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SHORT DURATION CHICKPEA TO REPLACE FALLOW AFTER *AMAN* RICE: THE ROLE OF ON-FARM SEED PRIMING IN THE HIGH BARIND TRACT OF BANGLADESH

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SUMMARY

Chickpea (*Cicer arietinum*) is a promising post-wet-season crop to follow rainfed rice (*Oryza sativa*) in the High Barind Tract of northwestern Bangladesh. Yields in farmers' fields, however, remain low (<1 t ha^{-1}) primarily due to such factors as poor crop establishment, late sowing, and terminal drought and heat stress. Having been shown to improve plant stand and yield of chickpea in other environments, seed priming – soaking the seed overnight before surface drying and sowing the next day – was tested for its efficacy under Barind conditions.

In the 1998–99 season, 30 trials grown entirely on residual soil moisture were conducted in farmers' fields. A statistically significant mean yield response to priming of 47% was obtained. In 1999–2000, 105 on-farm trials and 15 demonstrations comparing presence and absence of priming were conducted. The crop received rain during this growing season. In a randomly chosen subset of 35 trials, scientists recorded a mean yield increase due to priming of 20%; it was 22% (from 1.02 to 1.25 t ha^{-1}) in the remaining 64 trials (6 of the 105 trials were abandoned) where farmers recorded yields. Using a different variety, the mean yield response to priming in 15 demonstrations was 17% (from 1.25 to 1.46 t ha^{-1}).

The priming response was attributed mainly to rapid seedling establishment, with higher plant stand and earlier crop maturity allowing escape from end-of-season stresses. Priming also reduced the incidence of stem and root diseases, and increased nodulation by native rhizobia. This simple technology can substantially increase chickpea yields to remunerative levels for the resource-poor farmers in this difficult environment. Further, it is suggested that this technology can act as a catalyst for the introduction of further technologies that will permit reliable and profitable cultivation of post-rainy-season crops and thus improve the livelihoods of the rural population.

INTRODUCTION

Despite the ever-increasing demands for food production in South Asia, there are vast areas of lands left fallow following cultivation of rainfed rice (*Oryza sativa*), and even following irrigated rice when there is insufficient irrigation water for yearround cropping (Rahman *et al.*, 1995, for Bangladesh; Sharma, 1997, for India). Many smallholder rice farmers in the region have no, or limited, irrigation and are subsistence farmers with few opportunities for on-farm enterprise and income diversification. They have limited opportunity to grow crops that would complement the staple rice diet and thus improve family nutritional status.

After the rice harvest in Bangladesh, there is often enough stored soil moisture, along with any subsequent rainfall, to support a following, short-duration crop (Rahman *et al.*, 1995). For a number of reasons, legumes are a particularly attractive choice in this regard, and Johansen *et al.* (2000) recently reviewed the constraints and opportunities for legumes in rotation with rice. Better utilization of rice fallows by cultivating legumes should improve soil organic matter and fertility status, thereby contributing to the long-term sustainability of rice cropping (Kumar Rao *et al.*, 1998). Improved nutrient cycling resulting from multiple cropping would increase fertilizer-use efficiency and reduce polluting losses of nutrients from the system. Crop coverage during what would have been a fallow, should reduce soil erosion by wind or water, while the use of legume stover as fodder would improve animal nutrition and reduce grazing pressure on the natural vegetation. Diversification of the rice-based cropping system should break cycles of rice pests and diseases, increase incomes and improve nutritional standards for the farming community (Kumar Rao *et al.* 1998). The main biophysical reasons for fallowing are the suite of agronomic difficulties in establishing and growing a crop in paddy soils where a hard plough pan has been deliberately created to retain water for rice culture (Samson and Wade, 1998).

The Barind Tract in north-western Bangladesh comprises uplifted weathered alluvium of high clay content that is not subject to annual flooding by the major river systems. The undulating western part of this region, the High Barind Tract (HBT), covers some 2200 km^2 (Edris, 1990). Here the traditional cropping system of the area is predominantly *kharif* (rainy season), rainfed transplanted *aman* rice, which is transplanted mainly in July and harvested in October-November. The bunded fields are generally left fallow for the remainder of the year. Since rainfall averages 1285–1400 mm a^{-1}, however, there remains in the soil profile enough water to sustain a short-duration crop if the rice is harvested early enough. Late harvesting of rice results in surface soil moisture levels that are too low for successful crop establishment.

