CROP PROTECTION PROGRAMME

Promotion of integrated weed management for direct seeded rice in the Gangetic Plains of India

R 8233 (ZA 0540)

FINAL TECHNICAL REPORT

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D E Johnson, A M Mortimer, A W Orr

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Executive Summary

The project's purpose was to ***develop and promote weed management options for direct-seeded rice*** *in the Gangetic plains of India.* ***Information for farmers*** *on the options for direct-seeded rice would be developed and the* ***understanding of the options would be enhanced among extension and research systems****.*

The project established effective collaboration arrangements among three key Agricultural Universities in India, the International Rice Research Institute, the University of Liverpool and the Natural Resources Institute UK. This enabled a multi-disciplinary team covering socio-economics, weed ecology and agronomy to link effectively with regional organizations to local administrative bodies, extension organizations and to farmers and farmers groups and to develop effective weed management options.

On-station experiments in Uttaranchal, Uttar Pradesh and Bihar demonstrated that yields from wet, direct seeded rice (DSR) are broadly comparable to transplanted rice (TPR) providing management of weeds is effective, whilst yields of DSR tended to be about 0.5 – 1.0 t ha^{-1} less than TPR. If weeds were not controlled however, the yields in DSR were a small fraction of those in TPR. Highest yields were always achieved utilising a single herbicide application and at least one subsequent hand weeding. These findings were validated in three states over 48 farmers' field trials in 2003 and 67 field trials in 2004.

DSR was privately profitable for farmers, giving net returns of 13,350 Rs/ha for dry seeded and 11,592 Rs/ha for dry seeded rice compared to 10,343 Rs/ha for transplanted rice. Net labour savings with DSR compared to transplanting averaged 27 days/ha. A provisional cost-benefit analysis suggests that DSR was also profitable at the national level.

Species composition of the accompanying weed flora also may change with management practices. Direct seeding of rice is known to be accompanied by a rapid shift in the weed flora with an increase in abundance of *Echinochloa crus-galli*, *E. colona*, *Ischaemum rugosum* and *Leptochloa chinensis* and on more freely draining soils, *Cyperus rotundus.* The ingression of annual grasses and perennial sedges present particular weed management problems with continuous direct seeding. Quantifying the changes in weed species composition provides the basis for improved weed control methods.

Farmer groups, previously using transplanted rice, in Uttaranchal, Uttar Pradesh and Bihar were introduced to options for direct seeded rice and the related weed management practices. On-farm trials, over several seasons, at these sites demonstrated that direct seeded rice can be successful. Many farmers have expressed considerable interest and the systems are being adopted among lead farmers. In Uttar Pradesh and Bihar, diffusion of the DSR technologies has led to approximately 250 ha of direct seeded rice being grown by farmers in 2004.

A total of 13 farmer field days have been held, with events at each of the partner sites (GBPUAT, NDUAT and RAU), and these have been well attended by farmers and state officials. In 2004, at Patna 700 farmers and a Government Minister

attended one meeting and 250 farmers at another; at Faizabad 250 farmers and at Pantnagar 53 farmers and 16 scientists attended other field days.

Background

Rice-wheat is the principal cropping system of the Indo-Gangetic Plains, occupying some 13.5 million ha, contributing 40% of India's grains and its sustainability is vital to the livelihoods of the farmers of the region and national food security. Traditionally rice is transplanted at the end of the dry season (May / June) after the land has been flooded and puddled and wheat is planted in the dry season (November / December). Constraints to current system productivity include an increasing trend of shortage of agricultural labour, increasing costs of labour, relative cost of fertiliser (fertiliser consumption over the last 5 yrs has remained stagnant), and late sowing of wheat (partly dependent on the date of rice harvest).

This project has furthered the development of direct seeding and associated weed management options initiated under the CPP funded project - R7377 (1999-2002). Prior to the initiation of R7377, the Technical Co-ordination Committee of the Rice Wheat Consortium stated in 1998 that "the management of weeds in direct seeded rice (DSR)" was a crucial factor affecting the performance of the rice wheat system".

The project has found that most farms are less than 2 ha in area and farmers use 25-50% of their land for cultivating rice/wheat and derive 30-50% of agricultural income from rice. Labour shortages at times of transplanting, manual weeding, and harvest occur on most farms. Family labour is supplemented by hiring migrant labourers from eastern Uttar Pradesh, Bihar, Bangladesh, or from the local area. Direct seeding in place of transplanting can address some of these labour shortages. The labour requirement for establishing a transplanted rice (nursery and transplanting) is approximately 50 person days ha^{-1} in comparison to 3 – 7 person days ha^{-1} for drill or wet (broadcast and drum seeded) seeded rice . Most farmers are familiar with herbicide use in wheat and are using herbicides (commonly butachlor) in transplanted rice.

Direct (drill) seeding of rice is complementary to the reduced or zero-tillage systems for wheat as the same seed drills can be used and methods are similar. The area sown with zero-till seed drills has increased in recent years from virtually zero to around 200,000 ha in Pakistan and India. Drill seeding of rice was thought likely to reduce delays in sowing wheat as it advances the start of the rice season by up to one month resulting in an earlier harvest. A principal concern for the sustainability of the rice-wheat system is however the long term effect of alternate dry and wet cultivations for wheat and TPR, respectively. Wet cultivation (puddling) largely destroys the natural soil structure in the surface layers (particularly in clay soils) and forms an impermeable layer in the soil. While this is suitable for water management in TPR, it reduces the yield potential of the subsequent wheat crop. As dry direct seeding of rice avoids the need to "puddle" the soil, soil structure is retained with potential long term yield benefits.

Research on-station and on farmers' fields in Uttaranchal, on project R7377, established that rice yields from DSR can be comparable to transplanted rice (TPR) while weed management is adequate. Where weeds are not controlled yields in DSR however the yields may be a small fraction of those from TPR. Further, the composition of weed growth may change with management practices and understanding these changes can provide the basis for improved control methods. Farmer groups in Uttaranchal, in the Pantnagar area, had been introduced to weed management systems for direct seeding. By 2002, on-farm trials over several seasons had demonstrated that similar rice yields can be obtained from direct seeding as compared to transplanting. Many farmers have expressed considerable interest and the systems are being adopted among lead farmers.

