CROP PROTECTION PROGRAMME

Promotion of cost-effective weed management practices for lowland rice in Bangladesh

R8234 (ZA 0542)

FINAL TECHNICAL REPORT

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Executive Summary

The project scaled-up the validation and promotion of weed management practices previously evaluated by CPP project R7471 (2000-2002). These have potential for limiting yield losses in rice due to weeds and, increasing productivity and the stability of rice-based livelihoods in Comilla Region (rice/rice representative of 2 million ha in Bangladesh) of the High Barind Tract (rice/post-rice crop systems representative of 1.4 milion ha nationally). On-farm trials and demonstrations, managed in partnership by research, extension and NGOs, with associated field days were used to assess technology options and promote awareness of "best-bet " practices to the farming community. Appropriate training material was developed and use was made of the private sector to disseminate knowledge of safe and effective use of herbicides.

Trials and demonstrations at 73 and 240 sites respectively in rainfed monsoon and irrigated rice seasons demonstrated that herbicide use is a robust, labour and cost saving approach to weed control across a range of water management scenarios. Herbicide promotion by the private sector in selected districts resulted in sales increasing by 43% between 2002 and 2003. Both farmers and extension workers need information about safe and profitable herbicide use and on the integration of herbicides with cultural practices. R8234 has collaborated with the NGO SAFE, to examine a partnership between the NGO and the herbicide manufacturer Syngenta, resulting in the preparation of a training manual on herbicide use to be distributed to all upazilla agricultural offices in Bangladesh. The project has also raised awareness of information issues in the private sector by a seminar and discussions with 9 companies selling herbicides. A poster covering key issues on safe and efficient use of herbicides has been prepared and distributed for display in pesticide dealers stores throughout Comilla District.

Pre-emergence application of herbicides resulted in *aman* rice yields under direct seeding as good as or better than from transplanting in four seasons of replicated trials in the Barind. In 2003 and 2004, yields of improved early maturing and one widely grown local variety from dry direct seeding or wet seeding were equivalent to those from transplanting in on-farm trials and farmer managed field scale evaluations. Establishing the crop in this way, often a month earlier than is possible when transplanting, accelerates harvesting by 5 to 10 days. Assessment with farmers suggests that this increased the window of opportunity for seeding chickpea and other crops onto residual moisture has the potential to increase the area planted to *rabi* crops and hence the productivity of and incomes from Barind systems. Farmer evaluation of direct seeding across 70 sites in 2004 provided important lessons on the need for timely and quality tillage, key aspects of the knowledge that farmers will need to achieve good rice stands and adequate weed control. Monitoring of weed responses over the past four years indicates likely shifts in species abundance with change in management practices. Increased abundance of difficult to control grasses and sedges with direct seeding can be countered by supplementary hand weeding.

Access to knowledge is the key for farmers to take advantage of the new rice management opportunities. An extension to R8234 up to January 2006 will be used to consolidate knowledge and make it accessible in a form that enhances understanding of the new technology, promotion by extension, and adoption by farmers. This will be achieved by developing a decision support framework that will distil research findings into an inter-linked set of decision-tools for improved weed management for transplanted and direct seeded rice and for transition between both.

1.0 Background

Widespread adoption of fertiliser-responsive modern varieties (MVs) and, the expansion of the area under irrigation have driven the increase in rice production over the past 20 years in Bangladesh. To keep pace with internal demand it has been estimated that paddy production will need to increase from the current level of 22 million to 50 million tons by 2020 (Hossain, 2002), an annual growth in yield of 1.5 to 2.0 % per year. While plant breeding will continue to play a pivotal role, there has already been extensive adoption of high yielding MVs. In Comilla District for example, which has long been in the forefront of adoption of modern rice production practices, 80% and 100% of *aman* and *boro* crops respectively were planted to MVs by 1999 (BBS, 1999). Future increases in rice production will therefore also depend on improvements in the efficiency with which inputs are used. Closing the gap between the rice yields achieved by the best farmers and those with only average yields has now become a high priority. Reducing this yield gap will largely depend on improvements in farmers' management practices. Characterisation work by completed CPP project R7471 (Orr and Jabbar, 2002) and needs assessments undertaken independently by the Dhaka based DFID funded Poverty Elimination Through Rice Research Assistance (PETRRA) (Parul, 2000) have confirmed that weed control is a major cost to farmers in the rice production cycle in Bangladesh. On-farm studies have been undertaken by project R7471 in rain-fed rice-fallow/rice-rabi cropping (Rajshahi district), and in multiple intensive irrigated cropping systems (Comilla district). These have demonstrated that a significant component (0.5 –1.5 t grain / ha) of the yield gap (the difference between current on-farm yields and best practice attainable yields) can be explained by sub-optimal weed control. This, and the results from research and on-farm trials in both areas, suggests that there is considerable scope for raising average rice yields by improving weed management (Ahmed *et al* 2001; Mazid *et al* 2001).

Project R7471 made considerable progress to:

- Characterise rice-cropping systems, focusing on the role of weeds as a constraint to yield and system productivity.
- Understand both agronomic and socio-economic dimensions of weeds as a yield constraint, and their interactions to provide a systems framework for the development of weed management practices.
- Understand the factors that determine variability in weed flora composition and persistence, to provide a basis for the integration of crop establishment and in-crop weed control practices which impact on the long term persistence of weeds.
- Evaluate the role of weed management practices in reducing yield loss due to weeds in order to improve labour and system productivity.

The High Barind Tract includes 12% of the drought prone rainfed lowland rice in Bangladesh. Drought early in the season causes delays in transplanting while an early cessation of the rains in October impacts on grain filling and also leads to low yields. Due to the limited irrigation potential of the area there is relatively little production of *boro* (irrigated) rice in the dry *rabi* season. Thus much of the land lies fallow during the *rabi* season. Work undertaken by the Bangladesh Rice Research Institute over the past 12 years has led to the development and testing of a system which can allow farmers to increase cropping intensity by more reliable establishment of a *rabi* chickpea crop. This can be achieved by direct seeding a short duration rice variety to reduce field duration to 125-130 days, thereby releasing land when there is still sufficient moisture for *rabi* crop establishment. However, weeds are a major constraint to adoption as the advantage of effective weed control prior to transplanting through puddling is lost when rice is established by direct seeding.

Farmers had found the weeding labour input to direct seeded rice unacceptably high in on-farm trials conducted by BRRI/RLRRC (Mazid *et al.,* 2001).

There are therefore two situations in which the promotion of improved weed control to contribute to increased rice productivity in the Barind; in the existing transplanted *aman* (T-*aman*) and in rice established by direct seeding. R7471 has identified that late first weeding is a feature of T- *aman* in the Barind, partly due to a labour constraint but also due to inadequate farmer knowledge compared to other areas of the country. Trials completed by R7471 have shown that one application of the pre-emergence herbicide oxadiazon, used in combination with a follow-up hand weeding allows the direct seeded rice crop to establish and grow in weed free conditions early in the season and to produce yields comparable with transplanted rice. Widespread validation herbicide use in T-*aman* and of direct seeding with herbicide use by farmers, was therefore needed as the next step in the promotion of these components of an improved, low labour demanding and productive *aman* rice/*rabi* system.

With some 50% of the 482,000 ha of cultivated land in Comilla District under irrigation, double rice cropping (57% of the area) and triple rice cropping (26%) result in a cropping intensity of 209% compared to a national average of 134%. Transplanted *aman* rice in the monsoon season is found in two cropping patterns of which the double crop *boro* – Fallow – T.*aman* pattern occupies the largest area in the district with an average rice productivity of about 8 tons/ha (Nur-E-Elahi et al., 1999). Nationally this pattern covers about 2 million ha, producing approximately 50% of the country's rice crop. Comilla district was in the forefront of the adoption of Green Revolution technology. The farmers' major weed management practices are hand weeding and the use of a push weeder. Use of weeders is inefficient under conditions of poor water management and infestation by perennial weeds e.g. *Paspalum disticum*. Studies undertaken by project R7471 in Comilla have identified that labour constraints on timely weeding have increased, as farmers largely rely on migrant labour. Real wage rates for weeding labour have risen and this has increased demand for herbicides. Herbicide use is still at an early stage, but conditions appear ripe for rapid adoption particularly for irrigated *boro* rice. Analysis by the project suggests that sharecroppers whose primary concern is to ensure they retain a higher net quantity of the *aman* yield are among those willing to adopt herbicides that boost yields by reducing losses from weeds. On-farm trials undertaken in Comilla during both *aman* and *boro* seasons demonstrated that yields following weeding with a mechanical push weeder or after using herbicides are at least as good as those on fields that are hand weeded.

Timely weed control and use of herbicides are knowledge intensive and if improved weed control is to provide sustained increases in yield and productivity it will be vital to pay adequate attention to farmer training. As farmers begin to adopt herbicides they need a wide range of information on how to use this technology safely and in a cost-effective manner. R7471 identified that pesticide dealers and company representatives have played a key role in providing farmers with information about herbicides where before there was a knowledge gap in the farming community. As the number of farmers adopting herbicides increases, as an increasing range of products become more widely available, there is a need for the extension service, companies and other stakeholders to get together to plan for a more comprehensive provision of information. R7471 identified the need for a study to identify gaps in knowledge and ways of improving the effectiveness of delivering herbicide knowledge to farmers as the basis for the development of extension and farmer training materials.

Results from R7471 provided a platform from which to scale-up validation and promotion of weed management options. Further work was therefore designed to be implemented by R8234 to address the challenge of how to close the yield gap between the best on-farm yields and those of the majority of growers, through the promotion of a range of sustainable weed management options. Progress in this area has the potential to contribute to twin objectives of increased rice yield and improved labour productivity. Both are central to the livelihoods of predominantly resource poor rice farmers who derive much of their income from rice sales. Household surveys conducted by R7471 have shown that, depending on village, some 54-88% of households cultivate less than 1 ha in Comilla and Rajshahi districts. Tenants cultivate approximately 26 and 46% respectively of the land, in the two districts, mostly under share-crop arrangements. Cost-effective rice production is a central component of rural livelihoods with farm production accounting for 74% of total household income in Comilla and 81% in Rajshahi (Orr and Jabbar, 2002). Demand for improved and timely weed management has been demonstrated by high cash expenditure on hired labour for weeding, adoption of the rotary weeder (in Comilla district) and rapid growth in sale of herbicides for rice in both districts.

2.0 Project Purpose

The purpose of the project was “Promotion of strategies to minimise impact of target pests in rice-based Land-Water interface cropping systems, for benefit of poor people”. Specifically the project was designed to scale-up the testing and promotion of practices evaluated by CPP project R7471 which had shown potential for reducing yield losses in rice due to weeds, overcoming labour constraints and increasing the productivity of and income from lowland rice. The objectives of the project are to validate and promote weed management practices which will lead to an increase in the productivity and stability of rice-based livelihoods among resource-poor farm households in Comilla Region (rice-rice) the High Barind Tract (rice-fallow or rice-rabi based systems).

3.0 Research Activities

Activities were implemented by the core team of staff from Bangladesh Rice Research Institute, International Rice Research Institute and Natural Resources institute who had collaborated R7471. Additional partners from two NGOs and the Department of Agricultural Extension contributed to the programme of field demonstrations. From the private sector the herbicide manufacturer Syngenta collaborated in the use of the herbicide supply chain for providing farmers with information on chemical weed control. Staff members contributing to the work programme are shown below.

The Project Team

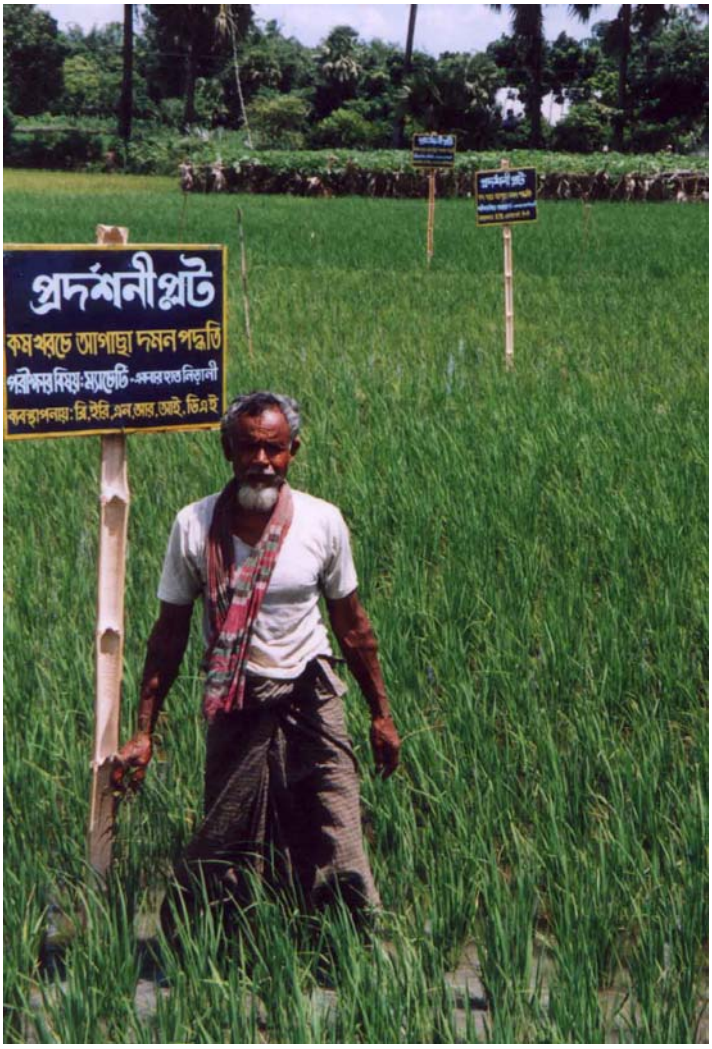
Natural Resources Institute	Dr C Riches	Project leader, Agronomist
	Dr A Orr	Economist
International Rice Research Institute	Dr M Mortimer	Weed Ecologist & Biometrics (University of Liverpool from 08/03)
	Dr D Johnson	Weed Scientist (from 09/03)
Bangladesh Rice Research Institute	Dr J Uddin Ahmed	Weed Scientist
	Dr MA Mazid	Agronomist/Physiologist
	Dr MA Jabber	Economist
	Dr M Lotif	Plant Pathologist
	Mr K Bhuiyan	Agronomist
	Mr B. Karmakar	Agronomist
Peoples Resource Oriented	Mr M A Musa	Agronomist
Voluntary Association	Dr C Johansen	Agronomist
SAFE Development Group	Mr Gopal Chowan	Social Development
Syngenta Bangladesh Limited	Mr M M Rahman	Product Development Manager
Department of Agricultural Extension	District, Upazilla level management and Block supervisors in Comilla, Chapai Nawbgonj, Naogaon and Rajshahi Districts	

3.1 Output 1. Validation and promotion of the sustainable intensification of rice-rice farming systems through integrated management of weeds and water.

Activities for this output focused on the intensive T *aman*/*boro* system in Comilla District in Eastern Bangladesh. Field activities were managed by Dr Uddin Ahmed from BRRI HQ assisted by staff from BRRI Comilla sub-station and a field officer was stationed in Comilla to oversee field-work. Through the course of the project on-farm trials and demonstrations were conducted in Baruara, Burichang, Comilla Sadar, Debidwar, and Homna Upazillas (district sub-divisions). Sites offices were maintained in villages in Burichang and Comilla Sadar.upazllas to provide focal points for information and meeting for farmer group participants and block supervisors (village level extension officers).