Because of this harsh environment with limited opportunities for agricultural production, the poverty level of the region is high, a situation exacerbated by a high degree of absentee landlordism. Sharecropping is commonly practised but off-farm income or remittances are minimal compared with other parts of Bangladesh (Fakhrul Islam, 1988; Shafiqul Islam *et al.*, 1990).

Technology has been developed and demonstrated that permits the cultivation of *rabi* (post-rainy season) crops to follow rice (Kumar *et al.*, 1994). Essentially, this involves seedbed preparation and sowing of the *rabi* crop soon after the rice harvest while the soil surface retains sufficient moisture to ensure adequate crop establishment. Seedling roots penetrate the plough pan layer, because it is still moist, and can extract residual soil moisture from deeper layers after the surface soil and plough pan layers have dried out. If shorter-duration varieties of *rabi* crops are used, they can reach maturity before the residual subsoil moisture is exhausted.

Chickpea (*Cicer arietinum*) has proved to be particularly suitable for growing after rice in this system because of its strong rooting characteristics and the availability of new shorter-duration improved varieties, as compared with traditional local landraces (Rahman *et al*., 2000). The area of chickpea in the HBT in the 1984–85 season was around 1200 ha but in 1997–98 it was estimated to be 9000–10000 ha (Musa *et al*., 1998). Chickpea yields in the HBT are usually more than the national average due to a lower incidence of botrytis gray mold disease in this region. In most farmers' fields, however, yields normally remain below 1 t ha^{-1} mainly due to crop establishment problems and terminal drought and heat stress (Musa *et al*., 1999).

It has been reported that in trials in western India, on-farm seed priming increases chickpea yields and those of other rainfed crops (Harris *et al*., 1999). The seed-priming process simply involves soaking the seeds overnight (for about 8 h), surface drying them and then sowing within the same day. This treatment hastens germination, enhances crop establishment and promotes seedling vigour (Harris *et al*., 1999). It was considered worthwhile, therefore, to evaluate seed priming for its efficacy for chickpea grown in the harsh conditions of the HBT.

As resource-poor farmers of the HBT consider the cultivation of any rainfed crop after rice to be particularly risky, adoption of any new technology for such crops, even a simple one like seed priming, is likely to be dependent on a participatory approach involving farmers, extension personnel and scientists (Harris *et al*., 1999). Following surveys to gain an understanding of general farming practices and farmers' perceptions of crop establishment problems in the HBT (Musa, 1998; Musa *et al*., 1999), farmer-implemented trials comparing presence and absence of seed priming were conducted in the 1998–99 and the 1999–2000 seasons.

MATERIALS AND METHODS

Farmers' trials

In 1998, farmers implemented paired-plot trials under rainfed conditions at 30 locations in seven blocks of the HBT: two blocks each in Tanor *Thana* of Rajshahi District and Sadar *Thana* of Nawabganj District and three blocks in Nachole *Thana* of Nawabganj District (Fig. 1).

About 0.13 ha of land at each location was divided equally for the following two treatments: non-primed, where dry seeds were sown as normal; and primed, where seeds were soaked in water overnight, surface dried and then sown within that day. Farmers were trained in this methodology and they implemented all aspects of the trials. Seed of the chickpea variety Barichola-2, recently released for