In February 2002, the Executive of the Rice Wheat Consortium made the recommendation that there should be greater emphasis on the scaling-up of technologies within the region and more socio-economics aspects included in studies. Further, at an international workshop in Haryana, March 2002, several speakers called for greater emphasis to be placed on developing and promoting improved weed management methods for DSR and for scaling-up of activities to match advances made in the zero-tillage of wheat. At a workshop in Pantnagar in October 2002 at the end of R7377, attended by 100 research staff, extension and farmers, presentations described the successful application of direct seeding methods for rice over a number of years and at a range of sites within the Indo-Gangetic plains. There was a consensus that these technologies should be "scaled-up" and made more widely available to farmers. The Vice-Chancellor of GBPUAT (Professor Gautam) requested key organisations in the Indian agriculture sector be made fully aware of the conclusions of the workshop and the potential of direct seeding technology to address many of the sustainability issues of the rice-wheat system. The role of the current project was to demonstrate the opportunities for direct seeding of rice to farmers across a wide geographic area in the Indo-Gangetic Plains.

Project Purpose

The purpose of the project and how it addressed the identified development opportunity or identified constraint to development.

The project's purpose was to

1. Test weed management options for direct-seeded rice and widely promote these on farmers' fields.
2. Develop information for farmers on weed management options for direct-seeded rice.
3. Enhance knowledge and understanding of weed management among regional extension and research systems.

Research Activities

The research activities in India were led by G.B. Pant University of Agriculture and Technology (GBPUAT), Uttaranchal State where the principal collaborator was Professor G Singh of the Dept. of Agriculture, GBPUAT. Professor Y Singh had been on the staff of GBPUAT until retirement and was retained as consultant on the project. Through GBPUAT, collaboration was established with Rajendra Agricultural University (RAU), Patna Bihar (850 km east of Delhi) and Narendra Deva University of Agriculture and Technology (NDUAT), Faizabad, Uttar Pradesh (550 km east of Delhi) to provide a wide coverage of target environments (Fig 1). In general, towards the east, farms are smaller, farmers have more limited access to resources and irrigation is less developed.

Staff of GBPUAT, NDUAT and RAU, together with extension services, have been the primary collaborators in the research. Experiments have been conducted on research stations in each of these areas and a range of establishment / weed control options treatments has been tested. These experiments have been used to gain an understanding of the constraints and benefits of the systems, and to develop data sets on crop performance and weed growth. The experiments have also been used to demonstrate establishment methods and to provide the focus of farmer and researcher meetings. On-farm trials have been established in each of the study areas, with farmers undertaking field scale testing of direct seeding after having selected options from demonstrations / researcher experiments. Researchers have in turn monitored the performance of on-farm trials and direct seeding has been compared to transplanting at each farm. The experimental areas have been in the order of 0.4 ha in the on-farm trials.

The International Rice Research Institute (IRRI) is a partner in the project. Through Dr Mortimer (and Dr Johnson after September 2003), the IRRI weed ecologist, the project has links with the Weed Ecology Working Group of IRRI that, in turn, brings together weed scientists working in rice in Asia. The project, through IRRI, has funded the Indian collaborators to attend meetings elsewhere in Asia and at IRRI. Drs Mortimer/Johnson have been closely involved with the planning of studies and analyses of the data, and have made frequent visits to India. After leaving IRRI to join University of Liverpool, Dr Mortimer continued involvement with the project. G. B. PUAT is a benchmark site of the CIMMYT/IRRI Rice Wheat Consortium (RWC) and of the Irrigated Rice Research Consortium of IRRI. The project has also been linked with IRRI's MTP project "Enhancing Productivity and Sustainability of Favorable Environments".

Project on-farm activities on direct seeded rice

Fig 1. Project activities in northern India.

Outputs

The project's outputs are:

Project output 1: Weed management options for direct-seeded rice tested and widely promoted on farmers' fields

The project continued field experimentation initiated under project R7377 around Pantnagar in Uttaranchal and extended the activities to Uttar Pradesh and Bihar states.

The range of activities comprised

- researcher managed experiments with wet and dry direct seeding options with different levels of weed management ("system trials");
- on-farm testing where farmers grew field scale areas of direct seeded rice for comparison with transplanting;
- experiments on seeding rate and varietal choice.

Systems trials

These were designed to determine the relative performance of the crop under different crop establishment practices, the effectiveness of weed control measures and potential changes in the weed flora as a result. These experiments also provided a focus for farmer and researcher field days and enabled researchers to gain experience with the direct seeding options.

Grain yields

The GBPUAT "systems" experiment had been established in the earlier phase of the project and this was maintained with identical treatments and layout. The establishment methods were conventional transplanting into a puddled soil; pre-germinated "wet seed" sown with a drum seeder into puddled soil; dry seeded sown with a conventional seed drill after dry tillage, and dry seeded with a zero-till drill after no tillage. Rice was grown in the wet season and wheat was sown in the cool season with plots being divided and sown with wheat either after conventional tillage or zero-tillage. Different weed management methods in rice included: no control, hand weeding and herbicides plus one hand weeding. The effect of the treatment on grain yields over four years are shown in Table 1.

Table 1 The effects of rice establishment method and weed control on rice and mean wheat grain yields (t ha) at one site over four years, Pantnagar, India.

Rice establishment	Weed control	Rice yields				Wheat Yield 2001-04
		2001	2002	2003	2004	
Transplanting	Hb+Hw	7.85	6.14	5.33	6.84	3.82
	Nc	5.89	4.56	4.98	6.71	-
Wet seeding	Hb+Hw	8.14	6.76	6.39	7.13	3.84
	Nc	1.03	0.95	0.33	2.26	-
Dry Seeding	Hb+Hw	6.11	6.69	5.52	5.93	3.95
	Nc	0	0.99	0	1.97	-
Zero Tillage	Hb+Hw	6.61	6.11	5.43	6.36	3.88
	Nc	0	0.36	0	2.39	-
S.E.D		± 0.33				± 0.11

Note. Hb+hw = Herbicide + one hand weeding Nc = no control of weeds

The main effects of rice establishment method, weed control and year were significant ($P<0.001$), and there were significant interactions of rice establishment and weed control. Over the four years, with herbicide and one hand weeding, the yields with transplanting and direct seeding were similar with the wet seeding tending to get slightly more than transplanting and the dry seeding a little less. With no weed control however all the yields of the direct seeded options were sharply depressed compared to transplanting. There were no effects on rice of where wheat had either been established after conventional or zero tillage and there were no significant effects of the rice establishment method on the subsequent wheat crops.