3.1.1 On-farm trials: OFTs focused on validation of the benefits of adoption of weed management options in intensive rice production in *boro*/T-*aman* systems. Participatory on-farm trials were implemented in order to investigate the effectiveness of, and economic risks associated with, a range of practices under variable field conditions, especially in relation to water supply. Depth of water varies in fields in T-*aman* due to plot position and soil type while timeliness of access to water in *boro* is also variable from field to field. Six herbicide and mechanical weeding based options were compared side by side in each season to determine the conditions under which each one is effective and profitable. In the *boro* season sites were purposively selected where timing of irrigation water could be controlled for comparison with sites where water was poorly controlled, essentially on fields distant from tube wells. Training was provided at the beginning of each season to participating farmers who applied herbicides and weeder treatments with supervision of researchers and DAE BSs. Data collection included: depth of ponded water at herbicide application, after 7 days and in *boro* before and after each irrigation; weed biomass and weed species composition at 25 and 45 days after transplanting (DAT), yield, dates of all operations. Different fields were used in each year and season with trials completed at a total of 73 sites as follows:

Year/Season	Upazilla	Villages	Sites
2003 - *boro*	Burichang, Comilla Sadar	2	12 (3 good and 3 poor water management per village)
2004 - *boro*	Burichang, Comilla Sadar, Debidwar	3	22 (11 good and 11 poor water management per village)
2003 - *aman*	Burichang, Comilla Sadar, Debidwar	3	19
2004 - *aman*	Burichang, Comilla Sadar, Debidwar	3	20



Demonstration plots in Baruara upazilla in the *boro* season 2004

Treatments were superimposed on fields managed by farmer's choice of variety, planting date and nutrient management. All herbicides were applied within 5 days of transplanting by knapsack sprayed, except for granular Machete that was broadcast, and a follow-up hand weeding was undertaken at 30 DAT.

1. Rifit (pretilachlor 470 g a.i. ha^{-1}) + one hand weeding;
2. Argold (cinmethalin 7.5 g a.i. ha^{-1}) + one hand weeding;
3. Machete (granular butachlor 1.25 kg a.i. ha^{-1}) + one hand weeding;
4. Hand weeding at 15 and 30 DAT;
5. "BRRI" rotary push weeder at 15 DAT + one hand weeding at 30 DAT;
6. Farmer practice weed management – this was either one or two hand weedings with variable timing;
7. No weeding.

Socio-economic research supported the OFTs to provide an economic ranking of weed management options. In addition, a farmer evaluation was conducted using informal methods to elicit farmers' views on the effectiveness of the proposed interventions and identify possible constraints on uptake.

3.1.2 Demonstrations to promote weed management options: In villages, selected in collaboration with DAE, demonstration plots were set up with participation of farmers. Weed control options were explained to farmers during pre-season training sessions by DAE with BRRI support. Participating farmers each choose one option for evaluation in their own rice crop in comparison with their own practice. This activity was undertaken in both *boro* and *aman* seasons at a total of 280 sites in four upazillas over two years. New sites were selected in each season and year to ensure as great a demonstration effect as possible. Farmers selected from the following options:

1. Rifit (pretilachlor 470 g a.i. ha^{-1}) + one hand weeding;
2. Argold (cinmethalin 7.5 g a.i. ha^{-1}) + one hand weeding;
3. Machete (granular butachlor 1.25 kg a.i. ha^{-1}) + one hand weeding;
4. Ronstar (oxadiazon 360g a.i. ha^{-1}) + one hand weeding;
5. "BRRI" rotary push weeder at 15 DAT + one hand weeding at 30 DAT;

A minimum set of data including water depth at herbicide application, weed infestation at 45 DAT and yield was collected at demonstration site. Selected sites were used by DAE for field days so as to raise farmer awareness of the available weed control options. At least one field day was held each season in each upazilla attended by 30 to 35 farmers and local extension officers. Demonstration sites were all located adjacent to roads and large signboards indicated the weed control practice used. Village meetings prior to the season, the signboard and field days all contributed to raising awareness of improved weed management in target communities. Demonstrations were undertaken as shown below.

Year/Season	Upazilla	Sites
2003 - *boro*	Burichang, Comilla Sadar	20
2004 - *boro*	Burichang, Comilla Sadar, Debidwar, Baruara	80
2005 - *boro*	Burichang, Comilla Sadar, Debidwar, Hamna	40
2003 - *aman*	Burichang, Comilla Sadar, Debidwar, Baruara	80
2004 – *aman*[*]	Burichang, Comilla Sadar, Debidwar	60

[*] Demonstrations also set up at 10 sites in Baruara upazilla but were destroyed by flooding at ± 55 DAT

3.1.3 Evaluation of public-private sector partnership for delivery of information on weed management to farmers: Project R7471 identified the role played by pesticide dealers in providing farmers with information on herbicide use and the potential for forming partnerships between the private and public sectors to enhance information flow (Riches *et al*., 2002). The Bangladesh based PETRRA research facility agreed to funding the NGO SAFE to undertake the project "Improved Information Flows from Private-Sector Suppliers for Weed Management in Rice" during the period October 2002 to June 2004. This work involved SAFE setting up farmer field schools focusing on herbicide use in Debidwar and Burichang upazillas to undertake farmer training in collaboration with Syngenta. Project R8234 assisted SAFE with training of field staff at a pre-season seminar and with the design and analysis of a Knowledge, Attitudes and Practices study in Comilla, focusing on herbicide information flow. Subsequently the project worked with SAFE and Syngenta to evaluate and learn lessons from of their partnership in order to identify any policy implications of the role of such partnerships as an uptake pathway to complement state-run extension services. R8234 also facilitated a seminar that brought together management of nine herbicide supply companies to explore the wider role of the private sector in disseminating weed management knowledge to farmers.

3.1.4 Development of non product-specific information on herbicides to support promotion by private sector and DAE and other dissemination activities: Collaboration with the NGO SAFE and Syngenta Bangladesh led to the development and printing of two training tools, a Rice Weed Management Training Manual and a poster covering key messages for effective and safe use of herbicides. These have been distributed widely in Comilla district and elsewhere in Bangladesh (see section 4.1.4). Two meeting were held to disseminate results to extension officers in Comilla District in March 2003. A one-day seminar was held on March 15th to raise the awareness of DAE managers at district and upazilla level of the importance of timely weed management and the available options. Research under R8234 had been conducted in one village in each of four upazillas. The seminar was an opportunity to inform extension managers from the nine upazillas in the district of opportunities for up-scaling promotion of improved weed management practices. Senior staff of a number of herbicide manufacturers and distributors also attended the meeting. On 2nd March a one day workshop was held to train 62 block supervisors from Comilla Sadar upazilla on "effective weed management"

3.2 Output 2. Validation and promotion of the sustainable intensification of rice-fallow farming systems through improved weed management and expanded winter cropping.

This output focused on the promotion of knowledge of improved weed management in rice with more reliable *rabi* cropping in the High Barind Tract. On-farm demonstrations were undertaken to promote improved weed management for T-*aman* in Chapai Nawbgonj, Naogaon and Rajshahi Districts in partnership with DAE and PROVA. A trial to study the long-term impact of direct seeding and herbicide use on weed populations and crop yields, initiated by R7471, was for a further three *aman/rabi* cycles. On-farm trials and participatory field-scale evaluations of direct seeding were implemented in three districts to derive an understanding the opportunities for adoption of rice direct seeding/modified weed control in terms of toposequence (landscape) niche, household and land tenure issues. These activities were designed to facilitate promotion of the knowledge that had been generated by project R7471.

3.2.1 *Evaluation of rice production practices in rice-chickpea systems*: A long term trial was established at Rajabari, Rajshahi district by the IRRI co-ordinated Rainfed Lowland Rice Research Consortium in the *aman* season of 1999. The trial was modified and monitored for three cycles of *aman*/*rabi* rotations by R7471 and was run through 2003 and 2004 *aman* and *rabi* seasons by R8234. The trial provided an important database from which to predict changes in the dominance of components of the weed flora with changing rice production practice and information which can be used to analyse the production constraints and opportunities from different systems. The modern variety, BRRI dhan 39 (maturity 120 - 125 days), is compared with the widely grown Swarna (maturity 150 – 155 days). The trial uses a split-split plot design with main plots (3) as crop establishment and associated weed management, sub plots (4) nutrient management and sub-sub plots (2) as varieties. Rice establishment treatments are 1) *Transplanted rice (TPR)* - soil puddled prior to transplanting and plots hand weeded twice at 30 and 45 days after transplanting (DAT); 2) *Direct seeded rice (DSR)* - soil ploughed prior to dry seeding (2001 and 2004) or ploughed and puddled before direct seeding of pre-germinated seed (2002 and 2003) in rows by hand with hand weeding at 21, 33 and 45 days after sowing (DAS); 3) *Direct seeded rice with chemical weed control (DSRH)* - as for DSR but with oxadiazon (375 g a.i./ha) applied 2-4 days after seeding with one hand weeding at 33 DAS. Chickpea (cv. Barisola 2) was broadcast sown onto residual soil moisture after harvest of direct seeded rice and covered with soil by cross ploughing with an ox-drawn country plough. In addition to rice yields, weed biomass was recorded in two unweeded quadrats per plot at 28 days DAS/DAT and total weed biomass at 25 and 45 DAS/DAT. The soil seedbank was sampled to determine changes in weed species dominance after the 2003 rice harvest.

3.2.2 *On-farm validation of direct seeding of rice with appropriate weed control*: Trials were undertaken at 16 on-farm sites during the 2003 *aman* season to verify the profitability of a DSR rice-chickpea system. Chickpea (cv. Barisola 2) was sown after harvest of Swarna or three shorter duration BRRI dhan varieties (maturity 140-145 days) established by either transplanting or direct seeding. Prior to dry direct seeding in June the land was ploughed (at least x 3) with an animal drawn country plough and levelled with a ladder. Seed was sown in lines by hand into furrows opened by a hand pulled lithao. Seedbeds were established at the same time and seedlings were transplanted at approximately 30 days after sowing following conventional ploughing and puddling operations. In direct seeded rice a single application of oxadiazon (375 g a.i. /ha) was made to control weeds whereas in transplanted rice pretilachlor (450 g a.i./ha) was applied. Heavy rain in the last week of June 2004 flooded trial sites across the Barind preventing dry direct seeding. This treatment was substituted by planting pre-germinated seed with a drum seeder (model imported from Vietnam) on to puddled soil. Weed control was similar to the system used for dry seeding the previous year. Chickpea was once again planted after rice harvest but had not been harvested when this report was prepared.

3.2.3. *Field-scale evaluation of direct seeding*: Evaluations of three practical methods of direct seeding rice on a field-scale, rather than on small research plots, were undertaken in three districts of the high Barind Tract during *aman* 2004. The NGO PROVA managed the evaluation of direct seeding on field-scale plots on-farm in nine upazillas across Chapai Nawbgonj, Naogaon and Rajshahi Districts. Initially training of block supervisors from participating villages was undertaken to provide them with knowledge about direct seeding and effective herbicide use. Two plots, each of 0.5 bigha (666 m^2) were planted at each site as shown:

Direct seeding (DSR) using Ronstar + one hand weeding	Transplanting (TPR) using Machete + one hand weeding

It had been planned to plant direct seeded plots by broadcasting of dry seed. However the inundation of fields following 300 + mm of rain in a single day in the last week of June prevented dry seeding at many sites so the drum seeder was used instead. Ronstar was applied after drum seeding of pre-germinated seed. In total plots were taken to harvest at 13 broadcast and 13 drum seeded sites out of 59 that were planted. Reasons for failure elsewhere were monitored in detail to learn lessons on how best to undertake direct seeding. Farmer group meetings were held during the season in all upazillas to collect information on farmer perceptions of direct seeding.

Dry seed of Swarna and variety BR 31 (duration 140-145 days) was sown into shallow furrows made by a manually drawn lithao on a number of fields managed by a group of farmers in Rajshahi district who had previously seen the technique used in research trials. The lithao opens three rows at a time into which seed is sown by hand. Fields were levelled with an ox-drawn ladder to cover the seed after sowing. Weed control was by oxiaiazon applied after seeding with a single follow-up hand weeding when necessary.

3.2.4 *Scaling-up of demonstration of T-aman rice followed by chickpea system in two districts of the High Barind Tract in collaboration with DAE*: In 2003 PROVA and DAE worked with farmer groups at 100 sites in the Barind to demonstrate timely weed control in *aman* rice with the granular herbicide Machete. Following the rice harvest plots were planted to chickpea in the *rabi* season. This activity was funded jointly by CPP and the DFID Plant Science Research Programme which was also collaborating with PROVA in a project on improved *rabi* cropping. At each site four plots were planted comparing two rice varieties and two methods of weed control:

Swarna Machete + one hand weeding	BR32 Machete + one hand weeding
Swarna Two hand weedings	BR32 Two hand weeding

Data will be collected on timing of operations, inputs, yields and farmer perceptions. Field days were held at a selection of sites prior to harvest.

3.2.5 *Analysis of economic returns from new technology and impact on resource-poor households*: Research focused, firstly, on the evaluation of new technology demonstrated through on-farm trials. A quantitative evaluation (cost-benefit analysis) was based on information on input use, input prices, and labour use provided by participating farmers. A qualitative farmer evaluation of direct seeding technology was also be made using focus-group discussions and individual interviews with participating farmers. Direct seeding systems and timely weed control with herbicides are both knowledge intensive. Socio-economic factors (labour resources, land tenure, household food security) are all likely to influence the adoption of new technology and the extent to which farmers can expand *rabi* cropping. These factors strongly influence the decisions farmers make about cropping strategies and practices. As the project progressed it became increasingly clear that there was a need to distil research findings into an interlinked set of decision-tools for improved weed management for transplanted and direct seeded rice and for transition between both in the Barind. Work on this consolidation of knowledge and provision in accessible forms to farmers (leaflets, posters etc) has been accepted by CPP as the basis for a 10-month extension to the project from April 2005. The decision support framework will address three domains in relation to policy, extension and on-farm technologies for weed management and be in the form of Policy Briefs, training of trainers modules, posters for pesticide retailers, or leaflets for farmers. A workshop was held with extension managers from Barind districts in Rajshahi in October 2004 to plan the future development of decision support tools. It was recognised that an important gap in our understanding of Barind systems concerns farmer decision making on *rabi* cropping practices and how *aman* management decisions affect *rabi* plantings. This information will form an important component of our assessment of the drivers of and the potential for wider uptake of direct seeding/*rab*i systems by resource poor farmers. It was therefore judged a higher priority to collect this information and to postpone farm-modelling work that had previously been planned by R8234, and indicated in the log-frame, until post-April 2005. Information on *rabi* decision making will also feed into the planned modelling work. This study will now be completed during the period of the project extension in order to suggest the resource groups of farmers most likely to be targets for the direct seeding/herbicide technology developed by BRRI and evaluated by this project.

4.0 Project Outputs

4.1 Output 1. Validation and promotion of the sustainable intensification of rice-rice farming systems through integrated management of weeds and water.

4.1.1 On-farm trials: As a key objective of on-farm trials in Comilla was to assesses the robustness of weed management options over a range of site and water management scenarios data from 2003 and 2004 was combined in one analysis for *boro* and *aman* seasons respectively. To compare both years, data sets were chosen such that two villages were compared (Chowara and Paruara) across all seven treatments, including 'good' and 'poor' water management in *boro*. The numbers of farmers participating in the trials differed in each season and so the design was unbalanced. Analyses were also done by season, to explore the role of covariates, in influencing yield, where appropriate. In this analysis, 'village' was considered to be a random effect factor, all others being fixed. Quasi F-ratios were calculated according to the expected means squares (Q in tables). Repeated measures analysis of variance was followed using approaches discussed by von Ende (2001). Both multivariate and univariate analyses were conducted and conservative approaches taken interpretation. Data were transformed where there was evidence of heterogeneity of error variance (Winer *et al*. 1991).