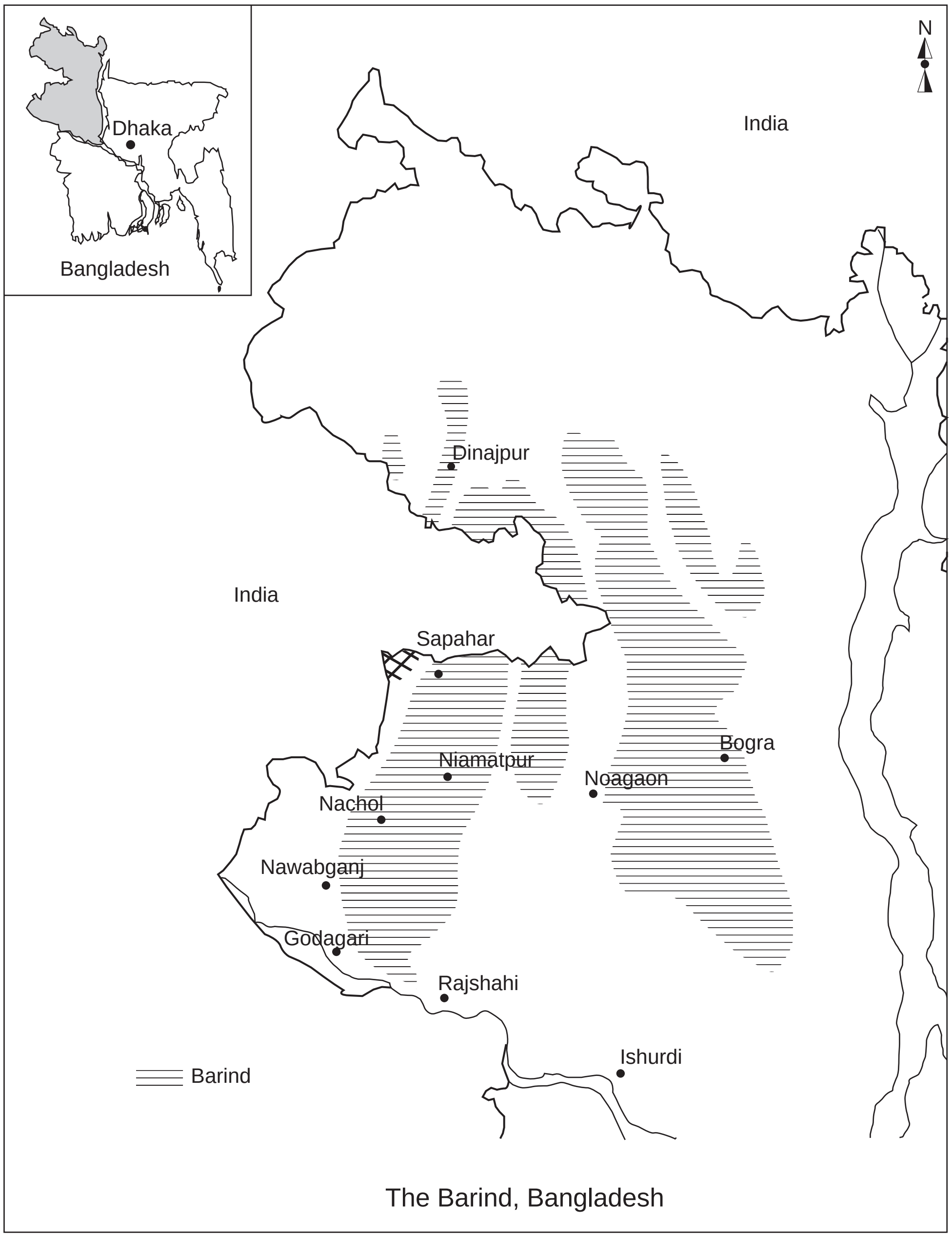

Fig. 1. Location of districts in the Barind region of Bangladesh in which trials were held.

cultivation in the Barind, was given to farmers and sown at a seed rate of 50 kg ha^{-1}. The trials were conducted under farmers' management. Most participating farmers applied P_2O_5 at 40 kg ha^{-1} as triple superphosphate, and K_2O at 20 kg ha^{-1} as muriate of potash. Neither fungicidal seed dressing nor *Rhizobium* inoculation was used. Fertilizer was applied at the time of land preparation by

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power tiller or bullock-drawn plough, followed by laddering (dragging a bamboo ladder across the soil surface to level the land). At the same time, seed was broadcast manually in each treatment plot, and a final laddering was given to bury the seed. The sowing dates for the different locations ranged from 19 November to 13 December 1998. Intercultural operations for weed control were done as needed and some farmers applied need-based sprays of insecticide to control *Helicoverpa armigera* pod borer.

During the crop growth period, measurements of emergence, early growth vigour and pest and disease incidence were made within five 1-m^2 quadrats per plot. Visual estimates of nodulation were made in a sample of plots. At harvest, three quadrats of 1 m^2 were placed at random within each plot and researchers measured plant population density, the number of filled and unfilled pods per unit area, grain yield, 1000-grain weight, and weight of crop residue. Depending on location, plots with the priming treatment were harvested from 20 March to 4 April 1999 and plots with non-primed seed were harvested from 25 March to 7 April 1999. The primed seed plots were harvested 3–7-d before their respective non-primed ones, but exact dates of physiological maturity for each plot were not recorded.

