *kharif* rice x 1 1
    - laboratory investigations of seed priming rice and maize

On-station trials - Save Valley Experiment Station, Zimbabwe
INSERT
(OS1-OS10)

INSERT data
- sorghum
- maize
- conditions after sowing, seed predation, dry sowing

On-station trials - KRIBP(W), India
INSERT
(OS11-OS13)

INSERT data
- maize
- chickpea

On-station trials - ICRISAT, India
INSERT
(OS14-OS25)

INSERT data
- pearl millet (overall, crusting, soil moisture)
- sorghum
- chickpea

On-station trials - Pakistan
INSERT
(OS32)

INSERT data
- maize
- wheat

On-station trials - Nigeria
INSERT
(OS28)

INSERT data
- rice

Controlled environment (in vitro) *studies*
INSERT
(IV1-IV47)

INSERT data

In vitro investigations of mechanisms and specific constraints

- safe limits
- effect of delayed sowing
- "competition" and "race" hypotheses
- salinity
- flooding tolerance
- weeds / competition
- dry sowing

- possible hypotheses [stand density, resource capture (water, nutrients, light) in relation to:
    - dynamic environment
    - other plants (weeds)
    - pests and diseases (timing and health)

    - system effects

1. *In vitro* crop and variety screening TABLE?

- Chickpea
    - germination x 2
    - emergence x 1
- Cotton
    - germination x 1
    - John Gorham ?
    - other KRIBP cultivars ?
- Cowpea
    - germination x 3
    - emergence x 2
- Finger millet
    - germination x 1
- (Forage spp.)
- Horsegram
    - germination x 1
    - emergence/intercropping x 1
- Kidney bean
    - germination x 1
- Lentil
    - germination x 1
- Maize
    - germination x 2
    - emergence x 1
- Mung bean
    - germination x 1
- Pearl millet
    - germination x 3
    - emergence x 2
- Pigeonpea

    - germination x 1
- Rice
    - germination x 2
    - emergence x 1
- Sorghum
    - germination x 2
    - emergence x 4
- Sunflower
    - germination x 1
- Wheat
    - germination x 3
    - emergence x 3

    -

Discussion and conclusions

- Widespread application and utility
    - crops
    - systems
    - constraints
- System effects
    - marginal areas
    - high potential areas
    - interaction with genotype
        - cropping patterns
        - weeds
        - pests & diseases
- Possible mechanisms
    - hydration *versus* thermal time
    - faster & better root development
    - sequestration of resources
        - water
        - nutrients (Birch effect?)
        - light
        - time/environment/temperature
    - population density effects *versus* individual vigour
    - modelling
- Seed priming as insurance
    - no insurmountable negative effects
    - occasionally no difference
    - generally benefits
    - low-cost, low-risk "key" technology
- Importance of FAMPAR for adaptation, ownership, uptake and spread of technologies
    - farmer research and problem solving
    - seed-based *versus* knowledge-based technologies

- seed priming a special case of k-bt, as no capital investment involved (in contrast to e.g. irrigation, new implements, fertiliser)
- impact assessment
    - cost benefit analysis (NRI)
    - overall KRIBP
    - students' survey

Annex 1

Number	SITE (origin of material)	MATERIAL	EXPERIMENTAL DETAILS	TEMPERATURE
	IN VITRO			
IV 1	CAZS (Zimbabwe)	Sorghum - (Red Swazi, Muchayeni)	Germination characteristics in response to seed priming	30°C
IV 2	CAZS (SMIP, Zimbabwe)	Sorghum - 3 varieties	Germination characteristics in response to seed priming	30°C
IV 3	CAZS (India)	Sorghum - (9 varieties)	Germination characteristics in response to seed priming	30°C
IV 4	CAZS (Zimbabwe)	Sorghum - (Muchayeni)	Emergence and early growth characteristics in response to seed priming	30°C/20°C
IV 5	CAZS (Zimbabwe)	Sorghum - (Muchayeni)	Emergence of primed seed after sowing in dry soil	heated glasshouse
IV 6	CAZS (Zimbabwe)	Sorghum - (Muchayeni)	Emergence of primed seed after sowing in dry soil	heated glasshouse
IV 7	CAZS (Zimbabwe)	Sorghum - (Muchayeni)	Emergence of primed seed after sowing in dry soil	heated glasshouse
IV 8	CAZS (SMIP Zimbabwe)	Sorghum - (3 varieties)	Emergence and early growth characteristics in response to seed priming	30°C/20°C
IV 9	CAZS (Zimbabwe)	Maize - (R201 hybrid)	Germination characteristics in response to seed priming	30°C
IV 10	CAZS	Maize -	Germination characteristics in response to seed priming	30°C