Weed management in *boro*: Analysis of rice yield data indicated only a significant effect of weed management practice among main effects and first order interactions as shown in the following table:

Source	DF	SS	MS		VR	P (Ho)
Weed control practice (T)	6	24918307	4153051		44.016	**0.0001**
Village (V)	1	56054194	56054194	Q	6.187	0.2434
Water management (W)	1	6880719	6880719		7.969	0.2167
V*T	6	566122	94354	Q	0.331	0.9536
V*W	1	863459	863459	Q	0.771	0.5412
T*W	6	493122	82187		0.217	0.9573
V*T*W	6	476504	79417		1.390	0.3497
Year (Y)	1	9318529	9318529		1.171	0.4749
Y*T	6	817808	136301		0.360	0.8802
Y*V	1	7955287	7955287	Q	5.369	0.2594
Y*W	1	6123592	6123592		5.497	0.2567
Y*V*T	6	2269943	378324		6.623	**0.0184**
Y*V*W	1	1113984	1113984		19.500	**0.0045**
Y*T*W	6	322778	53796		0.942	0.5281
Y*V*T*W	6	342760	57127		0.239	0.9630

Interactions between years x villages x weed control treatments and between years x villages x treatments were also significant. There was a trend for higher yields on more water retentive soils in Chowara. The low mean yield of 2918 $\pm$ 129 kg ha^{-1} on unweeded plots compared to 4002 $\pm$ 151 kg ha^{-1} on plots treated with Rifit and one subsequent hand weeding accounts for the significant difference among weed control practices (Figure 1). Otherwise all herbicide or cultural based weed management

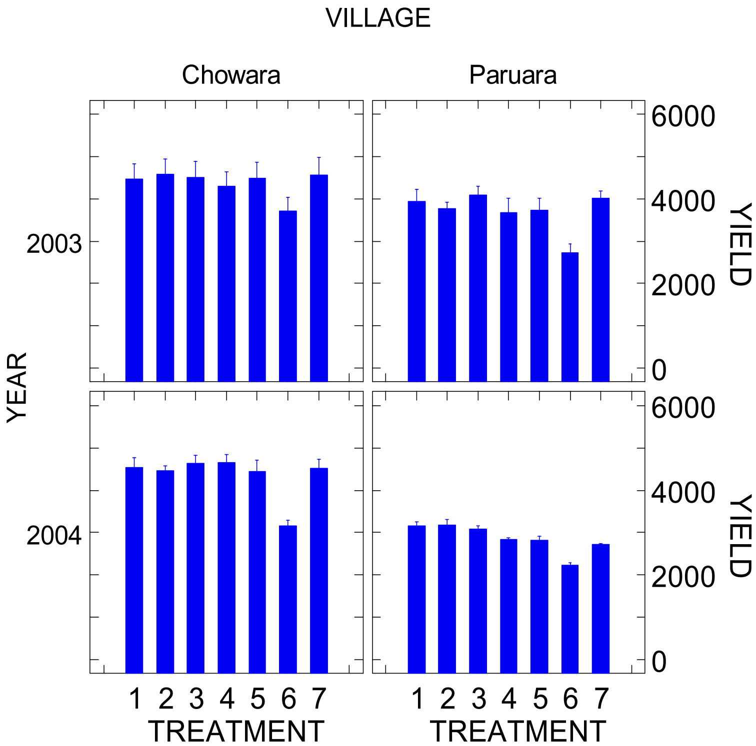


Figure 1. Effect of weed management practices in rice yield (kg ha^{-1}) in two villages in Comilla in *boro* seasons 2003 and 2004. 1 = Rifit, 2 = Argold, 3 = Machete, 4 = two hand weedings, 5 = BRRI weeder and hand weeding, 6 = no weed control, 7 = farmer practice.

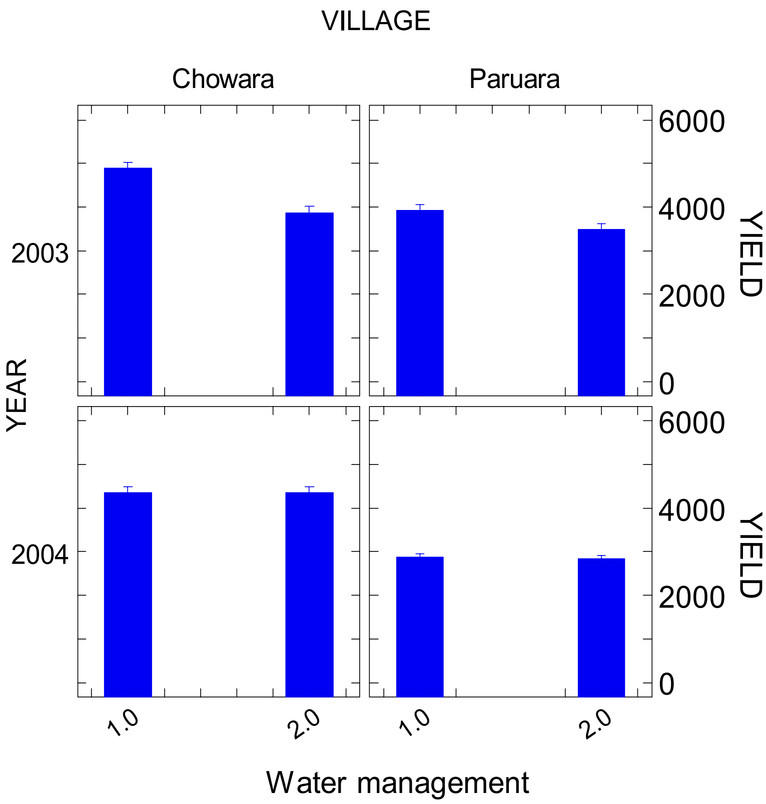


Figure 2. Effect of water management practices in rice yield (kg ha^{-1}) in two villages in Comilla in *boro* seasons 2003 and 2004. 1 = "good water management" 2 = "poor water management".

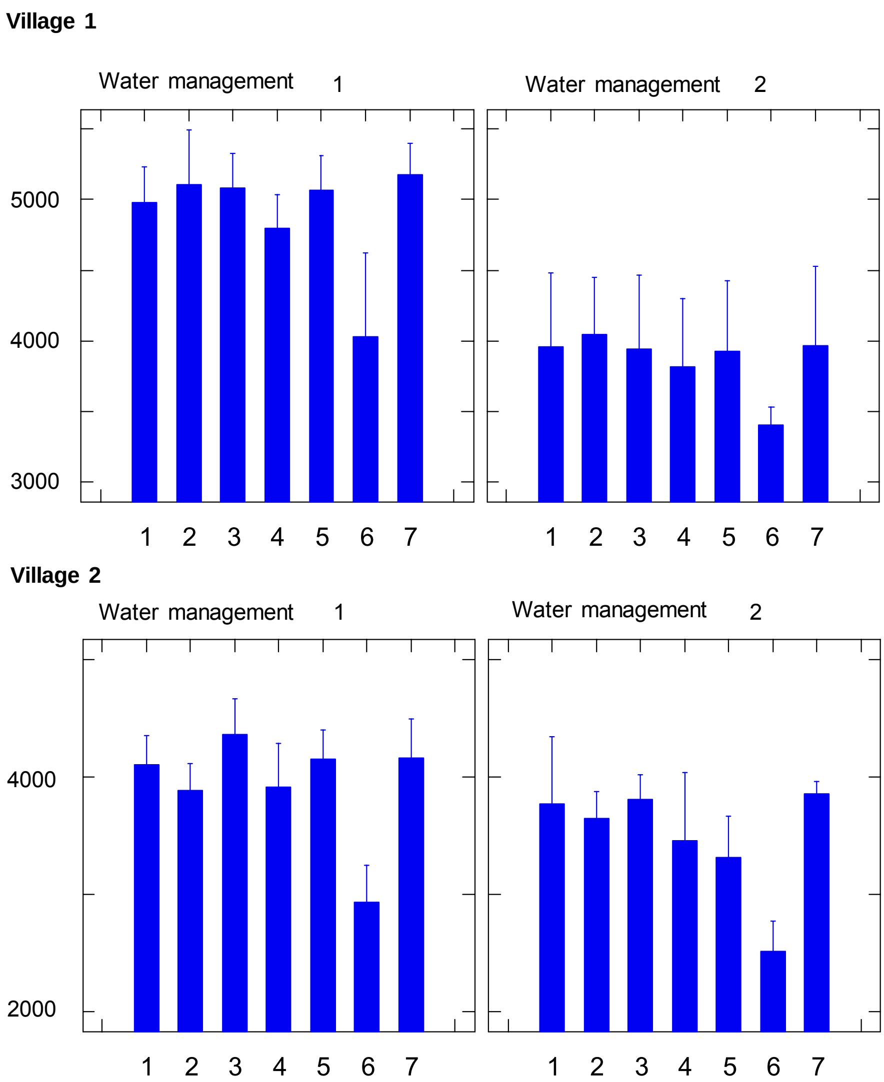


Figure 3. Effect of irrigation water management (1 = good. 2 = poor) on mean rice yields (kg ha^{-1}) in *boro* season 2003 in Chowara (village1) and Paruara (village 2).

treatments resulted in similar yields to farmer practice. Although the main effect of water management was not significant lower yields were observed from plots where water management was poor (Figure 2). However analysis of interactions indicated that the effect of water management on yield varied amongst farms within villages. Individual analysis of the data for 2003, demonstrated the critical importance of water management as good management had a positive effect of yield in both villages (p=0.0095). In 2004 season data was also available from trial sites in Zaforganj (Debidwar upazilla). All weed management practices once again improved yield over no weeding (P=0.003) with no interaction with water management. Good water management resulted in higher mean yields (5682 $\pm$ 168 kg ha^{-1}) compared to poor water management (4291 $\pm$ 202 kg ha^{-1}). These trials have demonstrated that in the *boro* season yields are equally as good when weed control is undertaken by different herbicides with supplementary hand weeding or timely hand weeding or by using a push weeder with supplementary hand weeding. Furthermore, not surprisingly, highest yields are associated with timely application of irrigation water.

<u>Weed management in *aman*</u>: Promotional work by the private sector to introduce herbicides in Bangladesh has largely been targeted at the *boro* season when timing

of irrigation water and hence water management at time of herbicide application can be controlled. Trials were undertaken in *aman* 2003 and 2004 to assess the potential for herbicide use in rainfed rice. The combined analysis of data from Chowara, Parara and Zaforganj indicated a significant effect of weed control practice, year of trial and a year by village interaction:

Source	DF	PHo
Tmt (T)	6	**0.00**
Village (V)	2	> 0.1
Vill*Tmt	12	0.92
Year (Y)	1	**0.02**
Y*T	6	0.82
Y*V	2	**0.00**
Y*V*T	12	0.97

As in the *boro* season differences among weed control practices can be explained by the low yield from no weeding (2855 ± 136 kg ha^{-1}) compared to any other option (Figure 4). Most importantly was the lack of significant difference in performance of weed control practices, including herbicide options, between villages or years. This demonstrates that herbicides or the push weeder are robust options for the *aman* season.

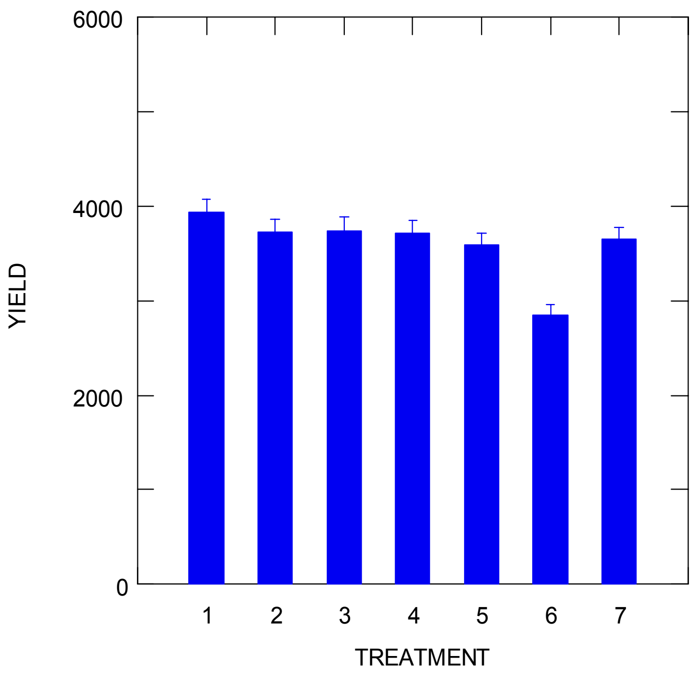


Figure 4: Mean rice yields kg ha^{-1} following various weed management practices on farms in Chowara, Paruara and Zaforganj villages in rainfed *aman* rice in 2003 and 2004. (1 = Rifit, 2 = Argold, 3 = Machete, 4 = two hand weedings, 5 = BRRI weeder and hand weeding, 6 = no weed control, 7 = farmer practice.)

Yields were lower in 2004, and particularly so in Paruara (Figure 5), following crop damage caused by flooding after rainfall at approx. 50 to 55 DAT. In Paruara, depending on site, crops were submerged for 3 to 7 days. Submergence lasted for 1 to 2 days in Chowara and 2 to 3 days in Zaforganj (Debidwar) allowing the crop to make a better recovery. This does however demonstrate the risk associated with investment in the *aman* crop when flooding occurs after expenditure on either herbicides of labour for weeding.

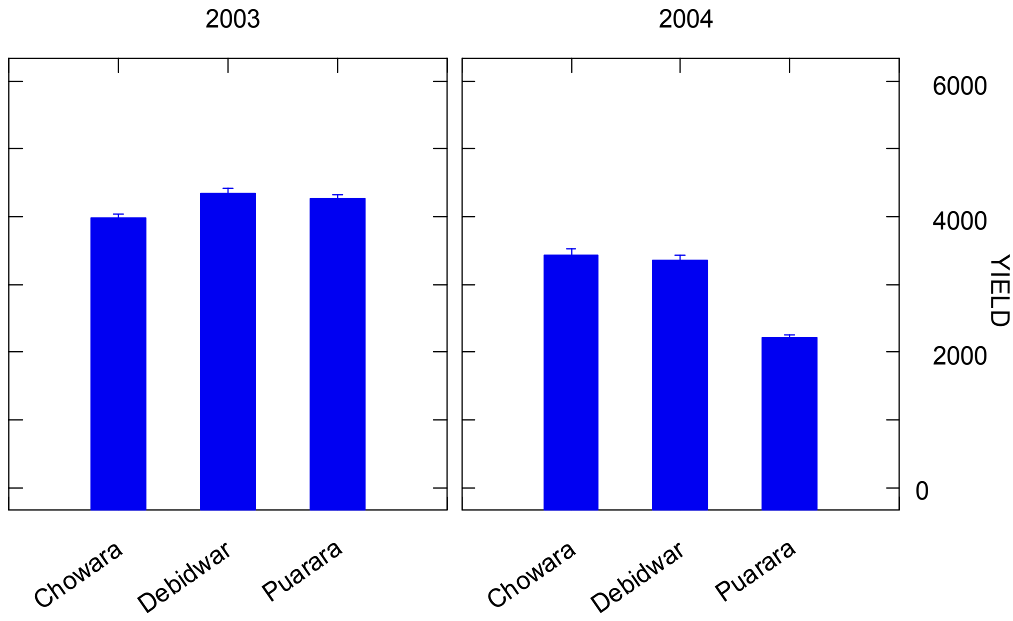


Figure 5. Variation in mean rainfed rice yields in Chowara, Paruara and Debidwar in 2003 and 2004 *aman*.

Similar crop management was applied on all plots with the exception of weed control. Covariance analysis indicated that neither seedling age at transplanting or date of transplanting had significant effects on rice yields. In 2003 the range of seedling ages and transplanting dates were 47 and 41 days respectively compared to 31 and 40 days in 2004. For optimal effect each of the herbicides tested needs to be applied into 1.5 to 3 cm of standing water with this maintained for one week to avoid weed emergence. Conditions were favourable for herbicide application in both seasons but water levels had fallen by 7 DAT (Table 1).