In 1999, 105 on-farm trials were implemented in 17 blocks of eight *Thanas* in the HBT districts of Rajshahi, Nawabganj, Naogaon and Niamatpur (Fig. 1). Plot size, variety and cultural operations were the same as in 1998. Sowing dates ranged from 19 November to 14 December 1999. Primed plots were harvested between 25 March and 10 April 2000, while non-primed plots were harvested between 13 March and 13 April 2000. Primed plots matured earlier and were harvested 3−7 days earlier than non-primed plots.

Of the 105 trials sown in 1999, a random sub-sample of 35 trials was sampled intensively using quadrats, six were abandoned for various reasons and yields from the remaining 64 were determined by the farmers themselves after the area of each plot had been measured by researchers. In all trials, measurements were made on emergence, early growth vigour and pest and disease incidence. Measurements of yield and other parameters were made in these 35 trials in three quadrats of 1 m^2 placed at random within each plot, as in 1998–99. Mean plant height and canopy diameter were measured on 10 randomly selected plants per plot, while the number of unfilled pods and the number of nodules per plant were measured on five plants per plot.

Demonstration plots

Fifteen demonstrations of the effects of priming chickpea were implemented by researchers on farmers' fields in Digram, Kazipara and Bisnathpur villages in Godagari *Thana* in 1999. At each location, two plots of 0.13 ha were planted with primed and non-primed chickpea seeds of the cultivar Barichola-5 as described above for farmers' trials. Seed rate for this smaller-seeded variety was 38 kg ha^{-1} and sowing dates ranged from 8 November to 8 December 1999. Plots were harvested between 25 March and 4 April 2000. Data on plant height, population

Table 1. Monthly rainfall (mm) at Chabbishnagar, Rajshahi, Bangladesh. The growing period for chickpea is shown in bold type.

Month	Year			
	1987–1999 (mean)	1998	1999	2000
January	**7**	**20**	**0**	**9**
February	**19**	**7**	**0**	**76**
March	**29**	**58**	**0**	**20**
April	**35**	**1**	**0**	
May	82	0	120	
June	226	130	380	
July	270	180	342	
August	225	200	342	
September	260	150	508	
October	67	0	128	
November	**19**	**40**	**0**	
December	**8**	**0**	**0**	
Total	1245	785	1820	
s.d.	330			

density at harvest, the number of pods per plant, 1000-grain weight, grain yield and yield of crop residue were measured using quadrats as described above.

Rainfall data were collected at the meteorological station at Chabbishnagar, Rajshahi, the site of the Farming Systems Research Division of the Bangladesh Agricultural Research Institute.

Analysis

Data on yield and yield components for each plot were analysed using a paired two-tailed *t*-test to compare differences between primed and non-primed plots at 30 locations (1998–99, quadrat data), 35 locations (1999–2000, quadrat data), 15 locations (1999–2000, demonstration plots) and 64 locations (1999–2000, farmers' yield estimates). The probability of achieving a given yield was estimated for each of the two priming treatments over a range of yields between 0.5 and 2.0 t ha^{-1}. Probability was calculated as the proportion of all 144 paired-plot trials in which the yield outcome was equal to, or greater than the chosen yield.

RESULTS

Farmers' trials

Mid-November rains in 1998 (Table 1) delayed maturation and harvesting of rice and, consequently, the sowing of chickpea crops. From 22 November, however, there was no effective rainfall for the whole chickpea growth period. Thus the chickpea crops in this first season grew entirely on residual soil moisture.

In the 1998–99 season, seed priming resulted in earlier emergence of seedlings,

Table 2. Yield and yield components from on-farm, paired-plot trials of seed priming in chickpea (cv. Barichola-2) in the High Barind Tract of Bangladesh during the *rabi* (post-rainy season) of 1998-99 (30 farmers) and 1999-00 (35 farmers).