	(India)	(Shweta, Sameri)		
IV 11	CAZS (Zimbabwe)	Maize - (R201 hybrid)	Effect of early emergence of maize in competition with weeds (also maize)	heated glasshouse
IV 12	CAZS (India)	Maize - (GDRM 187)	Effect of seed priming on early development of root systems using mini-rhizotrons	Heated glasshouse
IV 13	CAZS (India)	Horsegram and Maize	Emergence and early growth of intercrop -/+ priming	heated glasshouse
IV 14	CAZS (Zimbabwe)	Pearl millet - (PMV 2)	Germination characteristics in response to seed priming	30^oC
IV 15	CAZS (India)	Pearl millet - (11 varieties)	Germination characteristics in response to seed priming	30^oC
IV 16	CAZS (India)	Pearl millet - (11 varieties)	Germination characteristics in response to seed priming	40^oC
IV 17	CAZS (India) *PCI*	Wheat (HI-1077)	Preliminary germination test of priming characteristics	30^oC
IV 18	CAZS (India) *PCI*	Wheat (12 varieties)	Germination characteristics in response to seed priming	20^oC
IV 19	CAZS (India) *PCI*	Wheat (2 varieties)	Germination characteristics after drying back primed seed	heated glasshouse
IV 20	CAZS (India) *PCI*	Wheat (5 varieties)	Emergence characteristics in response to seed priming	heated glasshouse
IV 21	CAZS (India/Pak)	Wheat (2 varieties)	Effect of seed priming on germination in 200 mM NaCl	30^oC
IV 22	CAZS	Wheat (2 varieties)	Effect of seed priming on emergence in 150 mM NaCl	heated glasshouse

	(India/Pak)		environment (Experiment 1)	
IV 23	CAZS (India/Pak)	Wheat (2 varieties)	Effect of seed priming on emergence in 150 mM NaCl environment (Experiment 2)	heated glasshouse
IV 24	CAZS (India)	Rice - (Kalinga 3)	Germination characteristics in response to seed priming	30^{o}C
IV 25	CAZS (India/W. Africa)	Rice (Kalinga III and 4 WARDA vars)	Emergence characteristics in response to seed priming for different times	30^{o}C
IV 26	CAZS (/India)	Rice (Kalinga III	Effect of early emergence of rice in competition with weeds (also rice). Expt. 1	heated glasshouse
IV 27	CAZS (India)	Rice (Kalinga III	Effect of early emergence of rice in competition with weeds (also rice). Expt. 2	heated glasshouse
IV 28	CAZS (Zimbabwe)	Cowpea	Germination characteristics in response to seed priming	30^{o}C
IV 29	CAZS (Zimbabwe)	Cowpea	Germination characteristics in response to seed priming in various sugar solutions	30^{o}C
IV 30	CAZS (Nigeria/Ab erdeen)	Cowpea	Germination characteristics in response to seed priming	30^{o}C
IV 31	CAZS (Nigeria)	Cowpea	Emergence characteristics in response to seed priming	heated glasshouse
IV 32	CAZS (India)	Chickpea - (Dahod Yellow)	Germination characteristics in response to seed priming	30^{o}C
IV 33	CAZS (India)	Chickpea (5 varieties)	Germination characteristics in response to seed priming	20^{o}C
IV 34	CAZS	Chickpea -	Emergence characteristics in response to seed priming	30^{o}C

