FINAL TECHNICAL REPORT

R7540 `Promotion of Chickpea following rainfed rice in the Barind area of Bangladesh'

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Executive Summary

There is great potential for improving the livelihoods of poor farmers in the High Barind Tract (HBT) area of Bangladesh by growing chickpea on residual soil moisture after the harvest of rainfed rainy season (*aman*) rice. The area, covering about 2,200 km^2, was traditionally left fallow after the single crop of *aman* rice, mainly because of the lack of irrigation potential and the hard-setting nature of the soils. Technology to permit crop establishment after rice and growth on residual soil moisture and winter rain was developed in the 1980s and implemented over the subsequent decade. Chickpea has proved to be a particularly suitable crop in this system and its area in the region has increased ten-fold from a base of around 1,000 ha in the 1980s. However, constraints to wider adoption of chickpea are: low yields due to use of inappropriate varieties; an inefficient seed supply system; insufficient knowledge by farmers of chickpea production and storage techniques; poor nodulation and nutrient deficiencies of soils in some areas; difficulties in obtaining good crop establishment as top soil dries rapidly at the end of the rice season. On-farm trials during 1998/99 demonstrated that priming chickpea seed overnight with water before sowing improved crop establishment and plant vigour, gave a 47% increase in grain yield and reduced the risk of crop failure by half. This simple, low-cost, low-risk 'key'

technology makes chickpea a much more attractive crop for farmers to grow. This project was aimed to address the purpose, pathways for the potential equitable uptake of technologies from PSP outputs 2-6 identified, piloted and promoted. The project has evaluated seed priming i.e. overnight soaking of seed in water prior to sowing, as a means of increasing grain yields and as a vehicle for expanding chickpea area. Multilocation, farmer-managed evaluation of priming response was conducted at many locations across the HBT over four years (1998-2002). Mean response to priming in grain yield ranged from 22 to 48% with responses inversely proportional to winter rainfall. Priming also reduced seedling disease incidence and increased plant population, early growth vigor, plant biomass and nodulation by native rhizobia. Farmers readily adopted the simple priming technology to the extent that at least one quarter of the chickpea sown in 2001 was primed. Along with priming technology, improved varieties of chickpea such as Barichola 2 or 5, and appropriate fertilizer practice e.g. phosphorus fertilizer, were introduced.

There was clearly ready adoption by farmers of the improved technology. The major constraint to further adoption was availability of seed and lack of knowledge of the improved technology outside of project areas. Seed of improved chickpea varieties particularly suitable for the HBT, such as Barichola 2 and Barichola 5, were widely disseminated as a result of project activities. The Pulses Research Centre (PRC) of Bangladesh Agricultural Research Institute (BARI) and Department of Agricultural Extension (DAE) voluntarily participated in seed production, demonstration and extension activities. Techniques of seed preservation and storage at village level were successfully tested, to encourage village-level entrepreneurship in chickpea seed production and supply, and farmers trained accordingly.

An adoption and impact analysis of the project assessed the effects of project intervention on livelihoods of the rural community in the HBT. The high and annually increasing prices of chickpea grain suggest that increased cultivation of this crop would significantly improve livelihoods in the region; reasonable yields (> 1 t ha^{-1}) are currently more remunerable than irrigated *boro* (winter) rice or wheat (these irrigated cereals have high yields but inevitable high input costs).

Background

The undulating or High Barind Tract (HBT) north and west of Rajshahi in north-western Bangladesh comprises some 2,200 km^2 (Edris, 1990). The area is characterised by clayey soils used to grow transplanted *aman* rice during the *kharif* season (July-October/November) followed, where irrigation is not available, by fallow. Without a *rabi* crop, farmers have few options for on-farm income to sustain them throughout the year. However, since rainfall averages 1285-1400 mm per year, there remains in the soil profile enough water to sustain a short duration crop if rice is harvested early enough for the subsequent crop to be established properly. Delay in harvesting rice means that surface soil moisture levels become too dry for successful establishment. Because of this harsh environment with limited opportunities for agricultural production, the region has a particularly high poverty level, exacerbated by the 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, 1990).