Variable	Mean (primed)	Mean (non-primed)	Increase due to priming (%)	*s.e.d.*	Significance
Emergence (seedlings m^{-2})					
1998–99	36.7	30.2	21	0.8	***
1999–00	35.1	28.8	22	0.6	***
Early growth height (mm)					
1998–99	105	86.0	22	2.0	***
1999–00	99	82.0	21	1.0	***
Height at harvest (mm)					
1998–99	364	330.0	10	5.0	***
1999–00	413	371.0	11	8.0	***
Canopy diameter (mm)					
1998–99	–	–	–	–	–
1999–00	45.7	42.5	7	12.0	*
No. diseased plants m^{-2}					
1998–99	1.1	2.0	−45	0.2	***
1999–00	1.6	2.3	−30	0.1	***
Pod borer damage m^{-2}					
1998–99	3.6	4.1	−13	0.5	ns
1999–00	37	36.0	2	1.9	ns
No. unfilled pods $plant^{-1}$					
1998–99	3.4	4.4	−21	0.6	ns
1999–00	3.4	4.5	−23	0.6	ns
No. plants m^{-2} at harvest					
1998–99	30.6	25.0	22	0.8	***
1999–00	32.4	26.7	22	0.7	***
No. nodules $plant^{-1}$					
1998–99	–	–	–	–	–
1999–00	21.3	14.3	48	1.1	***
No. pods m^{-2}					
1998–99	1493.0	1074.0	39	87.0	***
1999–00	1226.0	1105.0	11	30.0	***
1000 grain mass (g)					
1998–99	117.7	111.3	6	3.4	ns
1999–00	120.0	115.0	5	1.5	**
Grain yield (t ha^{-1})					
1998–99	1.63	1.11	47	0.10	***
1999–00	1.44	1.21	20	0.03	***
Residue yield (t ha^{-1})					
1998–99	2.00	1.53	31	0.09	***
1999–00	1.88	1.68	12	0.04	***

by 1–3 d, and significantly increased (mean across 30 locations) plant stand and initial growth vigour (Table 2). Soil-borne diseases, mainly caused by collar rot (*Sclerotium rolfsii*) and *Fusarium* wilt, were much lower in primed plots (Table 2). Although only a few plots were examined for nodule number per plant, primed plots generally had better nodulation by native rhizobia; nodule number ranged from 7 to 51 $plant^{-1}$ in primed plots and from 6 to 18 $plant^{-1}$ in non-primed

Table 3. Yield and yield components from fifteen demonstrations of seed priming in chickpea (cv. Barichola-5) in the High Barind Tract of Bangladesh in the *rabi* (post-rainy season) 1999–00.

Variable	Mean (primed)	Mean (non-primed)	Increase due to priming, (%)	*s.e.d.*	Significance
Height at harvest (mm)	441	425	4	6.0	**
No. plants at harvest (m^{-2})	38.8	35.4	10	1.5	*
No. pods $plant^{-1}$	46.9	40.7	15	14.2	ns
1000-seed weight (g)	87.2	84.1	4	1.8	ns
Grain yield (t ha^{-1})	1.46	1.25	17	0.09	*
Residue yield, (t ha^{-1})	1.87	1.72	9	0.06	**

plots. In this season, priming of seeds resulted in an overall 47% grain yield advantage with all measured yield-contributing factors showing positive effects of priming (significantly for all parameters in Table 2 except 1000-grain mass).

In the 1999–2000 season, the rainfall pattern was very different, with no rainfall in November but 105 mm during the chickpea growth period (Table 1). Nevertheless, a 20% yield response to priming was obtained in the intensively measured plots (Table 2). All components of yield were affected by priming in the same way as in 1998–99. All differences between treatments were statistically significant (P<0.05) in both seasons except for pod-borer damage and the number of unfilled pods per plant, both of which were consistently non-significant, and 1000-grain mass, which was significantly different only in the second year. The more rigorous sampling of the number of nodules per plant in 1999–2000 confirmed the observations made in 1998–99, that is, primed plants had more nodules (48% in 1999–2000) than did non-primed plants. It was observed also that nodulation, plant growth and grain yield generally were better in the lower valleys, with soil of higher organic matter content and better water retention, than on higher slopes.

Averaged over the two strongly contrasting seasons, emergence, early growth and plant stand at harvest were increased by about 21%, height at harvest by 10%, the number of pods per plant by 25%, residue yield by 21% and grain yield by 33%. Priming did not significantly affect either the level of damage due to pod borers, despite the ten-fold differences in pest incidence between seasons, or the number of unfilled pods per plant, although the latter showed a consistent but non-significant reduction in primed plants.

The mean grain yield reported by farmers at the remaining 64 sites in 1999–2000 was 1.25 t ha^{-1} in primed plots, and 1.02 t ha^{-1} in the non-primed plots (P<0.001).