	(India)	(Dahod Yellow)		
IV 35	ICRISAT (India)	Chickpea (2 cvs)	Emergence characteristics in relation to soil moisture conditions	??
IV 36	CAZS (Pakistan)	Cotton (MNH-147, linted seed)	Germination characteristics in response to seed priming	30^{o}C
IV 37	CAZS (Zimbabwe)	Sunflower PAN 7392	Germination characteristics in response to seed priming	30^{o}C
IV 38	CAZS (India)	Horsegram	Germination characteristics in response to seed priming	30^{o}C
IV 39	CAZS (India)	Pigeonpea (ICPL-87119)	Emergence characteristics in response to seed priming	30^{o}C
IV 40	CAZS (India) *PCI*	Mungbean (5 varieties)	Germination characteristics in response to seed priming	30^{o}C
IV 41	CAZS (Nepal) *PCI*	Lentil (landrace)	Preliminary germination characteristics in response to seed priming	20^{o}C
IV 42	CAZS (India) KRIBP (W)	Soybean (2 cvs)	Preliminary germination characteristics in response to seed priming	30^{o}C
IV 43	CAZS (Nepal) *PCI*	Kidney bean (1 cv)	Preliminary germination characteristics in response to seed priming	20^{o}C
IV 44	CAZS India KRIBP (E)	Finger millet (5 cvs)	Preliminary germination characteristics in response to seed priming	30^{o}C
IV 45	CAZS (Nepal)	Mustard	Preliminary germination characteristics in response to seed priming	20^{o}C

	PCI			
IV 46	CAZS (India) KRIBP (W)	Niger (2 cvs)	Preliminary germination characteristics in response to seed priming	30^oC
IV 47	CAZS (India)	Forage spp.	Germination characteristics -/+ pelleting	30^oC

	ON-STATION			
OS 1	Zimbabwe	Maize - R201	Emergence and early growth -/+ seed priming	
OS 2	Zimbabwe	Sorghum - (2 varieties)	Emergence, early growth & yield -/+ priming. 5 sowing dates (95-96 season)	
OS 3	Zimbabwe	Sorghum - (2 varieties)	Emergence, early growth & yield -/+ priming. 5 sowing dates (96-97 season)	
OS 4	Zimbabwe	Maize	Emergence, early growth & yield -/+ priming. 5 sowing dates (97-98 season)	
OS 5	Zimbabwe	Maize	Emergence, early growth & yield -/+ priming. 5 sowing dates (98-99 season)	
OS 6	Zimbabwe	Sorghum (2 cvs) and Maize (2 hybrids)	Emergence, early growth & yield -/+ priming, 4 rainfall regimes (96/97 season)	
OS 7	Zimbabwe	Sorghum (2 cvs) and Maize (2 hybrids)	Emergence, early growth & yield -/+ priming, 5 rainfall regimes (97/98 season)	
OS 8	Zimbabwe	Sorghum and Maize	Emergence, early growth & yield -/+ priming -/+ control of seed predation (carbofuran) (96/97 season)	
OS 9	Zimbabwe	Sorghum and Maize	Emergence, early growth & yield -/+ priming -/+ control of seed predation (carbofuran) (97/98 season)	
OS 10	Zimbabwe	Sorghum and Maize	Emergence, early growth & yield following ‘dry-sowing’ of -/+ primed seed (97/98 season)	
OS 11	India *KRIBP* (W)	Maize - (2 varieties)	Emergence	
OS 12	India *KRIBP* (W)	Maize, chickpea, rice	Emergence, growth and yield (*kharif* 96)	
OS 13	India *KRIBP* (W)	Chickpea (2 cvs)	Emergence, growth and yield (*rabi* 96-97)	

OS 14	India *ICRISAT* *Fatehpur*	Pearl millet - (11 varieties)	Line-source sprinkler x -/+ priming. Expt. 1	
OS 15	India *ICRISAT* *Mandor*	Pearl millet - (11 varieties)	Line-source sprinkler x -/+ priming. Expt. 2	
OS 16	India *ICRISAT* *Fatehpur*	Pearl millet - (3 varieties)	Line-source sprinkler x -/+ priming x 3 sowing dates.	
OS 17	India *ICRISAT* *Fatehpur*	Pearl millet	Emergence through crusted soils -/+ priming, date of sowing	
OS 18	India *ICRISAT* *Fatehpur*	Pearl millet	Emergence through crusted soils -/+ priming. Expt. 1	
OS 19	India *ICRISAT* *Mandor*	Pearl millet	Emergence through crusted soils -/+ priming. Expt. 2	
OS 20	India *ICRISAT* *Fatehpur*	Pearl millet	Emergence through crusted soils -/+ priming, delayed sowing after rain.	
OS 21	India *ICRISAT* *Mandor*	Pearl millet	Emergence -/+ priming, -/+ presswheel. Expt. 1	
OS 22	India *ICRISAT* *Mandor*	Pearl millet	Emergence -/+ priming, -/+ presswheel. Expt. 2	
OS 23	India *ICRISAT*	Pearl millet	Emergence -/+ priming, -/+ presswheel. Expt. 3	