Table 1. Mean water depths at herbicide application and after 7 days at on-farm trial sites in rainfed *aman* 2003 and 2004.

	Water depth (cm)			
Year	At application		After 7 days	
	Mean	Range	Mean	Range
2003	3.3	5.0	2.2	5.5
2004	2.5	3.3	1.6	4.0

Table 2. The significance (P H_o) of the effects of the covariates, water depth at herbicide application and 7 days after on weed density and biomass at 25 and 45 DAT in rainfed *aman* 2003 and 2004. (NS = not significant).

	2003		2004	
Variable	**At application**	**At 7 days**	**At application**	**At 7 days**
Weed density 25 DAT	NS	NS	NS	0.027
Weed biomass 25 DAT	NS	0.024	0.014	NS
Weed density 45 DAT	NS	NS	NS	NS
Weed biomass 45 DAT	NS	0.028	0.050	NS

In 2003 a 1 cm increase in water depth 7 days after herbicide application reduced weed dry biomass at 25 and 45 DAT by 0.29 and 0.15 g m^2 respectively. In 2004 differences in water depth at both herbicide application and after 7 days had an effect on subsequent weed infestation levels. A 1 cm increase in water depth at application reduced weed biomass by 0.5 g m^2 at 25 DAT while a 1 cm increase at 7 days reduced weed density by 1.9 plants m^2. Effects were also seen in 2004 at 45 DAT when increased water depths significantly reduced weed density at 7 days after herbicide application.

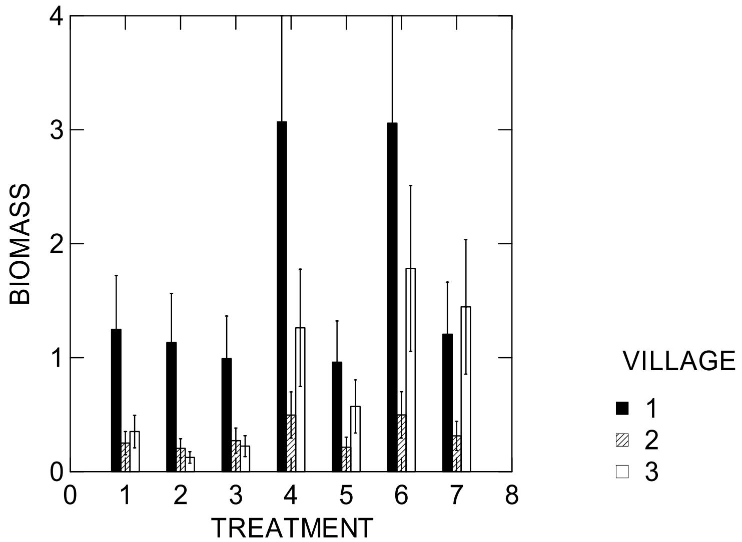


Figure 6. Weed biomass (g m^2 dry weight) at 25 DAT in Chowara (village 1), Paruara (village 2) and Zaforganj (village 3) in *aman* 2003 following various weed control treatments. (1 = Rifit, 2 = Argold, 3 = Machete, 4 = two hand weedings, 5 = BRRI weeder and hand weeding, 6 = no weed control, 7 = farmer practice.)

Figure 6 indicates the effectiveness of the herbicide treatments in reducing wed infestation levels early in the season below those associated with farmer practice, hand weeding or when using the push weeder. Following herbicide application a supplementary hand weeding was undertaken at 25 to 30 DAT compared to weeding with the push weeder or by hand in cultural weed control treatments at 15 DAT. The latter were clearly less efficient than using a herbicide. These results demonstrate that under rainfed conditions early in the *aman* season there can be sufficient water for flooding to augment the effect of the herbicide, an effect that was particularly clear

in 2004. The extent of early season flooding influences weed infestations by the time a supplementary hand weeding is undertaken by 30 DAT. An important component of the knowledge that farmers need to use herbicides effectively, particularly in *aman* is the need for timely follow up hand weeding. The
extent of this will depend on water conditions following herbicide application.

Socio-economic considerations: An economic evaluation of on-farm trials (OFTs) and on-farm demonstrations (OFDs) in Chowara and Parura villages, Comilla district, was made for the Boro season, 2003. The analysis was made for a sample of 16 farmers with on-farm trials and 16 farmers with demonstrations. A full report of this evaluation is presented in project Working Paper 6. Results showed that:

- Yields from OFTs and OFDs showed that, on average, herbicide-treated plots had higher yields than plots treated either with the push weeder or with two hand-weedings. On OFTs in Chowara village, the Argold-treated plot yielded higher than Rifit, Machete, push weeder and hand Weeding.
- Dominance analysis showed that no weeding, two hand-weedings, the push weeder, and Machete + 1 hand-weeding were "dominated", that is, they had higher costs that varied and lower net benefits than Rifit or Argold + one hand-weeding. Therefore, these treatments were excluded from marginal analysis. Of the two remaining treatments, the marginal rate of return between Rifit + one hand-weeding and Argold + one hand weeding was 14% in favour of Rifit. This low marginal rate of return suggests that farmers are unlikely to prefer Rifit to Argold on purely economic grounds. We conclude that herbicide use with Rifit or Argold + one hand-weeding was economically superior to other treatments.
- Farmers perceived Argold to be more effective than other herbicides and Ronstar as least effective.

Partial budgets were also calculated for inouts and returns based on on-farm trials in Comilla for *aman* season, 2003. These are reported in detail in project Working paper 7. These showed that:

- Hand-weeding was less profitable than herbicides, incurring 4341 Tk/ha lower return.
- The rice weeder was less profitable than herbicides, incurring 2959 Tk/ha lower return.

Few farmers' involved in the trials used herbicide on theor own land due to lack of knowledge but they reported that they will use more in future. The three main reasons farmers gave for not already using herbicides were (1) a spraying machine was essential; (2) there should be standing water in the plot for at least one week and (3) the erroneous belief that herbicide reduced the quality of the soil. These economic studies show that in Comilla herbicides were consistently more profitable than either hand-weeding or the rice weeder in both the rainfed lowland and irrigated rice ecosystems. Constraints to the uptake of herbicides lay mainly in the availability of information about how to use this new technology safely and judiciously.

4.1.2 Demonstrations to promote weed management options: Although the demonstrations in Comilla were primarily undertaken to raise farmer awareness of alternative weed management options, the sites were monitored and yields recorded.

In *aman 2003* there was a significant difference in yields between six weed control practices (Figure 7) implemented across all sites (p = 0.0014).

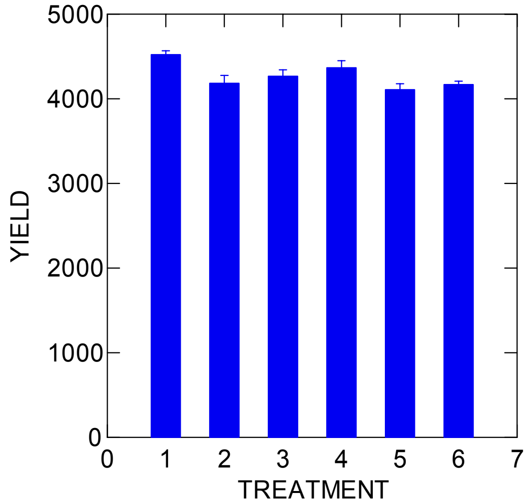


Figure 7. Rice yields (kg ha^{-1}) in *aman* 2003 following five weed management practices. Mean of 12 sites for each practice compared to farmer practice. 1 = Rifit + hand weeding (HW); 2 = Argold + HW; 3 = Machete + hand weed; 4 = Ronstar + hand weed; 5 = BRRI weeder + HW; 6 = Mean farmer practice at all sites.

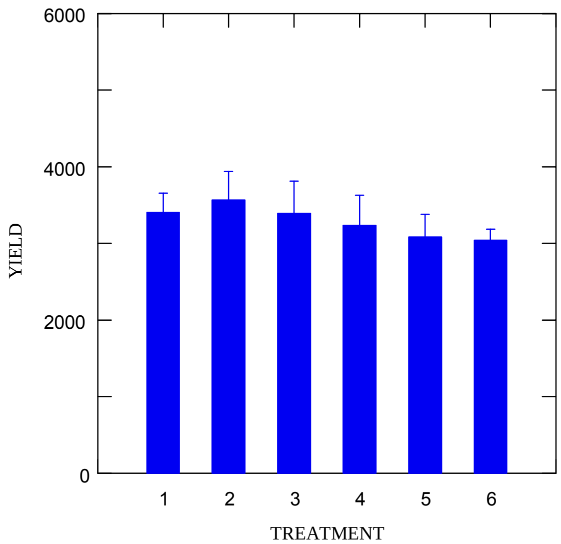


Figure 8. Rice yields (kg ha^{-1}) in *aman* 2004 following five weed management practices. Mean of 12 sites for each practice compared to farmer practice. 1 = Rifit + hand weeding (HW); 2 = Argold + HW; 3 = Machete + hand weed; 4 = Ronstar + hand weed; 5 = BRRI weeder + HW; 6 = Mean farmer practice at all sites.

Application of Argold (cinmethalin) or use of the BRRI weeder resulted in similar yields to farmer practice. The yield advantage over farmer practice, either one or two hand weedings, was on average 355 $\pm$ 18 kg ha^{-1} for Rifit (pretilachlor), 281 $\pm$ 39 kg ha^{-1} for Machete (butachlor) 210 $\pm$ 34 kg ha^{-1} for Ronstar (oxadiazon). Yields were not different following the use of different weed control practices in 2004 (Figue 8). Variability between site yields was high following submergence of crops around 50-55 DAT, the effect being especially severe in Paruara. Farmers lost all crops planted at 10 sites in Baruara upazilla. Once again however, there was no village x weed control interaction indicating the robust nature of demonstrated options in rainfed rice. In 2004, lowest weed densities after supplementary hand weeding followed herbicide application (p = 0.0237) and lowest weed biomass (not significant) was observed after use of either Rifit or Argold (Figure 9).

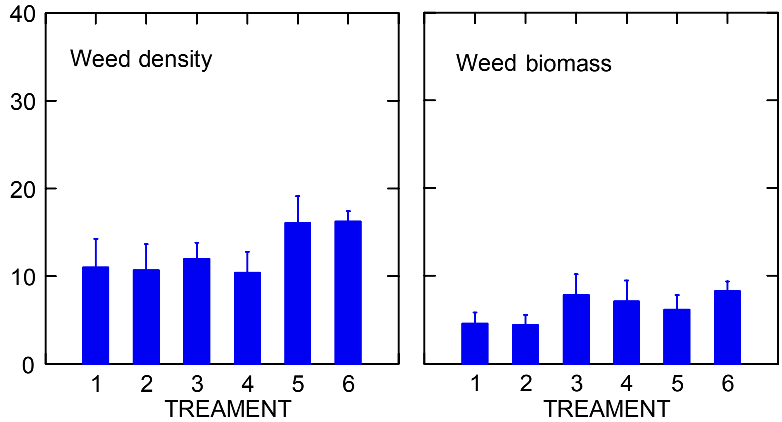


Figure 9. Mean weed density (No. m ^{2}) and dry biomass (g m^2) at 45 Dat in *aman* 2004 at demonstration sites in Comilla. 1 = Rifit + hand weeding (HW); 2 = Argold + HW; 3 = Machete + hand weed; 4 = Ronstar + hand weed; 5 = BRRI weeder + HW; 6 = farmer practice.

Despite clear trends it has not been possible to demonstrate significant differences between rice yields after the use of different weed practices in *boro* rice. This is due to the limitations of available analytical technique. Although demonstrations were monitored at a total of 60 sites in 2004 only up to12 comparisons were undertaken for each "selected option" v farmer practice. Unbalanced numbers of comparisons and standard errors for individual treatments limited the power of our analysis.

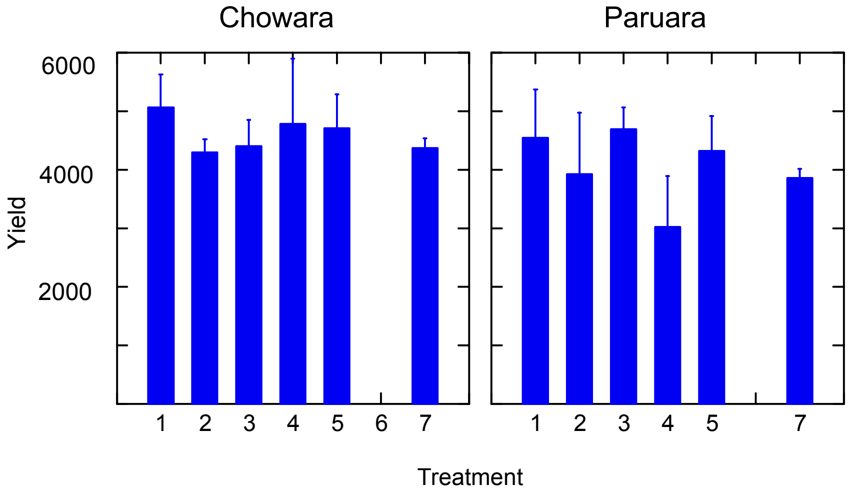


Figure 10. Rice yields (kg ha^{-1}) in *boro* 2003 following five weed management practices. Mean of $\pm$ 12 sites for each practice compared to farmer practice. 1 = Rifit + hand weeding (HW); 2 = Argold + HW; 3 = Machete + hand weed; 4 = Ronstar + hand weed; 5 = BRRI weeder + HW; 7 = Mean farmer practice at all sites.

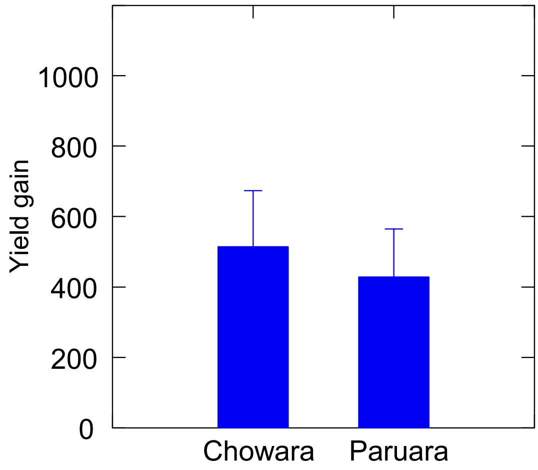


Figure 11: Mean yield gain (kg ha^{-1}) from use of selected weed management options compared to farmer practices at 10 sites in Chowara and Paruara, *boro* 2003.

Ronstar performed poorly in Paruara in 2003, reducing the average yield gain for herbicide or push weeded based options (Figure 10 and 11). Yield gains from these improved practices were between 400 and 500 kg ha^{-1}. A similar trend was observed in 2004 (Figures 12 and 13). Yield gains from individual improved practices, with the exception of using Rifit and one hand weeding, were below 400 kg ha^{-1}. The level of yield gains reported here are of the order of magnitude of yield losses due to weed in farmer managed rice crops observed in Comilla by project R7471 (Ahmed *et al*., 2001). Approximately one third of farmers lose 0.5 kg ha^{-1} in both *aman* and *boro*. The yield gains are most likely associated with timely early season weed control with herbicide or push weeder and a longer period of weed suppression compared to farms were usually only one weeding is used.