At Kashipur - Uttaranchal, a "systems trial" was established in 2003 and this was run for one year only. There were significant ($P<0.001$) main effects of rice establishment method, and weed control, and significant interactions (Table 2). The yields between transplanting and direct seeding were similar with good weed control, but losses were greater in direct seeding where weeds were not controlled.

Table 2 The effects of rice establishment method and weed control on rice grain yields (t ha), Kashipur, Uttaranchal.

Rice establishment	Weed control	2003
Transplanting	Hb+Hw	4.50
	Nc	4.17
Wet seeding	Hb+Hw	4.39
	Nc	2.76
Dry seeding	Hb+Hw	3.94
	Nc	1.90
Zero tillage	Hb+Hw	4.12
	Nc	1.48
S.E.D.		± 0.39

Two trials, at Masodha and Kumarganj, were established by NDUAT to take account of the predominant soil types in the area. The effects of the establishment methods on rice and wheat yields are shown in Tables 3 and 4.

Table 3 The effects of rice establishment method and weed control on rice and wheat grain yields (t ha) at one site over two years, Masodha, Faizabad.

Rice establishment	**Weed control**	**Rice 2003**	**Rice 2004**	**Wheat 2003/4**
Transplanting	Hb+Hw	4.04	2.42	3.61
	Nc	3.28	1.96	-
Wet seeding	Hb+Hw	3.77	2.06	3.62
	Nc	1.98	1.10	-
Dry seeding	Hb+Hw	2.93	1.87	3.47
	Nc	0.36	0.58	-
Zero tillage	Hb+Hw	3.04	2.33	3.52
	Nc	0.53	0.47	-
S.E.D.		± 0.32	± 0.14	± 0.08

At Masodha, there were significant (P<0.001) main effects of rice establishment method, weed control, and significant interactions. The highest yields were obtained from transplanting with wet seeding giving the largest yield of the direct seeded plots in 2003 and the zero-tillage giving the largest in 2004. There was no effect of rice establishment method on the subsequent wheat crop in 2003/4.

Table 4. The effects of rice establishment method and weed control on rice grain yields (t ha) at one site over two years, Kumarganj, Faizabad.

Rice establishment	**Weed control**	**Rice 2003**	**Rice 2004**	**Wheat 2003/4**
Transplanting	Hb+Hw	2.91	3.33	4.13
	Nc	2.70	3.05	-
Wet seeding	Hb+Hw	2.63	2.94	4.06
	Nc	1.69	1.42	-
Dry seeding	Hb+Hw	1.13	2.81	3.77
	Nc	0.33	0.85	-
Zero tillage	Hb+Hw	1.82	3.59	4.03
	Nc	0.24	0.12	-
S.E.D.		± 0.35	± 0.28	± 0.22

At Kumarganj, there were significant (P<0.01) main effects of rice establishment method, weed control, and significant interaction effects. With the same pattern as at Masodha, wet seeding gave the largest yield of the direct seeded plots in 2003 and the zero-tillage giving the largest in 2004. There was no effect of the rice establishment method on the subsequent wheat crop in 2003/4.

Table 5. The effects of rice establishment method and weed control on rice grain yields (t ha) at one site over two years, Bikramganj, Bihar.

Rice establishment	Weed control	2003	2004
Transplanting	Hb+Hw	6.54	5.70
	Nc	5.95	5.62
Wet seeding	Hb+Hw	5.72	5.64
	Nc	3.27	0.00
Dry seeding	Hb+Hw	5.22	5.21
	Nc	2.59	0.00
Zero tillage	Hb+Hw	5.64	5.51
	Nc	2.95	0.00
S.E.D.		± 0.51	± 0.29

At Bikramganj - Bihar, in 2003 and 2004, there were significant ($P<0.01$) main effects of establishment method and weed control, and significant interaction effects (Table 5). In 2003, the transplanted rice gave 1 t ha or more than the direct seeded rice though in the following year, where the weeds were controlled, the differences between transplanted and direct seeded plots were small. In 2004, the losses due to weeds were greater than in 2003.

Weed management

Pantnagar (GBPUAT)

The Pantnagar trial examined three different weed management practices which were designed to:

1) examine the efficacy of control of recommended herbicides
2) explore long term cultivation effects of both rice and wheat on rice weeds
3) identify species likely to rapidly increase in abundance.

Weed management regimes were:

a) unweeded
b) one hand weeding 28 - 30 days after planting / seeding
c) weed free (early post-emergence herbicide followed by 2 hand weedings) : Herbicides applied differed according to rice establishment method :Transplanted – butachlor, Wet seeded – anilofos, Dry drill seeded and Zero tillage – pendimethalin. They were applied at establishment or early post-emergence.

An additional rice crop establishment method was a flush irrigation after land preparation with glyphosate followed by drill seeding.

Weed species were recorded by biomass and number at 28, 56, 84 days after seeding and at harvest. Fourteen principal weed species in the systems trial, over the four cropping seasons, were :

Caesulia axillaris
Commelina diffusa
Cynotis spp
Cyperus difformis
Cyperus iria

Cyperus rotundus
Echinochloa colona
Echinochloa crus-galli
Eragrostis japonica
Fimbristylis milliacea
Ischaemum rugosum
Leptochloa chinensis
Paspalum distichum

Influence of crop establishment method

Comparison of unweeded plots after four seasons (2001-2004) indicated that cultivation practices associated with both rice and wheat crop establishment method influenced the weed flora emerging in the rice crop.