On-farm research initiated in the 1980s by the On-Farm Research Division (OFRD) of the Bangladesh Agricultural Research Institute (BARI), and carried forward by them, has developed and demonstrated technology that permits cultivation of winter (*rabi*) crops to follow rice (Kumar et al. 1994). Essentially, this involves seedbed preparation and sowing of the *rabi* crop soon after harvest of rice while the soil surface retains sufficient moisture to ensure adequate crop establishment. Seedling roots penetrate the then moist plough-pan layer and can extract residual soil moisture from deeper layers after the surface soil and plough pan layer dry out. If short duration varieties of *rabi* crops are used they can reach maturity before the residual subsoil moisture is exhausted. Also, if shorter duration *aman* rice varieties are used, or the rice is transplanted earlier than normal, rice maturity can be reached at an optimum sowing time for *rabi* crops (their late sowing, in late November or early December, retards vegetative growth and root penetration and hence they face a greater degree of terminal drought stress). Recently, rice scientists from BRRI have also tried direct seeding of rice to shorten the duration of the rice-growing season.

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. However, yields in most farmers' fields normally remain below 1 t ha^{-1} due mainly to crop establishment problems and terminal drought and heat stress. At this level, the crop remains a marginal proposition for most farmers. Previous PSP-funded research has shown that establishment, early vigour, growth and yield of chickpea can be improved by 'on-farm' seed priming (Harris et al., 1999). The seed priming process simply involves soaking the seeds overnight (for about 8 hr), surface drying them and then sowing within the following day (Harris et al., 1999). Seed priming was evaluated in the HBT during 30 on-farm trials in 1998/99. Seed priming raised yields by almost 50%, from 1.1 to 1.6 t ha^{-1} and reduced the risk of crop failure by half (Musa et al., 1999). The results were very impressive but represent performance in only one season. Trials with chickpea in India suggest that priming consistently improves yields, but trials need to be repeated throughout the Barind over several more seasons. If the benefits are confirmed, growing chickpea should become much more attractive to Barind farmers.

Over and above the marked effects of seed priming, there is still much scope for further improvements in chickpea production (Musa et al., 1998; Maniruzzaman et al., 1991). Priming could be easily combined with *Rhizobium* inoculation, required because of low levels of effective native rhizobia, and fungicidal application, for protection against collar rot and other soil-borne diseases. Due to the acid nature of the surface soil, the efficacy of lime pelletting needs to be tested. Seed application of deficient nutrients (e.g. phosphorus, boron, molybdenum) could also be effective. Further systematic experimentation is needed to establish optimum seed treatment methods for the region. Crop protection measures found useful for chickpea elsewhere (e.g. need-based spraying of bioinsecticides) need to be evaluated in HBT. Proven post-harvest seed storage techniques, such as those described by Musa (1998), need to be introduced and widely demonstrated.

With the shift in chickpea cultivation away from traditional areas and towards the Barind, the Pulses Research Centre (PRC) of BARI is giving increasing emphasis to producing chickpea varieties better adapted to the Barind environment (e.g. among other traits they are breeding for greater rooting ability, to better exploit soil moisture and nutrients below the plough-pan). These efforts need support and expansion. The Bangladesh Rice Research Institute (BRRI) also realizes the importance of using early duration rice varieties in the region, to escape terminal drought stress as well as to allow rabi cropping. They are therefore encouraging development and dissemination of such varieties. To promote dissemination of improved chickpea varieties, buy-back seed production schemes have been established with farmers in recent years (Musa, 1998). This activity needs to be expanded in order to meet the region's expanding chickpea seed requirements.

Chickpea production in the HBT was proving to be the path-breaking technology for the integrated farming approach for the area promoted by OFRD-BARI. Islam *et al* (1994) demonstrated that farmers should be able to double their on-farm returns by growing chickpea instead of leaving land fallow. The approach proposed here should accelerate adoption, not only of chickpea, but of *rabi* cropping in general, resulting in substantially improved livelihoods for HBT farmers.

Project purpose

Methods to optimise cropping systems by agronomic means developed, tested, piloted and promoted.

There is great potential for improving the livelihoods of poor farmers in the High Barind Tract area of Bangladesh by growing chickpea on residual soil moisture after the harvest of rainfed rainy season (*aman)* rice. Chickpea has proved to be a particularly suitable crop in this system and its area in the region has increased ten-fold from a base of around 1,000 ha in the 1980s. However, there are constraints to wider adoption of chickpea and the most important one being difficulties in obtaining good crop establishment as top soil dries rapidly at the end of the rice season. On-farm trials during 1998/99 demonstrated that priming chickpea seed overnight with water before sowing improved crop establishment and plant vigour, gave a 47% increase in grain yield and reduced the risk of crop failure by half. This simple, low-cost, low-risk 'key' technology makes chickpea a much more attractive crop for farmers to grow.