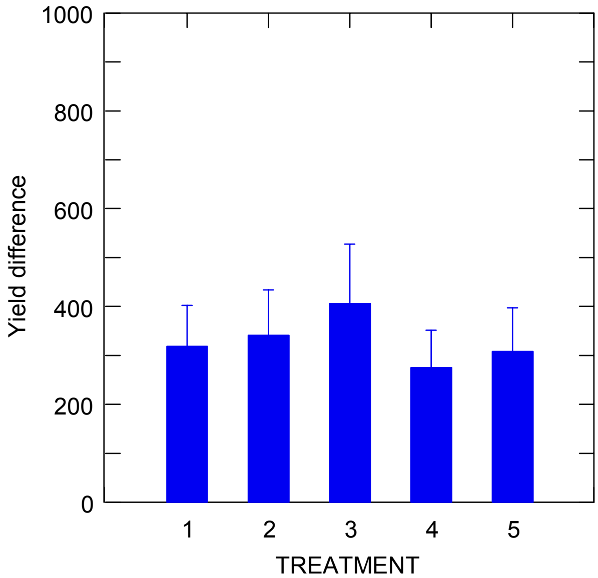


Figure 12. Mean rice yield gains (yield difference from farmer practice kg ha^{-1}) following use of Rifit (1), Argold (2), Machete (3), Ronstar (4) or the BRRI push weeder (5), each followed by one hand weeding, at 12 sites in *boro* 2004.

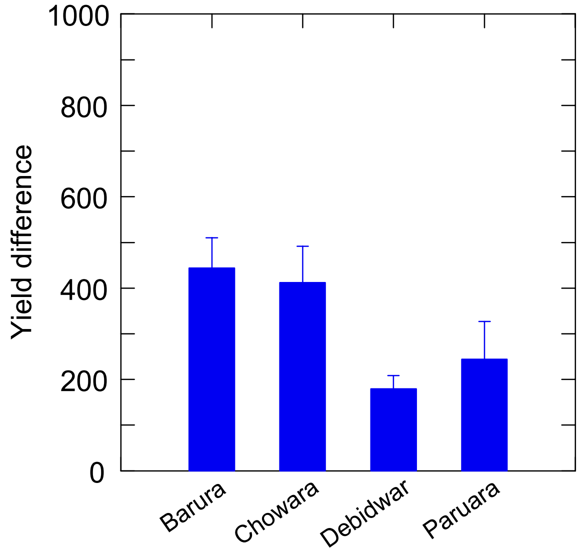


Figure 13: Mean yield gain (kg ha^{-1}) from use of selected weed management options compared to farmer practices at 20 sites each in Chowara and Paruara and at 10 sites each in Baruara and Debidwar, *boro* 2004.

4.1.3 Evaluation of public-private sector partnership for delivery of information on weed management to farmers: A public-private partnership was developed to improve the flow of information on herbicides reaching resource-poor farmers. The major actors were:

- Syngenta, an international company with world-wide sales of US $ 6197 million (2002). Syngenta Bangladesh Ltd. is the biggest private-sector company marketing herbicide in Bangladesh through a network of 300 distributors who supply 10,400 local retailers.

- SAFE, a local NGO founded in 2001 with experience in farmer participatory research, including Farmer Field Schools, acquired through previous employment of lead staff with CARE. Funding for SAFE's participation in the partnership was obtained through PETTRA, as part of its research programme on innovative uptake methods and pathways.

- NRI which provided technical backstopping and took the lead role in evaluating the partnership.
- Resource-poor farmers (including women) in 5 villages in Burichang and Debidwar upazilas in Comilla district, who participated in Farmer Field Schools (FFS).

Key pre-conditions for Syngenta's participation were its culture of environmental "stewardship", the importance of herbicides in its global growth strategy, and the fact that, as market leader in Bangladesh, Syngenta would benefit from increased demand for herbicides. SAFE provided methodological and organisational expertise in training farmer groups. Through Farmer Field Schools (FFS) and workshops, the partnership identified additional messages to improve farmers weed management with herbicides. These included information on weed identification, choice of herbicides, and how to avoid weed resistance by changing herbicide modes of action between seasons and following-up herbicide use by hand weeding.

The main lesson from the partnership was the key role played by retailers in the information flow for herbicides. Retailers supply farmers with information as well as products. They advise farmers on how to apply herbicides (and will calculate the correct dose based on the size of the farmers' field), when to apply, what level of water is needed at application, how long water should be retained after application, and safety precautions. Retailers often supply inputs on credit and are repaid after harvest. Some lease sprayers for herbicide application to farmers. Consequently, improving information flow for herbicides meant building capacity among retailers and making them aware of their responsibility for safe and efficient use of herbicides. Using the retailing network would also make any improvements in information flow sustainable, because it depended on the market not on public funds. A key output from the partnership was the development of a rice weed management manual and posters suitable for improving training of retailers (see 4.1.4). While the partnership has been successful in improving the stock of available information on herbicides, impact on farmers will depend on the agro-chemical industry incorporating this information into their future training programmes. A Workshop at BRRI in 2004 brought together representatives from 11 companies and agreed that several issues should be taken forward through the industry's own forum, the Crop Protection Association of Bangladesh (see Riches 2004a). These included:

- Development of appropriate training materials for health and safety.
- Training in herbicide use for DAE staff and retailers.
- Dissemination of general, non-product specific information*.*

A report on the evaluation was presented at the PETTRA Workshop on Uptake Methods and Pathways, Dhaka, 17-18 April 2004 (see Chowhan *et al*. 2004) A revised version of this report may be found in project Working Paper 5.

4.1.4 Development of non product-specific information on herbicides: Development of a poster "Effective control of weeds in rice" involved collaboration between Bangladesh Rice Research Institute in association with International Rice Research Institute, Natural Resources Institute and Syngenta. Printed in Bengali the poster lists key messages on efficient and safe use of herbicides in integrated weed management via text and pictures. Of 1000 copies printed 300 have been distributed by Syngenta to its village pesticide dealer network in Comilla district. A further 200 have been distributed via bock supervisors attending BRRI/DAE training sessions to be displayed in public places. In March 2005 copies were seen displayed in pesticide dealers shops in Paruara bazaar by the author. Dealers confirmed that many farmers are now referring to the poster when they purchase herbicides.

Front cover of “Rice Weed Management Training Manual” prepared by Syngenta and SAFE.

Poster on “Effective control of weeds in rice” displayed in pesticide stores in Paruara bazaar, Comilla in March 2005.

The project has also printed 500 copies of a "Rice Weed Management Training Manual" prepared SAFE in collaboration with Syngenta (Rahman, 2004). Copies have been distributed as follows: All 464 Upazila Agricultural Offices in Bangladesh; to 64 DAE District Deputy Directors' Offices, 50 to herbicide companies, 50 to NGOs, 60 to all partners involved in PETRRA., 15 to BRRI sub-stations and 250 to Syngenta product distributors.

Outputs from project work in Comilla were also summarised on a poster "Cost Effective Weed Control Technology in Rice" displayed at the PETRRA Communication Fair held in Dkaka (see Ahmed, 2003).

4.2 Output 2. Validation and promotion of the sustainable intensification of rice-fallow farming systems through improved weed management and expanded winter cropping.

4.2.1 *Evaluation of rice production practices in rice-chickpea systems*: Yields of direct seeded rice recorded over four years on medium toposequence Barind soil were similar to or better than those of transplanted rice (Figure 14). Swarna significantly outyielded BR39 in 2002 when direct seeded, and also under transplanting in 2001, ($p < 0.05$). However no significant difference was observed between varieties under transplanting in 2002 and under direct seeding in 2001. Yields of transplanted rice in 2003 were severely depressed by drought from early July to mid-August that led to late transplanting, whereas under direct seeding yields were higher and Swana exhibited a 1 t/ha higher yield than BR39. Direct seeded rice reached maturity significantly earlier than transplanted rice ($p < 0.01$).

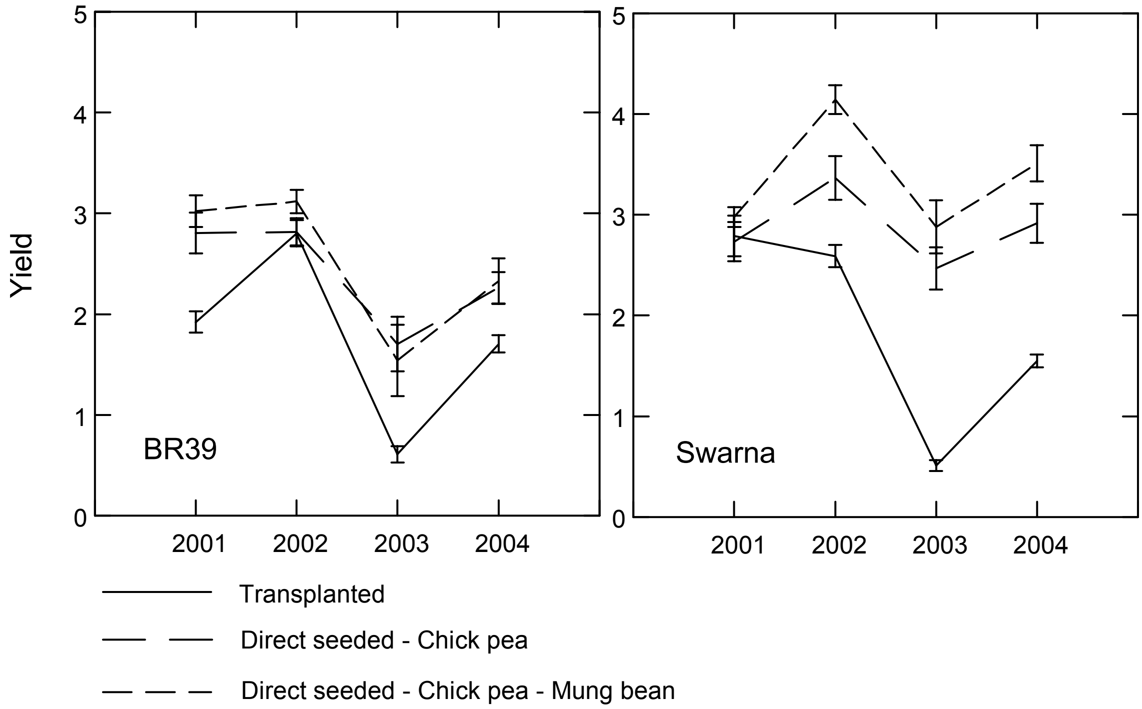


Figure 14. Trends in yields (kg ha^{-1}) of two rice varieties when transplanted or direct seeded (DSR) in the long-term trial at Rajabari, Rajshahi District. DSR was grown in rotation with legumes.

Climatic conditions in 2004 proved ideal for both dry direct seeded and transplanted rice. Showers in May (100 mm) and early June (45 mm) allowed timely land preparation for direct seeding by 16th of the month. Heavy rain, including 327 mm on 21st June inundated fields and transplanting after further rain into puddled soils on July 16th. Rain during the first week of October (107 mm) coincided with early grain filling for Swarna. Method of crop establishment (p= 0.0041) and rice variety (p <0.001) effects were both significant. Direct seeding outyielded transplanting. Swarna performed well under direct seeding and yields after weed control with the herbicide Ronstar (oxadiazon) were as good as following three timely hand weedings in direct seeded rice. Chickpea yield following direct sown rice declined from 2001-02 *rabi* season with planting on the same plots each year (Table 4.). The variety Barisola 2 was grown each season to allow uniformity for the analysis. However this proved susceptible to soil borne *Fusarium* wilt. Other varieties now available are more tolerant. Yields in the first two seasons of the trial demonstrate the potential of this high value *rabi* crop for improving total productivity on fields in the Barind where there is no irrigation.

Table 3. Effect of method of crop establishment and weed control on yield (t ha^{-1} $\pm$ SE) of two rice varieties. Long term trial, *aman* 2004.

Crop Estabishment	**BR 39**		**Swarna**	
Transplanting + hand weed	1.7	± 0.08	1.5	± 0.06
Direct seeding + hand weed	2.3	± 0.15	2.9	± 0.19
Direct seeding + Ronstar/hand weed	2.3	± 0.21	3.5	± 0.17

Table 4: Effect of rice variety on grain yield (t ha^{-1} $\pm$ S.E.) of a post rice chickpea crop 2002 – 2004, long-term trial

	Previous rice variety	
***Rabi* season**	**BR39**	**Swarna**
2001-2	1.01 ± 0.06	0.91 ± 0.05
2002-3	0.76 ± 0.05	0.49 ± 0.04
2003-4	0.38 ± 0.04	0.16 ± 0.02

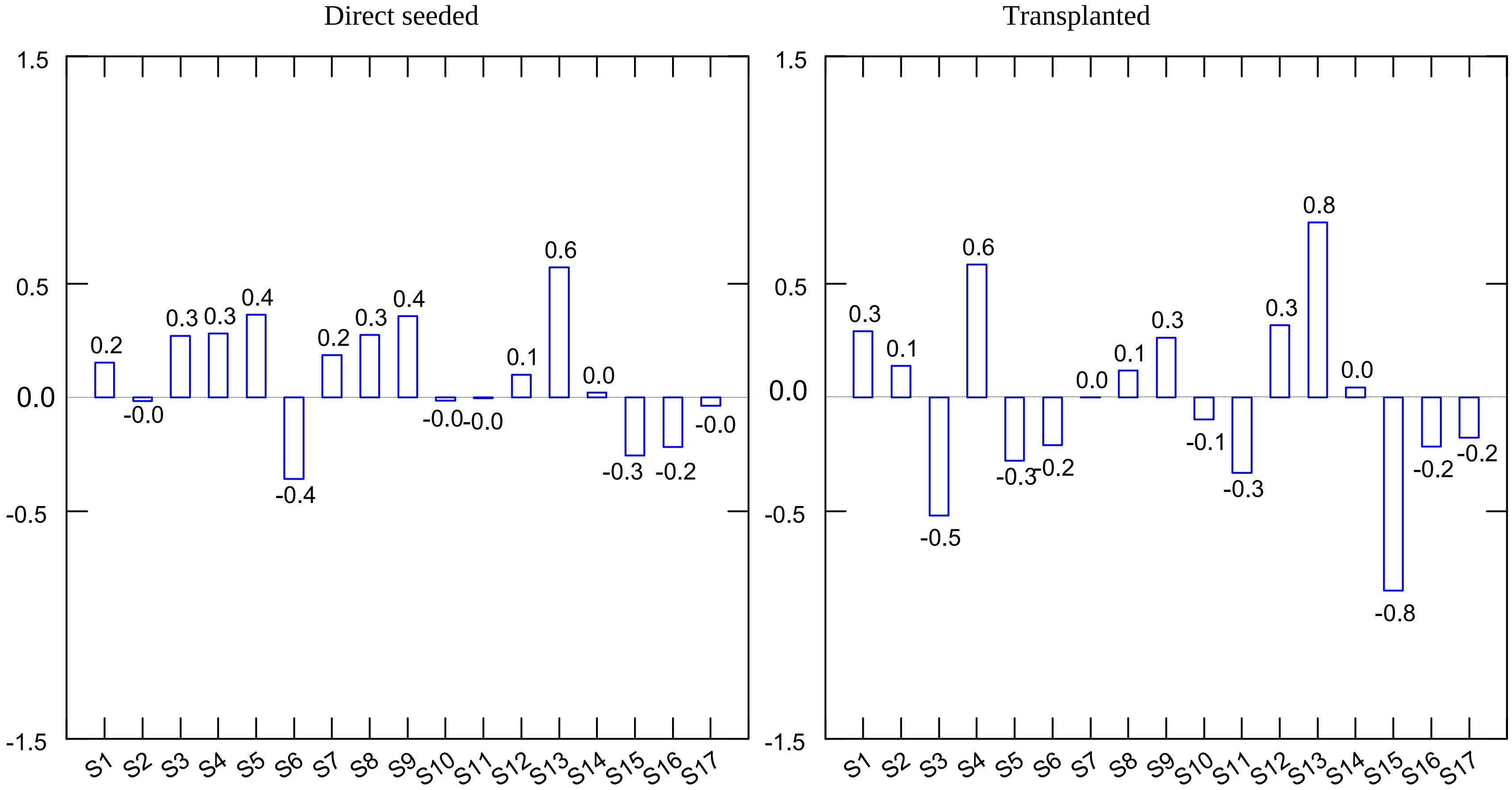
For the most abundant weed species, the change in abundance (based on density and biomass at 28DAS/DAT) from 2002 to 2004 was calculated as log10 (x+1/ y+1) where x and y are the abundance in 2002 and 2004 respectively. Similar analyses were completed for data at 45 DAS/DAT and at harvest. Results are presented are for 28DAS/DAT as the weed flora was most diverse at this census point. Individual species responses over three years of continuous use of particular cropping practices were mostly due to crop establishment method (Table 4). However available degrees of freedom for a significance test are too limited to distinguish the effects of continuous direct seeding on an annual basis. Multivariate techniques will be applied to this data prior to publication. Figures 15 and 16 illustrate the extent of this data set for describing trajectories (rate of change) in density and biomass of individual species. Further evidence will be provided from detailed analysis of soil

Table 5. Significance of effects of crop establishment, fertiliser use or rice variety on density of dominant weed species in at 28 DAS/DAT in *aman* 2004 in the long term trial.