Table 6 qualitatively summarises the responses of selected major species. *Cyperus iria* was unresponsive to establishment methods in both crops, whereas *C. rotundus* increased in abundance under zero-tillage. *Echinochloa colona* densities were highest in zero-tilled rice plots which had been conventionally tilled for wheat, conventional tillage in wheat also increasing the abundance of *Ischaemum rugosum* in rice. The role of wheat tillage on the abundance of *Caesulia axillaris* was reversed, lower densities being evident after conventional tillage. Wet seeding in rice increased densities of *Fimbristylis milacea*, *I rugosum* and *C. axillaris.* The mechanistic process(es) underlying these changes require further research, but one plausible hypothesis is that seed persistence is a function of seed size and the large seeded grasses are more likely to survive in the seed bank when buried through conventional tillage of wheat, exposure on the surface under zero-tillage enhancing mortality.

Table 6. The influence of rice and wheat crop establishment methods on abundance (density, 28 DAS / DAT) of selected weed species in rice. Differences of up to three fold in mean density are reflected in the abundance range low – high for each species.
Rice establishment methods : DS - dry seeded, WS – wet seeded, ZT – zero tillage.
Wheat establishment methods : Conv – conventional tillage, ZT – zero tillage.

Species	Response to rice establishment method [1]	Abundance [2]		Response to wheat establishment method [1]	Abundance [2]	
		Low	High		Low	High
Caesulia axillaris	Y	DS / ZT	WS	Y	Conv	ZT
Commelina diffusa	Y	WS	ZT	-	-	-
Echinochloa colona	Y	WS	ZT	Y	ZT	Conv
Echinochloa crus-galli	-	-	-	-	-	-
Ischaemum rugosum	Y	ZT	WS	Y	ZT	Conv
Fimbristylis miliacea	Y	DS	WS	-	-	-
Cyperus iria	-	-	-	-	-	-
Cyperus rotundus	Y	WS	ZT	Y	Conv	ZT

[1] Y = significant effect ($P < 0.05$) of establishment method from analysis of variance. - = not significant.

[2] Abundance estimate (Low / High) based on the density of plants 28DAS/DAT in unweeded rice plots in 2004.

Herbicide and manual weeding

Herbicide followed by two manual weedings reduced the weed flora to a negligible level in 2003 and 2004. The integration of hand weeding and herbicide in weed control for yield protection (Table 1) was essential and the use of herbicide followed by supplemental hand weeding gave yield gains over a single manual weeding. These gains were highest in direct seeded plots in all years. Illustrative gains are shown for 2004 (Table 7). Economically, the replacement of hand weeding by early post emergence herbicide represented a saving of 2.3 ~3 :1 in simple cost-benefit terms (see also internal report no 5).

As indicated above, crop establishment methods significantly influenced weed emergence and density 28DAS/DAT after crop establishment for major weeds.

Table 8 indicates that on average higher grass weed densities were associated with zero-tillage but species made different relative contributions to the total weed pressure by 28 DAS in relation to rice crop establishment. Weed population densities after hand weeding reflected emergence after 28DAS and escapes from manual weed control. The impact of zero-tillage in wheat was to reduce the overall density of weeds present 28-56 DAS under all rice establishment methods except wet seeding, due to late emergence of *I. rugosum. B*y implication, zero tillage of wheat will reduce the density of weeds in rice requiring removal by handweeding after herbicide application.

Table 7. Rice yields in relation to weed management.

Wheat establishment	Rice establishment	Herbicide followed by hand weeding	One handweeding at 28 -30 DAS/DAT	Gain due to herbicide
Conventional cultivation	Transplanted	7050	6700	350
	Wet seeded	7025	5950	1075
	Drill seeded	6075	5075	1000
	Drill seeded+ flush irrigation	6000	5275	725
	Zero-tilled	5375	3875	1500
Zero tillage	Transplanted	6625	6300	325
	Wet seeded	7225	5950	1275
	Drill seeded	5775	5650	125
	Drill seeded+ flush irrigation	6725	4265	2460
	Zero-tilled	5250	3855	1395

Standard errors of differences of means
comparing means with the same level(s) of

Wheat establishment	384.4
Rice establishment	286.7
Different levels of rice and wheat establishment	369.0

Table 8. Mean density (plants m^{-2}) of grass weeds present before hand weeding at 28 DAS/ 0 DAT and at 56DAS/28 DAT after handweeding at 28DAS/DAT. For each species the interaction of wheat x rice crop establishment method was significant ($p < 0.05$).

Species	Wheat establishment	Rice establishment			
		Transplanted	Wet seeded	Drill seeded	Zero-tillage
Before hand weeding at 28 DAS/ 0 DAT					
Echinochloa colona	Conventional tillage	0.0	4.5	17.8	18.3
	Zero tillage	0.0	1.8	5.5	22.2
Echinochloa crus-galli	Conventional tillage	0.0	2.0	8.5	0.0
	Zero tillage	0.0	10.7	10.0	14.0
Ischaemum rugosum	Conventional tillage	0.00	13.17	3.67	0.00
	Zero tillage	0.00	4.50	3.83	1.17
Total	Conventional tillage	0.0	19.7	30.0	18.3
	Zero tillage	0.0	17.0	19.3	37.3
At 56DAS/28 DAT after handweeding at 28DAS/DAT					
Echinochloa colona	Conventional tillage	0.00	1.67	7.67	8.83
	Zero tillage	0.33	1.33	4.33	10.50
Echinochloa crus-galli	Conventional tillage	0.67	1.00	4.83	3.33
	Zero tillage	0.33	2.83	2.00	0.83
Ischaemum rugosum	Conventional tillage	0.0	21.2	0.8	1.0
	Zero tillage	0.2	19.8	0.5	4.2
Total	Conventional tillage	0.67	23.87	13.3	12.66
	Zero tillage	0.86	23.96	6.83	6.53