The project will, using on-farm participatory methods, confirm over several seasons and in diverse agroecological conditions the beneficial effects of priming chickpea. Widespread adoption of chickpea will be stimulated and supported and the influence of a 'key' technology (seed priming) on farmers' perception of risk and likely benefits and the effect on farmers' livelihoods will be quantified. Focused Informal Research and Development (FIRD) will be tested for promoting this knowledge-based technology. This information will be of interest to researchers and extensionists working in other crops and production systems. Additional participatory research, development and training will refine and improve chickpea production technology appropriate to Barind farmers. Through seed production, dissemination and demonstration activities, an annual compound increase in area of 20% is envisaged, along with an increase in yields to a regional average of around 1 t ha^{-1} by three years. Thus, after three years of project operation, a doubling of chickpea production in the region is expected.

Research Activities

1. **On-farm participatory trials for group evaluation and promotion of seed priming**

On-farm seed priming is a very simple technique and requires no special equipment. Nevertheless, all on-farm evaluation and promotion of seed priming to date has been done using a FAMPAR (Farmer Participatory Research) approach. The need for some rudimentary training (`safe limits' for soaking, the need to surface-dry seed prior to sowing etc.) has always precluded the use of strict `IRD' (Informal Research and Development). Recently, an approach that incorporates elements of both IRD and FAMPAR, termed `focussed IRD' has been proposed. It involves a limited amount of pretrial contact between farmers and researchers enough to give simple training. Subsequent evaluation of the technology was done by the farmers as they see fit, and impact assessment was done using survey techniques to quantify persistence of the technology from season to season and from farmer to farmer.

A four – wheeler vehicle has been provided in the project to PROVA to facilitate frequent visits to farmers' fields and train the farmers, interested to grow chickpea in different areas of HBT, in collaboration with BARI, DAE and ICRISAT. A large number of on-farm participatory trials were conducted every year for group evaluation and promotion of seed priming in different areas of the HBT.

2a. **Participatory development of seed supply and on-farm storage systems**

A seed production and buy-back scheme which was in operation to provide seed of new varieties for testing and promotion of activities was continued. Chickpea is highly susceptible to insect storage pests and diseases, particularly so because seed needs to be stored over the humid, rainy season. Effective on-farm storage is essential if adopting farmers are to select, multiply and save their own seed. Effective and low-cost method of post-harvest protection (after harvest proper sun-drying of the seed, followed by storing in a thick polythene bag mixed with napthalene balls at the rate 1-2 per kg seed and making it air-tight, then storing on a raised platform in a large container so that it is protected from storage pests such as bruchids and rats) was tested in collaboration with farmers and found promising.

2b. **Farmer and extension officer training**

All participatory exercises, from rural appraisal and needs assessment to group assessment of trials, exposure visits etc., involved learning by farmers, researchers and extensionists.

2c. **Annual surveys of area sown to chickpea and farmers perceptions on adoption/non-adoption**

Area and yield data for crops, including chickpea, are collected primarily by the Department of Agricultural Extension (DAE) with verification by the Bangladesh Bureau of Statistics and OFRD-BARI at sample sites. This project tried to supplement these data by more intensive sampling in and around our study areas. Farm surveys were conducted to monitor and evaluate the adoption and impact of chickpea technology. Data obtained through the surveys were analyzed to identify the factors responsible for adoption of the new technology and constraints to adoption.

2d. **Conduct on-station and on-farm research to identify, develop and refine further appropriate chickpea production technology**

Chickpea varieties were screened in HBT and improved varieties suitable for HBT were identified. Seed priming process was evaluated to deliver *Rhizobium* inocula in both on-station and on-farm trials. Some opportunities, such as use of new short-duration varieties of rice, were tested to maximize overall returns to farmers by manipulating the duration of the preceding *aman* rice crop.

Back-up experimentation under the project quantified root distribution of chickpea and other crops in the HBT soils of high bulk density and responses to phosphorus, molybdenum and *Rhizobium* inoculation. Integrated pest management (IPM) procedures for control of *Helicoverpa armigera* pod borer were developed, based on the use of *Helicoverpa*-specific nuclear polyhedrosis virus (NPV).

3. **Survey farmers' perceptions of seed priming and chickpea production technology**

Farmers' perceptions of seed priming and chickpea production technology were assessed through surveys in HBT. This helped in assessing various biotic and abiotic and institutional constraints faced by them in producing chickpea.