	Mandor			
OS 24	India *ICRISAT Hyderabad*	Sorghum (20 cvs) and P. millet (11 cvs)	Emergence through crusted soils -/+ priming	
OS 25	India *ICRISAT, Hyderabad*	Chickpea (2 cvs)	Effect of seed priming, population density and sowing method (compaction) on emergence, growth and yield	
OS 26	India *RAU Borwat*	Rice (11 cvs)	Emergence, growth and yield -/+ priming, also priming with 2% NaCl (*kharif* 1997)	
OS 27	India *RAU Borwat*	Rice (Kalinga III)	Emergence, growth and yield -/+ priming (*kharif* 1998)	
OS 28	Nigeria	Rice	Emergence, growth, pest & disease resistance and yield -/+ priming (1998)	
OS 29	India *GAU Godhra*	Maize (2 cvs)	Emergence, growth and yield -/+ priming (*kharif* 1997)	
OS 30	India *GAU Godhra*	Maize (2 cvs)	Emergence, growth and yield -/+ priming (*kharif* 1998)	
OS 31	India *IARI Delhi*	Maize and rice	Germination and emergence -/+ priming	
OS 32	Pakistan	Maize and Wheat	Priming in field experiments on response to salinity.	

	ON - FARM			
OF 1	India *KRIBP(W)*	Chickpea	Overnight soaking. 12 farmers, September 1995 (rabi season)	
OF 2	India *KRIBP(W)*	Maize	Priming trial. 72 farmers, June 1996 (kharif season)	
OF 3	India *KRIBP(W)*	Rice - (Kalinga 3)	Priming trial. 72 farmers, June 1996 (kharif season)	
OF 4	India *KRIBP(W)*	Maize/ horsegram intercrop	Priming trial. 10 farmers, June 1996 (kharif season)	
OF 5	India *KRIBP(W)*	Maize	48 farmers. Priming trial. 96-97 (rabi season)	
OF 6	India *KRIBP(W)*	Chickpea	48 farmers. Priming trial. 96-97 (rabi season)	
OF 7	India *KRIBP(W)*	Maize, rice (cotton, p/pea)	Trials in 30 villages. 1997 *kharif*	
OF 8	India *KRIBP(W)*	Maize, chickpea, wheat	Trials in villages, 1997/98 *rabi*	
OF 9	India *KRIBP(W)*	Maize, rice (cotton, p/pea)	Trials in villages. 1998 *kharif*	
OF 10	India *KRIBP(W)*	Maize, rice, chickpea	Uptake survey 1998	
OF 11	India *KRIBP(W)*	Maize, chickpea, wheat	Trials in villages, 1998/99 *rabi*	
OF 12	India *KRIBP(E)*	Chickpea, wheat	64 farmers, 1998/99 *rabi*	
OF 13	India PCI	Wheat	Incorporated into PVS trials, 1997/98 *rabi*	

OF 14	India PCI	Wheat	Incorporated into PVS trials, 1998/99 *rabi*	
OF 15	India *PCI*	Wheat	Survey of previous year's trials participants, 1998/99 *rabi*	
OF 16	Bangladesh	Chickpea	30 on-farm trials -/+ seed priming	
OF 17	Nepal *PCI*	Lentil	Preliminary trials by farmers in project villages	
OF 18	Nepal *PCI*	All crops	Survey of knowledge of seed priming	
OF 19	Nepal *PCI*	Lentil, wheat, maize	On-farm trials by farmers in 3 villages 1998/99 season	
OF 20	Pakistan	Maize, wheat, (rice)	Participatory on-farm trials of seed priming in relation to saline conditions.	
OF 21	West Africa	Upland rice	Ad hoc investigations of seed priming 1998	
OF 22	Nigeria	Upland rice (4 cvs)	On-farm trial -/+ seed priming 1998	
OF 23	Zimbabwe	All crops	Farmer survey on cropping patterns. 90 farmers in communal areas.	
OF 24	Zimbabwe	All crops	Farmer survey on agronomic practices. 60 farmers in communal areas.	
OF 25	Zimbabwe	Sorghum and maize	Preliminary priming trials, 2 villages 96-97 season.	
OF 26	Zimbabwe	Sorghum and maize	On-farm trials with 120 farmers in 4 villages 97-98 season.	
OF 27	Zimbabwe	Sorghum and maize	On-farm trials with 171 farmers (each crop) in 4 villages 98-99 season.	