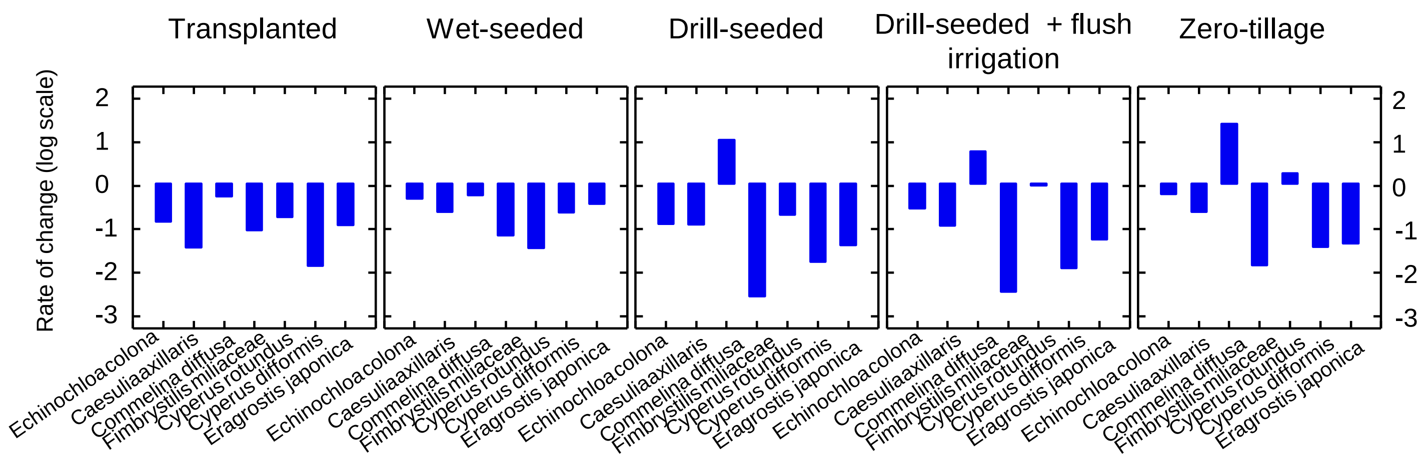
Weed species response to management

Major shifts in the composition of the weed flora were rapid over the period 2000-2002 (Final technical report, R 8233 (ZA 0540), Singh et al., 2003) in response to rice crop establishment methods. Significant seasonal variation (P <0.01) occurred in weed densities establishment from 2002- 2004. Figure 2 illustrates rates of change in abundance comparing densities present in 2002 with those in 2004 at 28DAS/DAT for most abundant species in 2002. In all cases (with the exception of *Commelina diffusa*) weed populations declined over this time period. Contrastingly by 2004 *Ischaemum rugosum*, *Cyperus iria*, *Leptochloa chinensis*, *Echinochloa crus-galli* and *Cynotis* had become incorporated into the flora and were recorded at 28 DAS/DAT.

Figure 3 shows the density of weeds present at 56 DAS/28DAT in 2004, the differential response of species to rice establishment method being highly significant (P<0.01) in all cases in unweeded plots. Significant changes (P< 0.05) in response to establishment after one hand weeding were only evident for *Cyperus rotundus, Echinochloa colona* and *Ischaemum rugosum*. The latter two species and *Cynotis* spp were also found after herbicide + hand weeding in either wet seeded rice plots or in dry drill seeded plots that had experienced flush irrigation.

Three species were identified as major threats to rice use with sequential use of the same crop establishment method: *Echinochloa colona* in drill seeded and zero-till rice, *Ischaemum rugosum* in wet-seeding and *Cyperus rotundus* in drill-seeding and zero-tillage. *Echinochloa crus-galli* and *Leptochloa chinensis* although present in unweeded plots and after a single hand weeding were effectively controlled by post-emergence herbicides.

Figure 2. Changes in abundance (mean density 28DAS/DAT) of weeds according to rice establishment method for species recorded in 2002. Data are the logarithm of the ratio of densities in 2004 to 2002).