4. **Conduct of surveys of farmers' livelihood structure and quantify the socioeconomic consequences of chickpea production on that structure**

A detailed baseline survey was conducted in year 1 on the livelihood details of selected farmers in representative villages. They were re-surveyed at the end of year 3 to quantify the socio-economic consequences of chickpea production on livelihoods. The partial budgets and opportunity costs of cultivating chickpea were calculated and gender and other social implications estimated (**Dave- please check**). The influence of seed priming on the decision to adopt chickpea was also determined.

Outputs

All the anticipated outputs have been achieved and they are briefly described below.

1. **Benefits of priming chickpea seed confirmed**

Chickpea has proved to be a suitable crop for growing rainfed after rainy season rice in the HBT of Bangladesh. This area was traditionally left fallow during the winter (*rabi*) season due to limited irrigated potential and difficulties of soil cultivation. The key to successful chickpea cropping in the HBT is ensuring reasonable crop establishment, before the surface soil dries. Seed priming was used as a vehicle to promote further expansion of chickpea in the HBT. Multilocation, farmer managed evaluation of priming response was conducted at many locations across the HBT over four years (1998-2002) (Johansen and Musa, 2000; Musa, 2001, 2002; Musa et al. 2001). It confirmed the beneficial effect of seed priming on chickpea grain yield (Table 1) and various yield contributing factors such as plant population, seedling growth vigor, time to maturity, incidence of soil-borne disease, and nodulation. Mean response to priming in grain yield ranged from 22 to 48% and the effects were found to be inversely proportional to winter rainfall (Table 1), further demonstrating the value of seed priming in drought-prone situations.

Table 1. Mean grain yields of chickpea with and without priming across the High Barind Tract over four seasons in farmer-managed, operational scale plots.

Rabi season	No. of on-farm trials	Grain yield without priming (t/ha)	Grain yield with priming (t/ha)	Yield response to priming (%)	Rainfall during chickpea growing period (mm)
1998-99	30	1.11	1.63	47	0
1999-2000	99	1.20[1]	1.45[1]	22[1]	105
2000-01	101	0.61	0.90	48	0
2001-02	50	0.82	1.12	37	16

1. Applies to only 35 trials from which quadrat samples were taken; in the remaining 64 trials mean farmer-estimated yields for primed were 1.25 t/ha and non-primed 1.02 t/ha, still giving a yield response of 22%.

2. Understanding of factors affecting adoption of chickpea technology

Seed priming technology, along with introduction of improved chickpea varieties and recommended use of phosphorus fertilizer, were widely demonstrated; inducing substantial farmer adoption of the technology in the 2001-02 season (Table 2). Seed of improved chickpea varieties particularly suitable for the HBT, such as Barichola 2 and Barichola 5, were widely disseminated as a result of project activities. The Pulses Research Centre (PRC) of BARI and Department of Agricultural Extension (DAE) voluntarily participated in seed production, demonstration and extension activities. Techniques of seed preservation and storage at village level were successfully tested, to encourage village-level enterprenuership in chickpea seed production and supply, and farmers trained accordingly (Musa 2001, 2002; Musa et al. 2001).

Table 2. Adoption of seed priming of chickpea in the High Barind Tract.

Season	Primed experimental area (ha)	Primed demonstration area[1] (ha)	Priming through farmers' initiative (ha)	Total primed area (ha)
1998/99	2	-	-	2
1999/2000	7	2	5	14
2000/01	8	60	25	93
2001/02	4	33	2,306[2]	2,343

1. Includes seed production and demonstration area. For demonstrations, 50:50 priming:non-priming was requested but farmers preferred to prime almost all plots. Thus 50% of these values are really priming on farmers' own initiative.
2. The most conservative estimate of Saha (2002); PROVA estimates about double this area.

In back-up research conducted under the project, genotypic differences were noted in priming response of chickpea, with improved varieties Barichola 2-5 responding to priming more than a local chickpea cultivar. Other *rabi* crops suitable for growing under rainfed conditions in the HBT, viz. wheat, barley, mustard and linseed, were also found to respond to seed priming under HBT conditions (Musa et al. 2001).