		Variable		
	Species	**Crop Estab.**	**Fertiliser**	**Variety**
S1	*Altenanthera sessilis*			
S2	*Ammania baccifera*	0.0488		0.0434
S3	*Cyndon dactylon*			
S4	*Cyperus difformis*	0.0979		
S5	*Cyperus iria*	0.0338		
S6	*Dopatrium junceum*	0.0508		
S7	*Echinocholoa crus galli*			
S8	*Eclipta prostrata*	0.0772		
S9	*Fimbristylis miliacea*		0.0355	0.0323
S10	*Hedyotis corymbosa*			
S11	*Lindernia ciliata*			
S12	*Lindernia sp*			
S13	*Ludwigia octovalvis*			
S14	*Marsilea minuta*			
S15	*Monochoria vaginalis*	0.0368		
S16	*Paspalum distichum*			
S17	*Rotala indica*		0.0349	

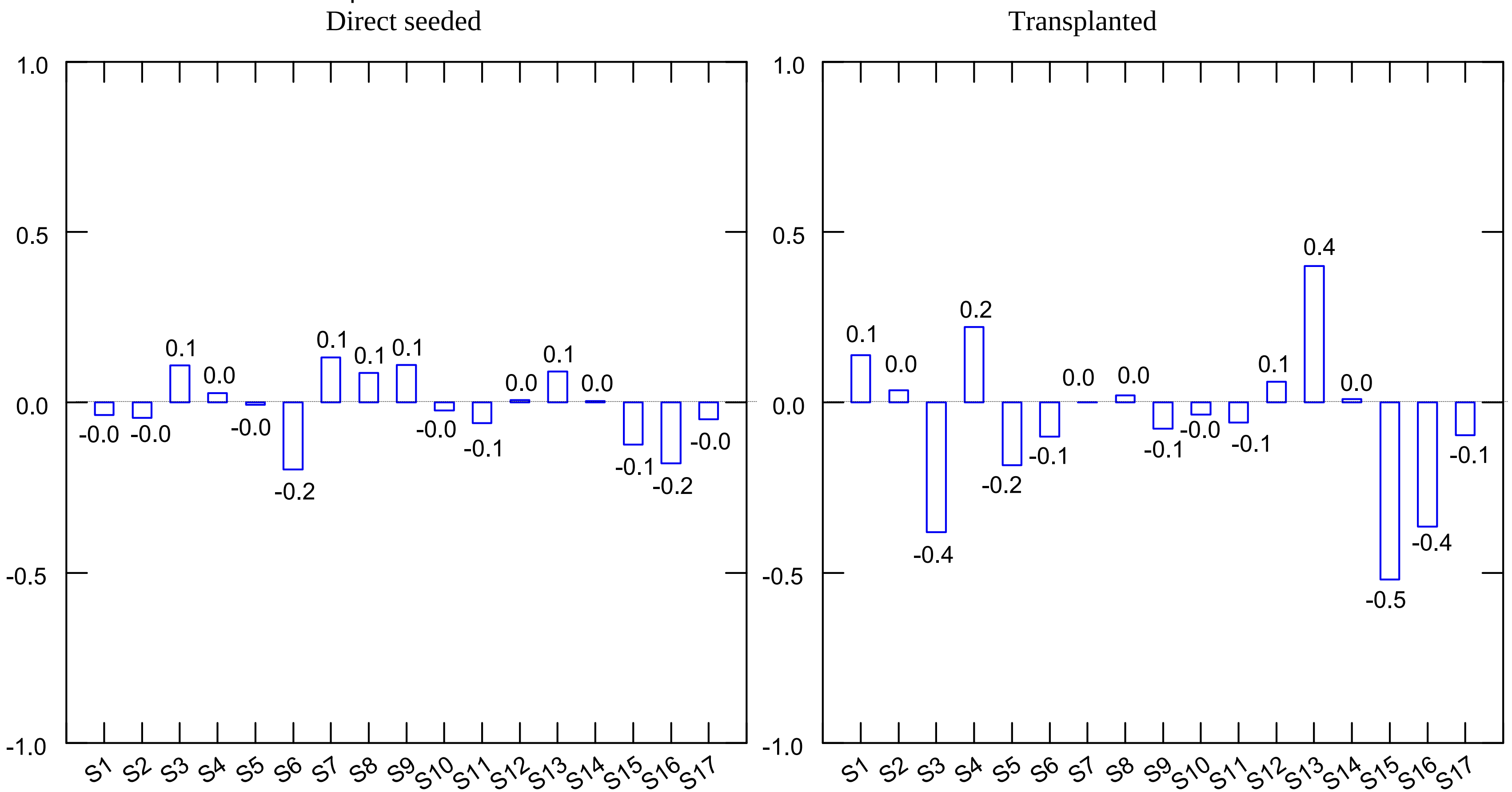
seed bank data collected following the final rice cycle of this trial. Densities of the perennial grass *Cynodon dactylon*, the annual grass *Echinochloa crus-galli*, the sedges *Cyperus iria* and *Fimbrystilis miliacea* and broadleaf weed *Eclipta prostrata* appear to be increasing under direct seeding. Analysis of weed responses during the first three seasons of this trial (2000 to 2002) indicated significantly higher densities of weeds on unweeded area that had been direct seeded at harvest (228 m^{-2}) in comparison to transplanted plots (75 m^{-2}; p = 0.023), (Mazid *et al.* 2003). Increase in abundance (biomass at 28 DAS/DAT) of the broadleaved species *Alternanthera sessilis, Eclipta prostrata, Lindernia ciliata* and *Ludwigia octovalvis* and the sedges *Cyperus difformis* and *Fimbrystilis miliacea* and the grass *Paspalum distichum* was noticeable under direct seeding. Conversely direct seeding decreased the biomass of *Monochoria vaginalis*. The long-term trial has demonstrated that while rice yield can be maintained, or even increased with the switch from transplanting to direct seeding, farmers will face a greater weed problem early in the crop season. Not only is there an increased burden of weeds in direct seeded rice but the change in establishment practice also leads to a shift in the relative abundance of important species. Use of a herbicide can reverse this trend in some cases, e.g. for *F. miliacea* an important weed in the Barind (Mazid *et al.,*2001) but to prevent the build-up of other species it is clear that follow-up hand weeding will be needed, particularly for perennial grasses (*C. dactylon* and *P. distichum)* which are not controlled by oxadiazon).

Figure 15. Trajectories (logarithm mean rate of change in density (plants m^{-2})) of selected individual weed species in response to crop establishment method. Census point 28 DAS/DAT in 2002 and 2004.



S1 - Altenanthera sessilis, S2 - Ammania baccifera, S3 - Cyndon dactylon, S4 - Cyperus difformis, S5 - Cyperus iria, S6 - Dopatrium junceum, S7 - Echinocholoa crus galli, S8 - Eclipta prostrata, S9 - Fimbristylis miliacea, S10 - Hedyotis corymbosa, S11 - Lindernia ciliata, S12 - Lindernia sp, S13 - Ludwigia octovalvis, S14 - Marsilea minuta, S15 - Monochoria vaginalis, S16 - Paspalum distichum, S17 - Rotala indica

Figure 16: Trajectories (logarithm mean rate of change in biomass (plants m^{-2})) of selected individual weed species in response to crop establishment method. Census point 28DAS/DAT in 2002 and 2004.



S1 - Altenanthera sessilis, S2 - Ammania baccifera, S3 - Cyndon dactylon, S4 - Cyperus difformis, S5 - Cyperus iria, S6 - Dopatrium junceum, S7 - Echinocholoa crus galli, S8 - Eclipta prostrata, S9 - Fimbristylis miliacea, S10 - Hedyotis corymbosa, S11 - Lindernia ciliata, S12 - Lindernia sp, S13 - Ludwigia octovalvis, S14 - Marsilea minuta, S15 - Monochoria vaginalis, S16 - Paspalum distichum, S17 - Rotala indica

4.2.2 *On-farm validation of direct seeding of rice with appropriate weed control*: On-farm, the yields of rice varieties Swarna, BR31 and BR 32 were independent of crop establishment method (Table 6) whereas yields of transplanted BR39 were over 1.8 t higher than when dry direct seeded (p = <0.001). Overall transplanting resulted in higher yields due to the poor performance of direct sown BR 39. This analysis does not include three sites where prolonged drought in July and early August prevented transplanting while farmers had direct seeded by mid-June. Herbicide use resulted in higher yields (p = 0.01) than hand weeding twice.

Chickpea yields (Figure 17) were not significantly affected by the preceding rice variety. Rain during November ensured adequate moisture for chickpea germination and establishment unlike in many years when the crop is established on residual moisture.

Table 6: Mean yields (kg ha^{-1}) of four rice varieties when direct seeded (DSR) or transplanted (TPR) at 16 on-farm sites in the high Barind Tract in *aman* 2003. Weed control was either by hand or by pre-emergence herbicide (oxadiazon in DSR, pretilachlor in TPR) plus one hand weeding.

Variable	**Description**	**Yield t ha**	**Significance (Pho)**
Toposequence	High	4.12	0.0013
	Medium	4.45	
Crop Est	DSR	3.9	< 0.0001
	TRP	4.7	
Variety	Swarna	4.5	< 0.0001
	BR31	4.91	
	BR32	4.54	
	BR39	3.28	
Weed control	Hand	4.19	0.01
	Herbicide	4.45	
Crop est x Var	DSR BR31	4.8	< 0.0001
	DSR BR32	4.16	
	DSR BR39	2.4	
	DSR Swarna	4.24	
	TPR BR31	4.98	
	TSR BR32	4.93	
	TSR BR39	4.14	
	TSR Swarna	4.87	

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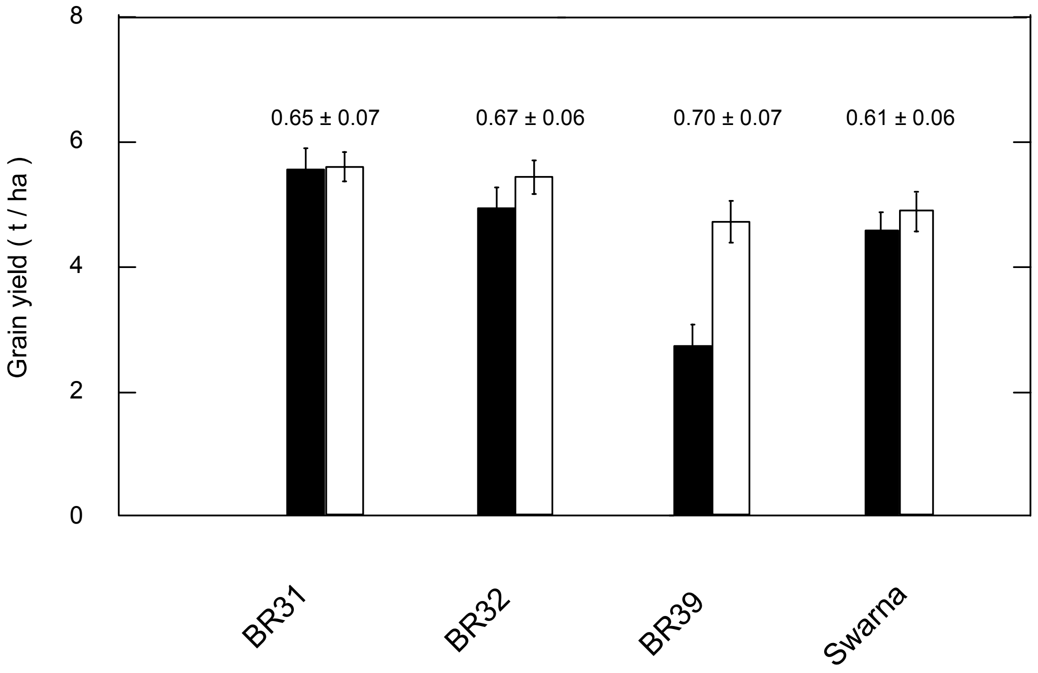

Figure 17. Productivity (t / ha) of rice and chickpea grown in rice TPR (open bars) and DSR (solid bars) systems. Data are means of 16 on-farm sites in 2003 (*aman* and *rabi*-seasons) Weed control in rice by pre-emergence herbicide. Data above each pair of bars are chickpea yields (t ha^{-1} ± S.E.).

In 2004 heavy rain in mid-June inundated fields so dry direct seeding was not possible. A drum seeder, imported from Vietnam by the Ministry of Agriculture for country wide testing, was used in the trials instead Crops of either Swarna or BR 11 established by drum seeder, significantly outyielded transplanted rice (Table 7). Drum seeding was undertaken during the last week of June with transplanting 21 to 33 days later.

Table 7: On-farm trials of a drum seeder, Barind 2004. Data are for 7 on-farm sites in aman 2004. Rice grain yield t ha^{-1} ± standard Error. Weed control in transplanted rice by hand weeding at ± 15 and 30 DAT; in Drum seeding by oxadiazon at planting plus hand weeding ± 30 DAS.

Variety	Transplanting	Drum Seeding
Swarna	4.66	5.90
BR 11	4.82	5.86
S.E.D (18 d.f.)	0.24	
Establishment method	P< 0.001	

Two field days were held at on-farm trial sites in November 2003, attended by a total of 57 farmers. 28 farmers attended a field day held in September 2004.

4.2.3. *Field-scale evaluation of direct seeding*: Although direct seeded rice was planted on a field scale by farmers at 59 sites across Chapai Nawbgonj, Naogaon and Rajshahi districts supervised by PROVA and DAE block supervisors, crops were established well and taken to yield at only 26 sites – 13 by broadcasting and 13 by drum seeding. Reasons for failure elsewhere ranged from flooding leading to loss of seeds, particularly when heavy rain fell within 10 days of broadcasting, to low plant populations associated with weedy, poorly levelled seedbeds at many sites where the drum seeder was used. This was the first experience of broadcasting *aman* or using the drum seeder for extension workers and farmers. Tillage at many sites was undertaken only a few days prior to planting, leaving insufficient time for weed suppression in a stale seedbed; laddering was also inadequate. An additional problem was a delay in application of pre-emergence herbicide, not sprayed until 5 to 7 days following seeding at 25% of sites. The sites taken to yield indicate the potential for wider adoption of direct seeding, provided farmers have sufficient knowledge of how to manage these alternative planting practices. Rice grain yields, averaged across all varieties chosen by farmers, were similar for transplanting, broadcast planting of dry seed or drum seeding of sprouted seed (Table 8). The early maturing variety BR 11 was used at a sub-set of 13 sites where there was a trend for direct seeding to out-perform transplanting (Table 9).

Table 8: Median planting and harvest dates and mean grain yields of all varieties used with three planting methods, field-scale evaluations in 2004. Dates are days after 1st June for planting and 1st November for harvesting, figures in parentheses indicate date ranges. Grain yields t ha $^{-1}$ $\pm$ standard error. Weed control in transplanted rice by butachlor plus hand weeding at $\pm$ 30 DAT; in Drum seeding by oxadiazon at planting plus hand weeding $\pm$ 30 DAS.