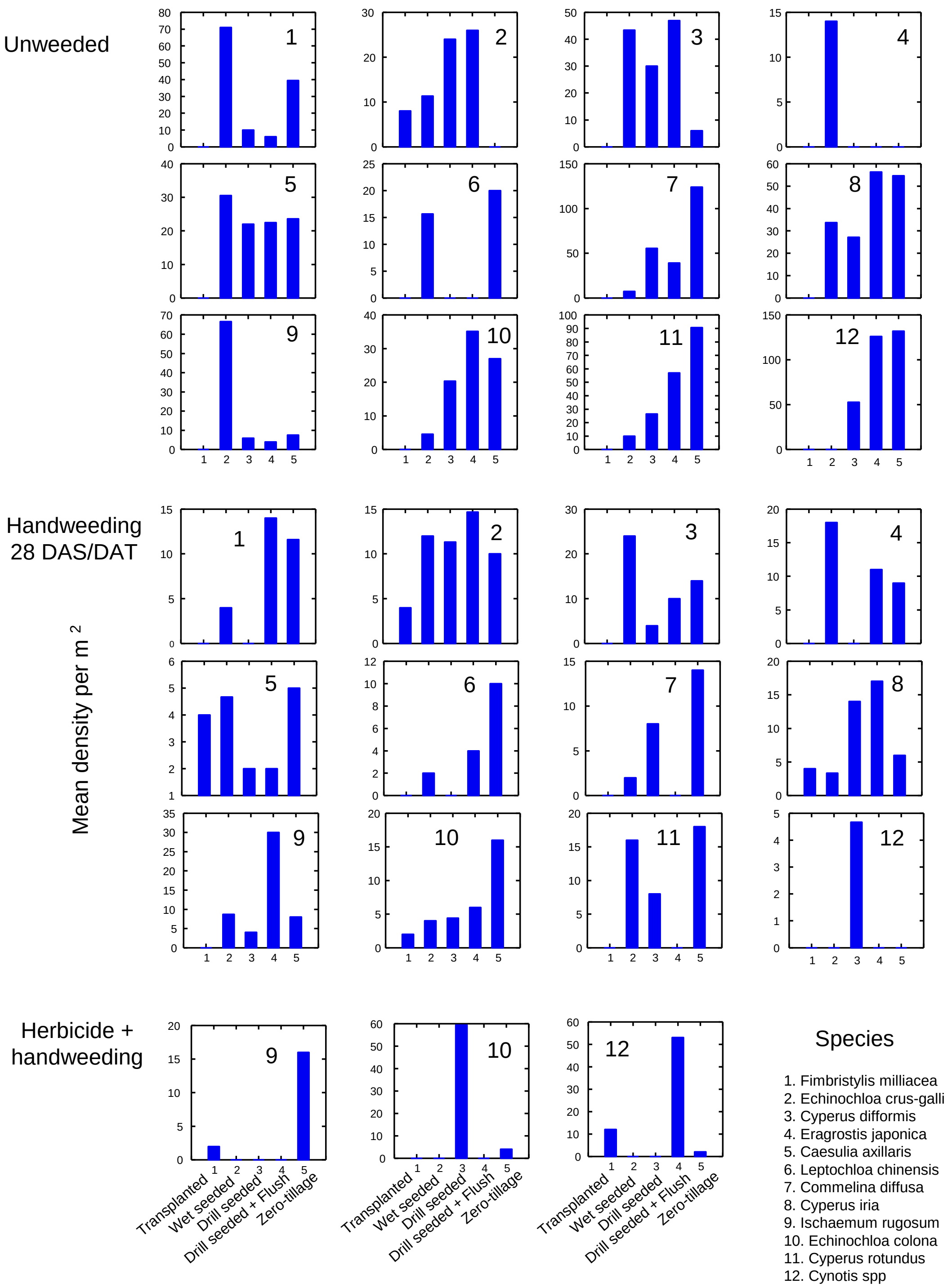


Figure 3. Density of weeds present at 56 DAS/28DAT in 2004, in response to rice crop establishment and weed management.

NDUAT and RAU, Uttar Pradesh and Bihar

Responses of the weed flora in system trials established in Uttar Pradesh (Masodha and Kumarganj, NDUAT) and Bihar (Bikramganj, RAU) were examined in 2003 and 2004.

In these sites the weed flora recorded at Pantnagar was represented with the addition of *Cynodon dactylon*, *Paspalum distichum* and *Alternanthera sessilis* *Cyperus rotundus* and *Ischaemum rugosum* which were recorded at higher densities in the 2003 season at all sites.

On-farm trials

Farmers were introduced to direct seeded after either attending field days, having visited researcher managed trials, or through personal contact with researchers and extension staff. Farmers interested to try direct seeding were supported by research / extension staff with technical advice and the loan of machinery. Farmers were also given options to try either dry or wet seeding. Around Pantnagar, small plots were retained in the fields where the weeds were not controlled for the early stages of the crop in order to allow the weed and crop growth to be sampled. The scale of the farm trials was dependent on locality. Plot size usually ranged from 0.1 to 0.5 ha. Commonly a single field was split with half of it being direct seeded and the other transplanted. The numbers of farmers participating was dependent largely on resources available.

Results of the on-farm trials monitored for yield are shown in Tables 9 and 10. The yields from transplanted rice were either the same or slightly greater than those of direct seeded rice. The variability in performance of the two establishment methods can be seen in Figure 4 where the differences between direct seeding and transplanting were only being marked on a few farms. On most of the farmers' fields it was dry seeding that was tested but where wet seeding was tried it was generally successful and the yield broadly equivalent to dry seeding.

Around Patna in 2004, the distribution of monsoon rains was unfavourable to many with long periods of drought around transplanting time. Farmers with dry direct seeding had an advantage under these conditions as they did not require the fields to be flooded to prepare the land and establish the rice. Large areas in Bihar remained unplanted in 2004 at the same time as the nurseries were full with seedlings. Farmers in Bihar also reported that direct seeded fields were less susceptible to moisture stress and, for those with the infrastructure, required less irrigation to maintain the crops.

Table 9. Grain yield of rice following different crop establishment methods in on-farm trials at four sites in India, Kharif 2003.

	Pantnagar			*Faizabad*	*Patna*
Number of farms	21	7		13	13
Weed control	-	CW	W	-	-
Wet seeded	-	5.02	3.46	-	-
Dry seeded	3.77	5.20	3.15	3.59	4.22
Transplanted	4.21	5.16	3.61	4.14	4.65
S.E.D. ±	0.12	0.31		0.15	0.35

Table 10 Grain yield of rice following different crop establishment methods in on-farm trials at four sites in India, Kharif 2004. CW = clean weeded; W = no weed control.

	Pantnagar		*Faizabad*	*Patna*
Number of farms	22		22	23
Weed control	CW	W	-	-
Wet, broadcast	-	-	4.12	-
Wet, drum seeded	-	-	3.64	-
Dry seeded	6.05	3.47	3.65	4.44
Transplanted	6.01	4.35	4.80	4.09*
S.E.D. ±	0.19		0.49	0.20

* includes two farms where transplanted rice failed due to drought, and at two other farms, both direct seeded and transplanted failed. CW = clean weeded; W = no weed control.