Detailed root excavations showed that chickpea roots could penetrate to at least 1 m depth in this HBT soil of high bulk density (Ali *et al*. 2002). However, root proliferation was less in HBT soil than in other soils with lower bulk density. Genotypic differences in root proliferation capacity, earlier demonstrated in studies at ICRISAT, were found to hold in the HBT environment; namely ICC 4958 was found superior in this regard. Soil moisture remained adequate below 40 cm soil depth well into the cropping season (e.g. mid-Feb) and thus deep rooting crops could exploit it (Ali 2000). Barley, mustard and linseed were also shown to have deep rooting capability in HBT soils, penetrating beyond 75 cm (Musa *et al* 2001). By contrast, most lentil roots remained near the soil surface and they did not penetrate beyond 60 cm.

Various experiments were done to determine the need to inoculate *Rhizobium* so as to ensure satisfactory nodulation and nitrogen fixation (Musa *et al*. 2001). Responses of nodulation, plant aerial biomass and grain yield to inoculation were found, but inconsistently. Generally, responses were greater at sites with low soil *Rhizobium* population and when levels of soil moisture and available phosphorus (P) were adequate. Acid surface soil (pH 4.8-5.5 at 0-10 cm) and other growth limiting factors complicated interpretation of *Rhizobium* inoculation responses and the conditions under which *Rhizobium* inoculation should be used in the HBT are yet to be established.

Most soils of the HBT have very low levels of available P (<1ppm P, Olsen's), and chickpea generally responds to P application. However, in some fields high levels of Olsen P have been recorded (>10 ppm), probably resulting from residual P applied to previous rice crops. Experiments are underway to determine the extent to which P applied to preceding rice can meet the needs of chickpea, which is known to be an efficient crop in acquiring soil P (Musa *et al*. 2002).

To determine if elements in addition to N and P are limiting chickpea, subtractive experiments were conducted in small field plots. In the 2001-02 season, a substantial response of chickpea to molybdenum (Mo) application was found, which is consistent with the presence of acid topsoil in HBT soils (Musa *et al*. 2002). Grain yield in plots without Mo, but with priming, *Rhizobium* inoculation and all other elements that could conceivably be limiting yield, was 0.97 t/ha. In the control treatment with Mo, the yield was 1.63 t/ha, a 73% response to application of Mo. Although further multi-locational, confirmatory trials on Mo response are required, a widespread Mo deficiency is consistent with the N deficiency symptoms commonly seen in chickpea during Jan-Feb in the HBT, and may contribute to the observed unclear, or even lack of, yield response to *Rhizobium* application. Thus future need-to-inoculate trials should be conducted in the presence of Mo.

During the 2001-02 season, NPV was multiplied and tested in chickpea fields. Effectiveness of NPV in reducing incidence of *Helicoverpa armigera* pod borer larvae was confirmed, but magnitude of effect depended on time of the season that NPV was sprayed and extent of infestation (Musa 2002). An IPM strategy for minimizing pod borer damage on chickpea was developed, involving use of NPV, regular scouting, placement of bird perches and use of mixed cropping.

3. Influence of seed priming on farmers' decision to adopt chickpea quantified

Socio-economic surveys showed that farmers were influenced to adopt chickpea by being exposed to the negligible-cost priming technology which resulted in 20-50% yield increases (Table 1 & 2). However, in addition to priming, an improved agronomic package was presented to farmers, essentially consisting of an improved variety, appropriate sowing/tillage, use of triple super phosphate (TSP), insect management and seed preservation. The improved package was demonstrated at various locations throughout the HBT, with the assistance of DAE. In areas sown for chickpea demonstration and seed production, it was intended that at least some non-primed plots be sown adjacent to primed areas, to be able to further demonstrate the priming effect, but farmers involved were reluctant to do so as they were convinced that failure to prime would result in a yield penalty. This was evidence of ready adoption of the technology.

4. **Profitability and socio-economic consequences of growing chickpea quantified**

Among both rainfed (e,g linseed) and irrigated (e.g boro rice, wheat) rabi crops, rainfed chickpea proved to be the most profitable crop at most locations surveyed (except one location where yields of all rainfed crops were very low). This was due to both low input costs (c.f. high input costs for irrigated crops) and high and increasing prices of chickpea grain (which are showing a continually increasing trend due to short supply of chickpea in Bangladesh). In the almost rainless Rabi season of 2001-02, farmers could realize up to Tk 16,000/- per ha profit from chickpea cultivation on owned land and up to Tk 9,000/- per ha from leased land or by share cropping. Rural household economies of the HBT are dominated by rice cultivation, which is progressively becoming less remunerative, even with availability of irrigation. Thus crop diversification, particularly to high value rainfed crops with minimal input requirements, represents an important avenue for poverty alleviation in the region.