Demonstration plots

Mean grain yields were very similar to those obtained in the 35 farmers' trials in 1999–2000 (Table 3) and priming was associated with a significant 17% increase. Height and number of plants at harvest, and residue yield, were also

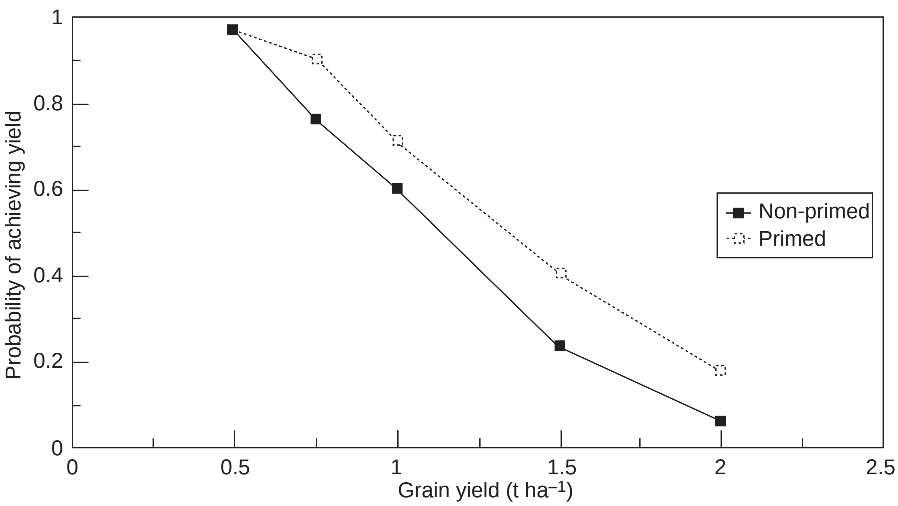

Fig. 2. Probability of achieving a given grain yield.

significantly increased by priming, whereas the number of pods per plant and the 1000-grain weight were not.

Probability of cropping success

Farmers' decisions to adopt an additional crop are based on complex criteria, one of which is risk of failure. He or she will have some expected yield in mind when sowing a crop. The likelihood of a farmer achieving any desired yield declined as that figure increased (Fig. 2). For any target yield above 0.5 t ha^{-1}, however, priming increased the probability of success by 18% (for 0.75 t ha^{-1}), 18% (for 1 t ha^{-1}), 74% (for 1.5 t ha^{-1}) and 240% (for 2 t ha^{-1}).

DISCUSSION

Chickpea production in the traditional growing areas of Bangladesh (flood-plain soils of the central west) has declined markedly in recent years. Primarily this is due to devastation of the crop by botrytis gray mold disease and increased cultivation of the staple cereals, *boro* (winter) rice and wheat (*Triticum aestivum*) (Rahman *et al.*, 2000). The resultant scarcity of chickpea grain along with that of other pulse crops, has caused marked price increases, pushing pulses beyond the reach of the poor. To maintain a reasonable market supply of chickpea and other pulses, the Government of Bangladesh imports these grains from countries such as Australia and Turkey.

Due to its elevation and slightly less humid environment compared with traditional chickpea-growing areas, the incidence of botrytis gray mold on chickpea in the HBT is much less, making the region suitable for stable production of chickpea if it can be successfully established in a timely manner (Bakr *et al.*, 1993). Markedly increased cultivation of chickpea in the Barind would permit import substitution to save precious foreign exchange. There is much demand for this popular pulse as evidenced by huge imports. Bangladesh imported 19 767 t of chickpea worth US$ 11.4 million in 1997 and 22 137 t worth US$ 12.2 million in 1998 (FAOSTAT, 2000). The price of chickpea is about three times that of unmilled rice.

With the shift in chickpea cultivation away from traditional areas and towards the Barind, there is increased emphasis on producing short-duration chickpea varieties better adapted to the Barind environment (Kumar *et al.*, 1996, Rahman *et al.*, 2000). The importance of the need to develop and disseminate in the region, short-duration rice varieties to escape terminal drought stress as well as to allow timely establishment of *rabi* crops, has been recognized (Mazid *et al.*, 1998). To promote dissemination of improved chickpea varieties, buy-back seed production schemes have been established with farmers in recent years (Musa, 1998). Such activities need to be expanded and farmer-managed seed production schemes developed in order to meet the region's expanding chickpea seed requirements.