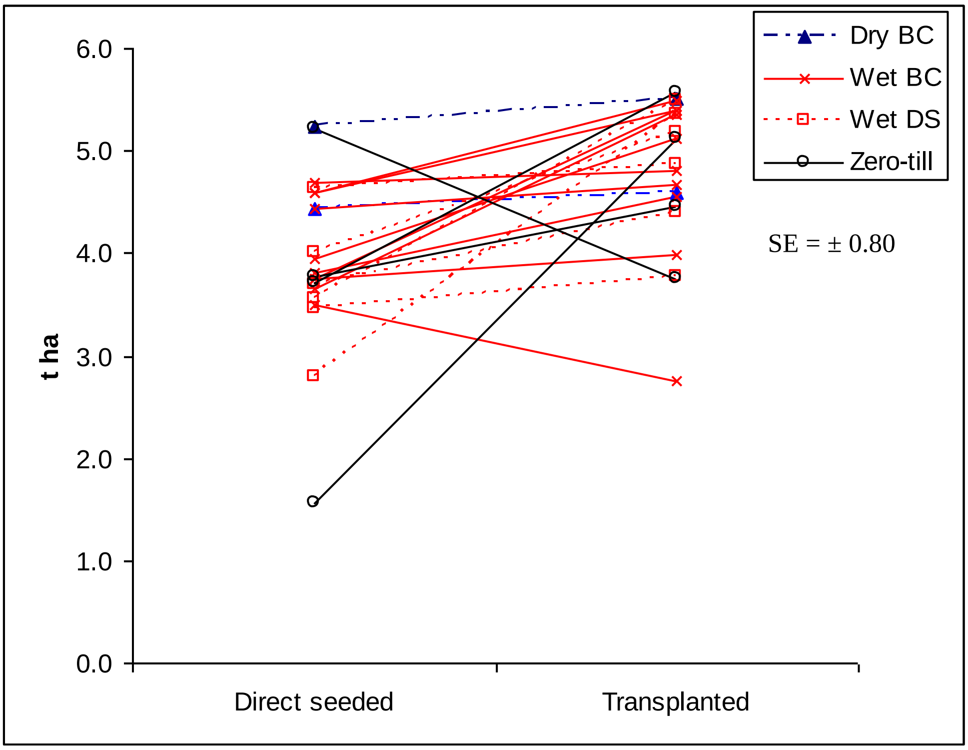


Fig 4 Rice grain yield in on-farm trials (n=22) comparing 4 direct seeding methods with transplanting, Faizabad, Kharif 2004. *[Dry BC = dry seed, broadcast after dry tillage, Wet BC = pre-germinated seed broadcast on puddled soil, Wet DS = pre-germinated seed sown with drum seeder; Zero-till = dry seed sown with zero-tillage drill.]*

Table 11 Grain yield of wheat following direct seeded or transplanted rice in on-farm trials at four sites in India, Rabi 2004.

	Faizabad	*Patna*
Number of farms	13	10
Direct seeded	4.08	3.56
Transplanted	3.77	3.63
S.E.D. ±	0.11	0.04

Wheat was grown after the rice in the on-farm trials around Faizabad and Patna and the yields are shown in Table 11. At Faizabad, wheat yields were significantly greater on farms where the previous rice crop had been direct seeded, though there were no significant differences at Patna. Zero-till sowing was tested at Patna and this gave significantly greater wheat yields than where the wheat had been sown conventional tillage (3.68 v. 3.51 t ha, S.E. ± 0.03).

Seed rate

A question of researcher and farmers had been "*what is the appropriate seed rate for the different methods of crop establishment*"? To address this an experiment was conducted at Bikramganj, Patna comparing four different seed rates in each of the crop establishment methods (dry direct seeding, wet seeding on puddled soil,and zero-till. The experiment had a plot size of 29 m^{-2} and comprised three replicates and the widely grown cultivar Rajendra Mahsuri was grown. At harvest, there were no significant differences in grain yield between crop established by dry or wet seeding, or by zero-tillage or whether the seed rates were between 30-75 kg ha. The main effect of seed rate are shown in Table 12)

Table 12 The effect of seed rate on rice yield, Patna 2004; values are the mean of establishment method.

kg ha	**30**	**45**	**60**	**75**	**SED**
Grain yield t / ha	4.87	4.78	4.74	4.77	± 0.15

Rice varietal choice for direct seeding

Rice varieties are selected for production systems where rice is established by transplanting and this is also the common method for establishment in varietal tests in the Gangetic plains. With the interest in direct seeding it is appropriate to assess currently available varieties for this method of establishment. In 2003 and 2004, a selection of varieties comprising local elite lines and WITA 3, WITA 4 and WITA 7 (lines developed in West Africa) was grown under clean weeded conditions and where hand weeding was carried once. The different weed control conditions were an attempt to identify any differences in weed competitiveness. In both years there was a significant main effect of variety (2003 $p<0.01$, 2004 $p<0.01$) and a main effect of variety (0.002, 0.004), but no interaction effects (Table 13, Table 14). The reduction in grain yield due to weeds, of about 7% in both years, is thought to have been to low to reveal differences in competitiveness.

Table 13. The effect of weed management on dry, direct seeded rice cultivars, Pantnagar, Uttaranchal, Kharif 2003.

Variety	Weed_trt	
	Clean	Weedy
Pant Dhan -6	5.13	4.96
IR-64	3.38	3.12
UPR-1561-6-3	4.77	4.39
Narendra -359	5.21	4.96
UPRI-93-63-2	3.70	3.57
WITA-4	4.30	3.50
IET-16843	3.65	3.50
Aditya	3.69	3.59
PUSA-44	5.29	5.04
UPRI-92-79	4.68	4.32
WITA-3	4.59	4.05
UPRI- 1230-9-2	4.57	4.41
WITA-7	4.84	4.33
FARO-8	1.45	1.92
Govind	4.15	3.41
Nidhi	6.63	5.59
Manhar	5.29	4.84
UPRI-95-49	5.23	4.91
IET-16613	3.96	3.75
IET-16615	4.41	3.99
IET-16840	3.62	3.45
S.E.D.	± 0.52	

Table 14. The effect of weed management on dry, direct seeded rice cultivars, Pantnagar, Uttaranchal, Kharif 2004.

Variety	Weed_trt	
	Clean	Weedy
Pant Dhan -6	4.59	6.06
IR-64	5.23	5.09
UPR-1561-6-3	6.94	6.39
Narendra -359	6.63	6.57
UPRI-93-63-2	4.74	4.44
WITA-4	5.24	4.72
IET-16843	4.78	4.19
Aditya	4.74	4.02
PUSA-44	6.00	5.39
UPRI-92-79	5.81	5.52
WITA-3	5.85	5.70
UPRI- 1230-9-2	6.39	5.19
WITA-7	6.48	5.56
FARO-8	4.65	3.11
Govind	6.57	6.48
Nidhi	4.54	3.89
Manhar	6.67	5.19
UPRI-95-49	6.76	6.67
IET-16613	6.06	5.67
IET-16615	6.46	6.31
IET-16840	4.04	3.83
S.E.D.	± 0.90	