	Median date		**Rice grain yield**
Method	**Planting**	**Harvesting**	**t ha $^{-1}$**
Transplanting	53 (33-65)	20 (3-37)	5.20 $\pm$ 0.20
Broadcast	28 (23-41)	15 (3-27)	5.34 $\pm$ 0.30
Drum seeder	33 (24-40)	11 (4-30)	5.61 $\pm$ 0.37

Median planting dates for broadcasting and drum seeding were 25 and 20 days earlier respectively than transplanting. This resulted in median harvest dates of 15th November for broadcast plots, 11th November for drum seeding and 20th November for transplanting with harvest continuing in transplanted fields for a week longer than direct seeded plots (Table 8). Harvest dates of the long duration variety Swarna, planted at only four sites ranged from 7th to 30th November for direct seeding and from 19th November to 6th December for transplanting. In comparison harvest of the shorter duration BR 11 was advanced to a median date of 11th and 15th November for broadcast and drum seeding respectively and to 22nd November when transplanted. It must be emphasised that these dates indicate when farmers actually harvested rather than when grain was sufficiently ripe so there may have been instances when harvest was delayed. The data do however demonstrate how direct seeding can bring forward rice harvest to allow farmers the opportunity for timely planting of *rabi*. All participants were encouraged to plant chickpea and a median sowing date of 25th November was achieved. Median sowing date on plots that had previously been direct seeded with rice was 21st November (ranging from 6th November to 7th December) some 7 days before planting of transplanted rice plots (11th November to

18th December). Chickpea sowing was however delayed at many sites by the Eid festival.

Table 9: Median planting and harvest dates and mean grain yields of variety BR 11used with three planting methods, field-scale evaluations in 2004. Dates are days after 1st June for planting and 1st November for harvesting, figures in parentheses indicate date ranges. Grain yields t ha $^{-1}$ $\pm$ standard error.

	Median date		**Rice grain yield t ha $^{-1}$**
Method	**Planting**	**Harvesting**	
Transplanting	52 (47-64)	22 (13-35)	5.79 $\pm$ 0.12
Broadcast	26 (24-31)	15 (9-18)	6.11 $\pm$ 0.10
Drum seeder	33 (24-44)	11 (9-27)	6.32 $\pm$ 0.16

PROVA/DAE held a series of farmer meetings at each evaluation site during the *aman* season to increase farmer awareness of direct seeding. These involved 112 farmers in 16 block meetings each with one extension worker.

Drum seeder (left) for wet direct seeding and a lithao for dry direct seeding (right)

Field-scale evaluation of direct seeding supervised by PROVA/DAE, 2004. Farmer managed plot in Tanore Upazilla. Broadcast direst seeded rice (BR31) on right and transplanted rice on left.

Field-scale evaluation of direct seeding by farmer group in Godagari upazilla. Transplanted rice variety Swarna, surrounding maturing crop of BR 31 direct seeded with a lithao.

Direct, dry seeded crops of Swarna, sown into furrows made by a lithao, produced higher yields than adjacent transplanted crops under farmer management (Table10). Yield of dry seeded BR 31 was similar to transplanted Swarna. Dry seeding was undertaken in the third week of June into weed free, moist seedbeds prepared by four previous passes with an ox-drawn country plough and 3 passes with a ladder to level the land. This is a similar intensity of tillage required to prepare land for transplanting. The crop survived more than 300 mm of rain in a 24 hour period five days after seeding as farmers drained their fields.

Table 10: Field-scale evaluation of dry direct seeding with a lithao. Data are for three farms in *aman* 2004. Rice grain yield t ha^{-1} $\pm$ Standard Error. Weed control in transplanted rice by hand weeding at $\pm$ 15 and 30 DAT; in DSR by oxadiazon at planting plus hand weeding $\pm$ 30 DAS.

Variety	***Transplanting***	**Dry seeding**
Swarna	5.71 $\pm$ 0.14	6.09 $\pm$ 0.24
BR 31	-	5.86 $\pm$ 0.17

4.2.4 *Scaling-up of demonstration of T-aman rice followed by chickpea system in two districts of the High Barind Tract in collaboration with DAE*: Demonstrations of weed control with granular butachlor (product Machete 5% granules) in transplanted rice variety Swarna and BR32 were monitored at 91 sites covering 15 extension blocks in 9 upazillas distributed through Chapai Nawbgonj, Naogaon and Rajshahi districts. Overall Swarna (4137 $\pm$ 49 kg ha^{-1}) produced a higher mean yield than BR 32 (3681 $\pm$ 51 kg ha^{-1}) ($p < 0.0001$). Plots with treated with herbicide and one hand weeding (3979 $\pm$ 52 kg ha^{-1}) yielded better ($p = 0.03$) than those that were hand weeded (3839 $\pm$ 53 kg ha^{-1}). There was no variety by weed control practice or district by weed control interactions demonstrating the use of butachlor to be a robust weed control technology, saving farmers expenditure for labour and providing significantly higher rice yield. Variety performance varied with district ($p = 0.0458$) as the yields (kg ha^{-1}) shown below indicate:

District	Swarna	BR32
Naogaon	4211	3937
Rajshahi	4136	3465
Chapi Nawobganj	4076	3673

Variety performance also varied in different upazillas within districts ($p < 0.0001$). Overall Swarna provided stable yields and broad adaptability while BR32 performed poorly in Rajshahi.

Demonstration sites were used for field days and farmer meetings during the *aman* season. A total of 418 farmers attended 34 field meetings and 114 attended 3 more formal field days, one in each of the three districts where demonstrations were located. Each field day was also attended by 11 to 18 extension workers.

Date of rice harvest, date of subsequent chickpea sowing and chickpea stand were all significantly influenced by the rice variety grown in *aman* (Table 11). On average rice variety BR 32 was harvested on 17th November some 7.4 days before Swarna and chickpea was sown after BR 32 a mean of 6 days earlier than after Swarna. Although earlier planting after BR 32 resulted in a better stand at 30 DAS and at harvest chickpea yield (878 kg ha^{-1} $\pm$ 28) while higher than that following Swarna (821 kg ha^{-1} $\pm$ 26) was not significantly different. As mentioned earlier, rain in November 2003 provided ideal

Table 11. Significance levels of factors influencing chickpea yields in *rabi* season 2003-4. PROVA/DAE demonstrations.

Source of variation	Date of previous crop harvest	Date of chickpea sowing	Number days turn around	Mean chickpea density plants / m^2 30 days after sowing	Mean chickpea density plants / m^2 At harvest	Grain yield
Upazilla (U)	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
Previous rice variety (V)	<.0001	<.0001	0.0054	<.0001	<.0001	
Previous weed control in rice (W)	NS	NS	NS	NS	NS	NS
U x V		0.0193	0.0229	<.0001		

moist seedbeds for chickpea emergence reducing the benefit of an earlier rice harvest that would be expected in years when chickpea is sown onto residual moisture. However the potential for earlier harvest of rice leading to earlier sowing of chickpea when a shorter duration rice variety is grown was clear, this trend being seen in most upazillas (Figure 18)

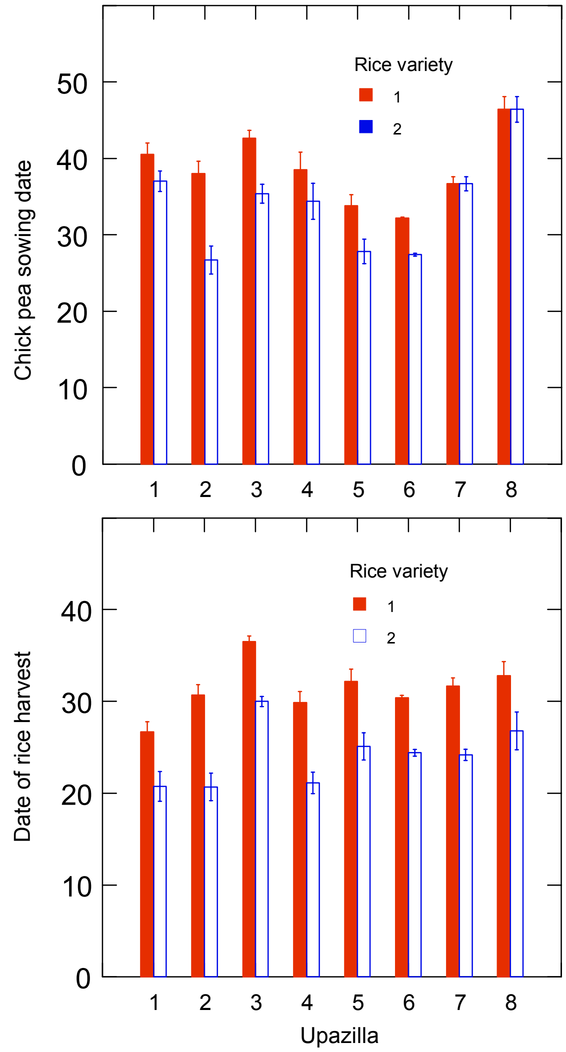

Figure 18: Mean harvest date of rice variety Swarna (1) and BR 32 (2) and subsequent chickpea sowing date in 8 upazillas of the High Barind Tract. Dates calculated from October 25 th = 1. PROVA/DAE demonstrations in 2003-4.

4.2.5 *Analysis of economic returns from new technology and impact on resource-poor households*: A farmer and formal economic evaluation of On-farm trials in the 2003 *aman* season was conducted in six upazilas in Rajshahi district. Nineteen farmers who participated in OFTs were interviewed. Results from the farmer evaluation showed that:

- Farmers were positive about direct-seeding, particularly the advantages of allowing timely crop establishment in a drought year, reducing the cost of planting, and allowing earlier harvesting. But they also experienced problems with water management and making plot boundaries.
- Farmers took a more positive view of herbicides, which they saw as saving labour costs, but some experienced problems with water management during the *aman* season.
- Farmers were enthusiastic about BR31, but much less enthusiastic about BR39, which matured earliest and was badly affected by pests. BR39 and BR32 were seen as more suitable for a short-duration irrigated crop in the pere-monsoon *aus* season.

- Land tenure was not viewed as an important constraint for adoption of herbicides, with some landlords even prepared to share the cost with tenants. Tenure was a more serious constraint on adoption of direct seeding, which was associated with insufficient labour for good crop management. Tenants reported a positive response to direct seeding from landlords who had visited OFTs. Once landlords accept that yields from direct seeding are the same as with transplanting, tenancy should not prove a binding constraint on adoption of direct seeded rice.

Results from the formal economic evaluation economic evaluation showed that:

- Total costs that varied were lowest for the eight transplanted treatments. This reflected the lower cost of weeding for transplanting and the lack of cost-savings in cost of crop establishment with direct seeding when dibbled rather than broadcast or planted with a lithao.
- The treatment with the highest net benefit was transplanted BR32 + herbicide. Three treatments showed net benefits of above 50,000 Tk/ha. This included direct seeded BR31 + herbicide, which had the highest yield of any direct seeded treatment. The lowest net benefits were recorded for direct seeded BR39. In sum, the economic evaluation identified direct seeding with BR31 as the most promising treatment and direct seeded BR39 as the least promising. This matches results from the farmers' own evaluation.

A full report on this farmer and economic evaluation is available in project Working Paper 4. The results from the economic evaluation confirmed that DSR was not economically superior to TPR when rice seed was dibbled, and that for this technology to be economically viable under farmers' field conditions, alternative methods of direct seeding are necessary. These were tested for the first time on a field scale in 2004. Records of labour inputs for direct seeding with a lithao, on plots of approximately 0.14 ha, indicate substantial savings in the time for crop establishment. Mean time for line opening, sowing and covering seed with an ox drawn ladder was 8.68 man days ha^{-1} (records from 3 farms at Sona Dighi, Godagari upazilla). This compares with 36.5 days ha^{-1} for transplanting (including seedbed operations, uprooting of seedlings and transplanting) reported in Working Paper 4. The profitability of direct seeding will however depend on the costs of in-crop weed control. Ronstar (oxadiazon) used in the trials to date costs TK 1606 ha^{-1} compared to only TK 673 for Rifit (pretilachlor) used in transplanting. While Rifit, or indeed Machete (granular butachlor), has provided efficient weed control in transplanted rice when applied into ponded water the effectiveness of Ronstar can be reduced when heavy rain follows application. At Sona Dighi in 2004 one farmer achieved excellent control and only needed 6.7 man hours ha^{-1} for subsequent weeding. However heavy rain after planting at he other two sites led to dense weed regrowth requiring 75 to 80 man hours per ha^{-1} for weeding. Typical inputs for weeding transplanted rice after use of Rifit in 2003 were 12 man hours per ha^{-1}. Further studies are needed with farmers to evaluate the costs and returns from direct seeding with a lithao, drum seeder or broadcasting on a field scale. These will be undertaken during an extension to the project in *aman* 2005.

Farmer decision-making for *rabi* cropping in the High Barind Tract was explored through a group meeting with 13 farmers and individual interviews with nine farmers in Godagari upazila, Rajshahi district, during the 2004 *rabi* season. Decisions on *rabi* cropping involved climatic, agronomic, and socio-economic variables. The key variable was the existence of sufficient soil moisture after the *aman* harvest, which determined whether *rabi* cropping was feasible, what type of *rabi* crop could be grown and whether the crop was sown or broadcast. Agronomic variables included the date of *aman* harvest, which was determined by landt ype (higher land was transplanted first) and by the choice of rice variety, which reflected household food security preferences. Soil type was an important agronomic factor for the decision to sow chickpea, which was not grown on certain soils. Socio-economic variables included the timely availability of labour, draught power, and of quality seed. Shortages of hired labour to remove dried *aman* from the field several days after harvest delayed and sometimes prevented timely sowing of *rabi* crops. Seed availability was less of a problem than the availability of labour or draught power. Farmers had developed innovative methods of testing the quality of purchased seed.

A decision-tree with 14 nodes was developed that captured the major *types* of decisions that farmers have to make, without attempting to capture minor variations from the general pattern revealed in particular cases. Since this decision-tree does not involve introduction of new technology, it is not intended to provide "decision-support" for farmers. Instead, the aim was to provide researchers with a clearer understanding of farmers' existing management decisions, which in turn will help to assess the likely impact of earlier rice harvesting on *rabi* planting.

The decision-tree highlights the importance of socio-economic constraints on increasing cropping intensity in the High Barind. Climatic and agronomic factors determine the quantity and quality of soil moisture that is technically available for use after rice harvest. However, the ability of farmers to exploit this technical maximum is limited by socio-economic factors. Competition for hired labour, and competition for draught power for haulage, may result in some farmers being unable to clear all their plots in sufficient time to allow timely *rabi* sowing. Availability of draught power for tillage may also be a constraint on timely sowing of chickpea, though not for other *rabi* crops that can be broadcast without ploughing. Thus, even when climatic and agronomic factors are favourable, farmers may still be prevented from sowing *rabi* crops by socio-economic constraints.

The short time currently available for *rabi* planting means that interventions to advance rice harvesting can have a dramatic effect at the margin. A saving of five days would increase the time normally available for *rabi* planting by half. Consequently, DSR and short duration varieties have the potential to significantly increase cropping intensity in the High Barind.

This decision tree remains provisional until validated against the experience of an independent sample of farmers from the same area during the 2005 *rabi* season. A full report on farmer decision-making is available in project Working Paper 8.