On-farm participatory trials have proved to be particularly effective in refining and developing technology according to farmers' needs, and are thus valuable tools for promoting uptake of the agreed technologies. On-farm seed priming is a very simple technique and requires no special equipment, input or effort. All on-farm evaluation and promotion of seed priming to date has been done using a Farmer Managed Participatory Research (FAMPAR) approach (for further details, see Joshi and Witcombe, 1996). From 1996, on-farm trials comparing primed and non-primed seeds in the Indian states of Rajasthan, Gujarat and Madhya Pradesh have shown positive results for maize, upland rice, wheat and chickpea sown into seedbeds reliant only on rainfall or residual soil moisture (Harris *et al.*, 1999). Regular 'farm walks' confirmed farmers' overriding perceptions that seed priming resulted in earlier seedling emergence and crop maturity, more vigorous vegetative growth, less pest damage, the ability to resist dry spells, and higher grain yields. Consequently, because the technology was low-risk, inexpensive and effective in their own hands, farmers adopted the practice widely in subsequent seasons and it has spread to adjoining areas (Harris *et al.*, 1999).

The practice of soaking crop seeds in water prior to sowing, dates back to ancient times. Van der Maesen (1972) reported the practice as being carried out by the ancient Greeks for chickpea cultivation. In more recent times there have been numerous, mainly laboratory, studies using many different chemical solutions to test the effect of pre-soaking seeds on their subsequent germination and seedling establishment, usually with positive results (Parera and Cantliffe, 1994). However, simply soaking seeds overnight in water has proved to be efficacious to initiate (but not to complete) the germination process before planting. This provides emerging seedlings with a head start in the often-hostile environment of heterogeneous seedbeds characteristic of subsistence farming conditions. In spite of the technology being so simple to implement and apparently effective, it is rare to find it applied by resource-poor farmers of the tropics or semi-arid tropics. Their rainfed crops invariably have poor and uneven plant stands, which contribute to the low yields obtained (Mazid *et al*., 1998).

The effect of seed priming on grain yield and its components is evidenced first in the better and faster seedling establishment, earlier flowering and earlier maturity that allow some escape from terminal drought and heat stress. Priming seems to affect, positively, all components of yield. The positive effects on disease control and nodulation are intriguing and deserve more in-depth study to understand the mechanisms involved. Soil-borne diseases are likely to assume greater importance as chickpea cultivation in the Barind increases. Knowledge of mechanisms to alleviate them, therefore, would be valuable. Possible synergistic effects of seed priming with other easily applied seed treatments also need to be examined. Such treatments would include fungicide application for soil-borne disease control, *Rhizobium* inoculation to enhance low populations of native rhizobia, and lime/phosphate/trace-element pelleting to alleviate effects of the acid surface soil and nutrient deficiencies.

Notwithstanding further studies on mechanisms of priming effects and possible synergies with other seed treatments, seed priming can be recommended as a standard practice for chickpea in the Barind region, especially as positive effects over a wide area were obtained in two contrasting seasons. Thus seed priming should be demonstrated on a large scale in this region, and perhaps further evaluated for its efficacy elsewhere on difficult post-rice soils in Bangladesh and adjacent areas of India.

Chickpea production in the HBT is proving to be the path-breaking technology for an integrated farming approach for the area. Islam *et al*. (1994) and Mazid *et al*. (1998) demonstrated that farmers should be able to double their on-farm returns by growing chickpea instead of leaving land fallow. Increased monocropping of chickpea may lead to a build-up of chickpea pests and diseases, however. This ultimately would lower chickpea yields and make the crop more risky. Appropriate crop rotations that include *rabi* crops other than chickpea, need to be instituted and any build-up of chickpea biotic stresses monitored so that remedial action can be taken. Research is ongoing into the effect of priming on other post-rice crops.

The participatory approach proposed here should accelerate adoption, not only of chickpea but of *rabi* cropping in general, resulting in substantially improved livelihoods for HBT farmers. Farmers in the project area have, after only two years' exposure to seed priming, adopted it widely for chickpea and, on their own initiative, for wheat and linseed (Musa, 2000). Seed priming, being a very simple technology, can be considered as a vehicle for the introduction of further technologies that can increase and stabilize yields for resource-poor farmers. Once they see good returns on investment in a simple technology they become more receptive to investment in additional technologies that would assist them to convert a traditionally subsistence crop into a commercial one.

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