Contribution of Outputs

Farmers are readily adopting the simple seed priming technology along with improved chickpea varieties and other optimum cultivation practices. This low-cost, simple priming technology has indeed been used as a vehicle to introduce other improvements in chickpea production in the region, such as insect pest management and seed storage techniques. An adoption and impact analysis of the project assessed the effects of project intervention on livelihoods of the rural community in the HBT (Saha 2002). The high and annually increasing prices of chickpea grain suggest that increased cultivation of this crop would significantly improve livelihoods in the region; reasonable yields (>1 t/ha) are currently more remunerative than irrigated *boro* (winter) rice or wheat (these irrigated cereals have high yields but inevitable high input costs).

a) **What further studies need to be done?**

Although the project has successfully introduced technologies that can be managed by resource-poor farmers, and the adoption process of these has been initiated, continued project intervention is needed to significantly expand upon project gains to date. Large-scale extension of project-derived technologies is needed to induce significant adoption, which will require the direct and formal involvement of DAE and possibly other NGOs besides PROVA. Key technologies requiring extension include improved varieties (e.g. Barichola 5), priming, sowing method, IPM techniques, and seed preservation and storage. A village level seed preservation and storage scheme is only into its second year of operation and would need expanded support and training inputs if it is to become sustainable. This appears to be the most viable means of disseminating seed of improved chickpea varieties in the HBT on a large scale and at a rapid rate as demands are not likely to be met from either Government or commercial sources. Continuing back-up research is needed to identify practical means of alleviating nutrient limitations (e.g. Mo deficiency), commercialize NPV production and distribution, identify alternative Rabi crops to chickpea (such that chickpea would not be continually grown on the same land and thus succumb to soil-borne diseases), and develop improved chickpea varieties for future release in the HBT.

b) How the outputs will be made available to intended users?

Large-scale extension of project-derived technologies is needed to induce significant adoption, which will require the direct and formal involvement of DAE and possibly other NGOs besides PROVA. Key technologies requiring extension include improved varieties (e.g. Barichola 5), priming, sowing method, IPM techniques, and seed preservation and storage.

c) What further stages will be needed to develop, test and establish manufacture of a product?

Improvements in *rabi* cropping in the HBT need to be considered in the context of the entire t. *aman*-based cropping system of the HBT. Farmer preference for the late maturing, but high quality, rice cultivar Swarna (135-145 days duration) in the HBT reduces the opportunity for establishing *rabi* crops on residual moisture. The Bangladesh Rice Research Institute (BRRI) has released short duration varieties (125-130 days) –

BRRIdhan 32 and BRRIdhan 39 – that mature by mid-November if transplanted by early July. However, there are problems with farmer adoption of these varieties, such as lodging in BRRIdhan 32 and farmers' preference to use BRRIdhan 39 for late transplanting (thereby negating early harvest to favour *rabi* planting). Another option to ensure timely harvest of rice for planting of a *rabi* crop is direct seeding. In this case, however, weeds become a major constraint. A DFID-funded project "Developing Weed Management Strategies for Rice-Based Cropping Systems in Bangladesh" (R 7471) has been addressing this weed constraint in both transplanted and direct seeded rice in the HBT, during the same period of operation of Project R 7540, namely 01-09-99 to 31-09-02. The project has characterized the weed ecology and yield losses involved, and farmer practices and perceptions regarding weeds. Integrated weed management strategies have been developed, including the use of herbicides. Interactions between management of weeds, nutrients and water have also been studied. Various options are now available for improved management of the rainfed rice crop that would both alleviate existing constraints to rice yields and permit timely sowing of a *rabi* crop.

d) How and by whom, will the further stages be carried out and paid for?

A follow –up project is essential, with the support of DFID/PSP, to promote additional rainfed *rabi* crop production in the HBT, and hence improve poor farmers livelihoods. Synergies can be gained by merging Projects R 7471 and R 7540, as they are addressing improvement of the same rainfed, rice-based cropping system. Further expansion of rainfed *rabi* cropping in the HBT will be enhanced by development and adoption of reliably high yielding rainfed rice systems whereby the crop is harvested by mid-November. To realise this synergy, it is proposed that CPP and PSP provide continued support such that the positive outcomes from Projects R7471 and R7540 can be translated into improved livelihoods for the rural community of the HBT.

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