5.0 Contribution of Outputs to developmental impact

The project has improved understanding of the agronomic, technical and socio-economic opportunities for productivity gains in two widespread rice-based systems in Bangladesh. These are: a) improved weed management practices for intensive transplanted *aman–boro* rice systems (monsoon and irrigated seasons found on 2 million ha) and, b) labour-efficient weed management facilitating the introduction of direct seeding of rice in rainfed *aman-fallow or aman-rabi* (monsoon and post-rice seasons found on 1.4 million ha). Previous research had highlighted the growing competition for and rising costs of labour for weeding in *aman-boro* in Comilla district and, the variability in timely access to irrigation water in *boro*. Results from on-farm trials undertaken by R8234 have demonstrated that the use of herbicides, allowing a reduction in production costs, is a robust approach to weed management. These proved effective and profitable in both rainfed *aman* and irrigated *boro* rice. Yields may also be maintained by use of a push weeder but with higher labour inputs. These practices were demonstrated at 240 sites over four crop seasons. Yield gains over use of the usual farmer practice of one or two manual weedings ranged from 200 to 600 kg ha^{-1} reflecting more timely and prolonged weed suppression. These yield gains are of the order of previously recorded yield losses due to weeds with existing farmer management – generally one third of farmers lose at least 500 kg ha^{-1} of the potential yield. Water management was shown to be critical in *boro* for maximising yield and therefore returns from weed management inputs. *Aman* production carries the risk of total crop loss due to extensive flooding across the toposequence, a situation experienced in 2004 when 12% of demonstration sites were destroyed mid-way through the season. Low cost weed control methods mitigate such losses.

Herbicide use, according to Bangladesh Crop Protection Association figures, is increasing at 40 to 50 % per year. Chemical weed control is a knowledge intensive technology with effectiveness influenced by field position, product choice, method of application and water management. The private sector has the key role to play in knowledge transfer to farmers through herbicide dealer networks down to village level. R8234 has demonstrated that partnerships between the private sector an NGO and researchers can accelerate delivery of information and particularly broaden the subject matter to non-product specific topics including safety, environmental issues, avoiding resistant weeds and integration of chemical and manual weed control. This partnership led to the production and distribution of a poster with key messages on weed control. Posters distributed via Syngenta Bangladesh Ltd are now on display in pesticide shops in bazaars in Comilla district, providing a source of information for farmers. Senior managers from nine herbicide producing or marketing companies in Bangladesh attended a meeting facilitated by the project to discuss opportunities for greater involvement in and stewardship of herbicide knowledge transfer to farmers. The majority of government employed extension workers have little experience or knowledge of herbicide use so farmers rely on pesticide dealers for information. As herbicide use increases the extension service needs to have the capability to support adoption and safe use. In partnership between Syngenata and the NGO SAFE, the project produced a training of trainers manual on herbicide use as a component of weed management. Furthermore all 62 block supervisors from Comilla Sadar Upazilla were trained in a seminar and extension managers from all 9 upazilas in the district attended a workshop covering the main findings and recommendations from the project.

Five seasons of a long-term comparison of rice direct seeding with the usual farmer practice of transplanting, on-farm trials and field-scale evaluations of direct seeding in three districts of the High Barind Tract were completed. Yields of rainfed *aman* rice can be maintained or even increased with direct seeding, but herbicide use is essential to overcome additional weed infestations that result. While direct seeding reduces the cost of crop establishment and facilitates earlier planting, the development of practical methods of seeding and effective weed control will be critical to widespread adoption. Planting dry seed with a locally made *lithao*, or wet seeding with an imported drum seeder, both showed potential when evaluated on farmers' fields. However experiences from use of these implements in 2004 indicated that it is important to undertake timely tillage and land levelling to ensure good crop stands and weed control when direct seeding. Farmers will need the knowledge on which to base new skills to achieve the benefits of direct seeding. Establishing the crop in this way, often a month earlier than is possible when transplanting, accelerates harvesting by 5 to 10 days. A study of farmer decisions on the extent of post-rice *rabi* planting suggests that this increased the window of opportunity for seeding chickpea (or other crops) onto residual moisture has the potential to increase the area planted to *rabi* crops and hence the productivity of and incomes from Barind systems.

The use of granular herbicide in *aman* rice was demonstrated at 100 sites in three Barind districts to raise farmer awareness of this opportunity for timely weed control. The demonstrations were accompanied by training of extension workers in safe, effective use if herbicides. Associated studies indicated that farmers, particularly those with larger holdings, and increasingly interested in adopting herbicides to reduce production costs in the Barind.

Work over the past six years by R7471 and R8234 has developed a considerable knowledge base on weed management in two of the most widespread rice cropping systems in Bangladesh. These are diverse in terms of agronomic practices with considerable variability at the field level, primarily due to crop establishment method and water regime. In the High Barind, direct seeding has the potential to increase the productivity of rainfed rice-systems, whereas in the *aman/boro* system of Comilla farmers are beginning to adopt herbicides to overcome labour shortages. With adoption of direct seeding, weed species shifts are to be expected as a consequence of change in crop establishment and of weed control methods. In transplanted rice weed management can be optimised according to prevailing water regimes while adoption of herbicides introduces an additional set of issues, including avoidance of resistance in target species. Access to knowledge is the key for farmers to take advantage of new crop management opportunities. CPP has agreed to continue funding work in Bangladesh up to January 2006 a period that will be used to consolidate knowledge and make it accessible in a form that enhances understanding of the new technology, promotion by extension, and adoption by farmers. This will be achieved by developing a decision support framework that will distil research findings into an inter-linked set of decision-tools for improved weed management for transplanted and direct seeded rice and for transition between both.

Rain-fed rice systems in the Barind are highly variable due to toposequence position effecting water supply, soil type, resource availability to farmers and rainfall variability. Technology testing and promotion has been through on-farm trials in collaboration with DAE and dry direct seeding has so far largely been evaluated on small plots. Work will evaluate different methods of direct seeding on a field scale to gain more experience in field-scale mechanisation. This will broaden understanding of options for farmers in a variable cropping environment. Work will also investigate other herbicides, particularly post-emergence options, to increase the effectiveness weed control in direct seeded rice. These studies will strengthen the knowledge base for decision support frameworks.

R8234, and previously R7471, have examined the need for improved weed management practices in intensive rice production systems, charted the uptake of herbicide use promoted by the private sector since 2000 and conducted on-farm demonstration/trials of a variety of improved weed management practices for transplanted rice. Synthesis of these findings within the context of decision support frameworks will provide a vehicle for technology assessment with the rapid expansion of herbicide use in these systems. The framework will address three domains in relation to policy, extension and on-farm technologies for weed management. Outputs will include Policy Briefs, fact sheets, training of trainers modules, posters for pesticide retailers, and leaflets for extension and farmers. This material will be placed on the Rice Knowledge Bank managed by BRRI/IRRI to ensure future accessibility by extension service providers. Sub-projects of PETRRA programme identified and piloted a range of uptake methods and pathways involving partnerships NGOs, government extension and the private sector.[1] These will be taken forward by a new dissemination project for major NGOs funded by EU. CPP funded work in 2005/6 will ensure that appropriate information resources on rice establishment and weed management are available for use by the diversity of extension providers that are likely to emerge in Bangladesh in the near future.

In addition to new technical knowledge, project outputs will contribute to current socio-economic debates over the future of agriculture in Bangladesh and the role of the sector in poverty alleviation. The achievement of rice self-sufficiency in 2002 and the emergence of the rural non-farm sector as the fastest-growing source of rural employment have increased the economic incentives for adoption of labour-saving technical change. Micro-level studies on the impact of DSR and improved weed management on farm income and rural employment will be summarised as a Policy Brief targeted at government policy makers and aid donors. This will provide new evidence of the continued relevance of agriculture and agricultural research to help reduce poverty and ensure the sustainability of rice production for the future.

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6.0 Project Publications:

6.1 Conference Papers

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6.3 Other Dissemination of Results:

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6.4 Reports in mass media

Newspaper coverage in Bangladesh (Eng = English; Ben = Bengali)

Date	Publication	Title
8/4/03	The Daily Jugantor	Modern system of rice weed control (Eng.)
24/4/03	The News Today	New Technology to reduce cost of rice production (Eng.)
24/4/03	The New Nation	Photograph of Cost effective weed management project rally (Eng.)
24/4/03	The Bangladesh Today	BRRI organises farmer's rally (Eng.)
24/4/03	The Daily Itefaq	Farmer's field day in Comilla (Ben.)
24/4/03	The Daily Ajker Janata	Field day and Farmer's rally in Comilla (Ben.)
24/4/03	The Daily Khabar	Field day and Farmer's rally (Ben.)
24/4/03	The Banglabazar Patrika	Photograph of Cost effective weed management project rally (Ben.)
24/4/03	The Daily Dinkal	Field day and Farmer's rally (Ben.)
24/4/03	The Daily Gonomookh	Field day and Farmer's rally (Ben.)
25/4/03	The Bangladesh Observer	BRRI's field day held in Comilla (Eng.)
8/8/03	The Daily Bangladesh Sangbad	Farmers training on weed management (Eng.)
10/8/03	The Daily Rupashi Bangla	Farmers training on weed management (Ben.)
6/9/03	The Daily Bangladesh Sangbad	Training on cost effective weed management in Barora (Eng.)
7/9/03	The Daily Rupashi Bangla	Training on cost effective weed management (Ben.)
09/2003	Extension News	Training on cost effective weed management (Ben.)
9/11/03	The Daily Rupashi Bangla	Farmers discussion on promotion of cost effective weed management (Ben.)
20/3/04	The New Nation	Workshop on Herbicide information flow (Eng.)
20/3/04	The News Today	Workshop on Herbicide information flow (Eng.)
20/3/04	The Daily Gonomookh	Workshop on Herbicide information flow (Ben.)
20/3/04	The Bangladesh Observer	BRRI Workshop held (Eng.)
20/3/04	The Independent	BRRI organises workshop (Eng.)
20/3/04	The Daily Sangbad	Workshop on Herbicide information flow (Ben.)
Date	**Publication**	**Title**
20/3/04	New Age	BRRI workshop on new technology (Eng.)
20/3/04	The Bangladesh Today	Workshop on cost effective weed management held (Eng.)
21/3/04	The Banglabazar Patrika	Workshop on Herbicide information flow (Ben.)

21/3/04	The Bhorekagoj	Workshop on weed control (Ben.)
21/3/04	The Daily Dinkal	Workshop on “Herbicide information flow” (Eng.)
24/03/04	The Daily Ajker Janata	Workshop on Herbicide information flow (Ben.)
24/03/04	The Daily Dinkal	Workshop on “Herbicide information flow” (Ben.)
27/11/04	The Daily Shamol Bangla	Low Cost Weed Management Systems: Farmers Field Day held in Comilla (Ben.)
28/11/04	The Sheronam	Low cost weed management systems/; Discussions and field day held (Ben.)
12/12/04	The Daily Rupushi Bangla	Low cost weed management systems: A field day (Ben.)
16/3/05	Banglabazar Patrica	Workshop held in Comilla regarding Weed management in rice technologies and planning (Ben.)
16/3/05	The Dainik Ajkar Janata	Weed management in Rice: New technology for weed management by weed management project (Ben.)
16/3/05	The News Today	BRRI holds workshop on weed management (Eng.)
16/3/05	The Independent	BRRI workshop on weed management (Eng.)
16/3/05	The Bangladesh Observer	BRRI developed new tech for weed control in rice (Eng.)

Television News coverage

18/03/04 Story and video footage of seminar held at BRRI Gazipur to discuss role of private sector in dissemination of weed management information broadcast on evening news on Bangladesh TV.

15/03/05 Story with video footage of Dissemination workshop in Comilla held 15/03/04 broadcast on evening news on Bangladesh TV, Bangladesh TV World Service.

Narrative Summary	Indicators of Achievement	Means of Verification	Risks and Assumptions
GOAL			
Livelihoods of poor people improved through sustainably enhanced production and productivity of RNR systems.			
PURPOSE			
Promotion of strategies to minimise impact of target pests in rice-based Land-Water interface cropping systems, for benefit of poor people.	By March 2005 information on application of improved weed management practices being used, or included in DAE management plans, for demonstration/promotion work in 4 districts in HBT and 4 districts in Chitagong Division	Project reports monitoring uptake.	Political and economic stability. Continuing widespread scaling-up and adoption by farmers of technologies and by private sector/extension of information systems. Demand for herbicides continues to increase.
OUTPUTS			
1. Validation and promotion of the sustainable intensification of rice-rice farming systems through integrated management of weeds and water.	By December 2005 information resources distributed to DAE in five districts in Chitagong Region providing recommendations on weed management options based on completed validation trials and farmer assessments.	Project reports	Political and economic stability. Suitable climatic conditions Extension organisations use the processes and technologies validated.
2. Validation and promotion of the sustainable intensification of rice-fallow farming systems through expanded winter cropping.	By December 2005 information resources distributed to DAE in four districts in HBT providing recommendations on weed management options for Ds and transplanted rice based on completed validation trials and farmer assessments.	Project reports	

ACTIVITIES			

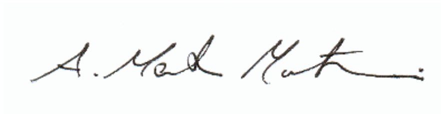
1.1 On-farm testing, development and distribution of non product specific information on herbicides to support promotion by private sector and DAE.	By September 2003, content of draft information leaflets assessed with farmer groups for two cropping seasons in Comilla. Final versions of leaflets printed for use by extension by March 2005.	Project report	Partner organisations continue to collaborate during the course of the project. Farmers continue to work closely with the project.
1.2 Evaluation of public-private service delivery for resource-poor farmers, using herbicides as a case study	By June 2004, qualitative assessment of flow of information to farmers completed in three thanas of Comilla District with SAFE.	Project working paper and FTR for PETRRA SAFE project	
1.3 On-farm trials to develop integrated crop management recommendations for weed control in relation to timing of irrigation management for irrigated *boro* and rainfed T-*aman* rice in Comilla District.	By 02/03 trials established at 12 sites and by 02/04 at 24 sites.	Project working paper showing analysis of results by 12.04	
1.4 Farmer evaluation of and demonstration of weed management options in Comilla district.	Established at 40 sites across three thanas in both *boro* and *aman* seasons in 2003 and 2004	Project working paper showing analysis of results by 12.04	
1.5 Facilitation of farmer meetings and field days at trial and demonstration sites in Comilla in collaboration with DAE	Field days for total of at least 300 farmers completed across three thanas in both *boro* and *aman* seasons in 2003 and 2004	Project reports.	
1.6 Analysis of economic returns from new weed management technology to identify constraints on uptake.	Cost-benefit analysis for Boro crop by 6/2003 and for T. Aman crop by 1/2004	Project working papers for Boro by 6/2003 and for T. Aman by 1/2004.	
2.1 Research managed trial of rice production practices in rice-chickpea systems.	By 11/04 field work completed and by 02/05 all analysis complete	Project working paper summarising lessons from 4 years of rice/rabi rotations available by 02/05. Two peer reviewed journal papers drafted by 03/05	
2.2 Farmer validation of direct seeding of rice with appropriate weed control in the high Barind Tract.	Validation plots established at 20 sites in across two districts by 08/03 and repeated in 04 *aman* season	Project working paper describing first season of results by 12/03 and two years data by 12/04	
2.3 Demonstrations of a T-*aman* rice followed by chickpea system in two	Sites established on 60 farms by 08/03 and 08/04 in	Project reports	

districts of the High Barind Tract in collaboration with DAE/PROVA.	three districts of the HBT.		
2.4 Training of trainers in efficient use of herbicides for use in demonstrations in collaboration with DAE	Block supervisors who supervise 60 demonstrations trained by end 05/03	Project reports	
2.5 Facilitation of farmer meetings and field days at trial and demonstration sites in High Barind Tract.	DAE collaborate with BRRI to hold field days at 40 demonstration sites and 5 validation ssites across two districts	Project reports	
2.6 Analysis of economic returns from new technology to target promotion to ensure impact on resource-poor households.	Collation of data by 12/03 and analysis complete by 6/04	Project working paper by 6/2004	

Biometricians Signature

I confirm that the biometric issues have been adequately addressed in the Final Technical Report:

Signature:



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