FARMER EVALUATIONS : Uttaranchal, Uttar Pradesh and Bihar in 2003 and 2004

Participatory farmer evaluations were conducted to assess the appropriateness of DSR for field conditions in eastern India, and identify potential constraints to adoption. These evaluations were conducted after the 2004 Kharif season. Participation was restricted to those farmers who had participated in OFTs. Exposure to DSR differed between research sites. In Faizabad district (Uttar Pradesh) and in south Bihar, the majority of farmers who participated in the evaluation had experience with DSR in on-farm trials (OFTs) over two rice seasons (*kharif* 2003 and 2004). In Udham Singh Nagar district (Uttaranchal), some farmers had more extensive experience. The socio-economic profile for OFT participants also differed between research sites. Farmers in Uttaranchal were generally large, capitalist farmers with access to irrigation and tractors who ran their farms as a business. By contrast, farmers in Uttar Pradesh and south Bihar were less likely to own tubewells or tractors. In general, however, farmers selected to participate in OFTs were better-off than average and prepared to risk experimenting with new technology. Their views on the relative advantages and disadvantages of DSR may differ from those of poorer farmers.

Farmer evaluation in Uttaranchal was conducted through individual interviews with 19 farmers using a structured questionnaire, that compared farmers' perceptions of the advantages and disadvantages of DSR with those of researchers. In addition, farmers' verbal comments were recorded in order to illuminate decision-making on DSR. For the two other research sites, evaluation was made through group interviews conducted with 30 farmers in five villages, two in Faizabad district, eastern Uttar Pradesh, and three in Patna, Rohtas, and Nalanda districts, south Bihar. The majority of farmers who participated in the evaluation had experience with DSR in on-farm trials (OFTs) over two rice seasons (*kharif* 2003 and 2004). Farmers were asked to identify what they perceived as the advantages and disadvantages of DSR, and to rank these in order of importance.

Results from Uttaranchal showed that:

- Farmers saw the top three advantages of DSR as reduced time and energy for tillage (rank 2.1), reduced labour for planting (rank 2.6) and reduced need for irrigation after sowing (rank 3.2). There was agreement on whether DSR allowed earlier maturity and harvest, or whether DSR allowed greater choice for the following crop. These advantages of DSR received relatively low rankings (ranks 6.7, 6.8, 6.2). Most farmers (12 of 17) believed yields were lower with DSR than with TPR. Many reported the difference was minimal, however.

- Farmers had mixed views on whether DSR resulted in more weeds or weed species or needed more hand weeding. Most believed that correct use of herbicide controlled weeds effectively. Farmers did not agree that DSR made the crop more susceptible to pests and diseases, or to zinc and iron deficiency, or to lodging. Farmers saw the main disadvantages of DSR in terms of weed management. This included more weeds (rank, 2.1), the higher costs of herbicides (rank 2.7) and the need for more hand weeding (rank 2.9).

Results from Uttar Pradesh and south Bihar showed that:

- Saving labour was ranked as the most important advantage of DSR by farmers in Bihar, and as the second most important benefit by farmers in Uttar Pradesh. Saving tillage was ranked as the most important benefit of DSR in Uttar Pradesh, though it was mentioned explicitly in only one of three villages in Bihar, where it was ranked 8th. Saving water was ranked first and third in the two villages in Uttar Pradesh, and second, third, and fourth in the three villages in Bihar. By contrast, early maturity ranked 5th and 6th in the two villages in Uttar Pradesh, and 3rd and 6th in two villages in Bihar. Other advantages (including better response to fertilizer) were largely associated with the use of drill-seeding.

- In Uttar Pradesh farmers ranked "more weeds" as the 2nd and 3rd most important disadvantages of DSR, while in Bihar "more weeds" was ranked 1st (twice) and 4th. Higher labour cost for weeding ranked 5th in the two villages in Uttar Pradesh and 3rd and 2nd in two Bihar villages. Other disadvantages of DSR included uprooting of wet-seeded plants after harvest, which required more cleaning, the uneven performance of different rice varieties under direct-seeding, and the lack of uniform sowing of rice with the seed-drill designed for zero-till wheat.

Based on these results, we conclude that farmers in eastern India saw great potential for DSR. The evaluation suggested that DSR will benefit both large and small farmers.

- Larger farmers valued DSR because of its potential for immediate savings in cash costs for rice, rather than for its potential to increase yields for crops following rice. Cost savings were seen primarily in terms of tillage, rather than in terms of labour. This reflected steep rises in fuel costs in the last year and the high cost of tractor servicing. in parts of India dominated by large, mechanised farms, adoption of DSR may not be driven solely by labour costs.

- Smaller farmers valued DSR because it reduced risks by making them less dependent on unpredictable monsoon rainfall and the markets for groundwater and draught power.

However, there remained three important constraints to adoption. For larger farmers with their own irrigation, it had proved impossible to replace TPR completely because of the difficulty and cost of water control needed for effective use of pre-emergence herbicide. Second, some farmers remained reluctant to adopt DSR because herbicides were ineffective at controlling particular weeds. Third, the cost of Pendamethalin (1188 Rs/ha) will be significant for poorer farmers and a reliable supply chain is required to reduce the risk of purchasing adulterated herbicides.

Full results from these farmer evaluations may be found in project internal reports no 2 and 4.

Project output 2: Improved information for farmers on weed management options for direct-seeded rice

Farmers have been closely involved with project activities through on-farm research and farmer field days. These activities fall within the mandates of the agricultural universities which the project collaborated as they operate on a model closely related to the US Land Grant System with research and extension services being closely linked. The project has provided the focus of direct seeding and related weed management and this has been the theme of field days and visits. Farmers have been encouraged to visit researcher and on-farm experiments as a means to provide broad exposure of the technologies. See Appendix 1 for photo gallery. Farmer field days have been held at each of the partner sites (GBPUAT, NDUAT and RAU) and have been well attended by farmers and state officials; thirteen field days were held in total (see Appendix 2, for list of publications field days, newspaper articles etc). At Patna, 700 farmers and a Government Minister attended one meeting and 250 farmers at another; at Faizabad 250 farmers and at Pantnagar 53 farmers and 16 scientists attended other field days. To increase awareness farmers have been brought from neighbouring areas as part of an exchange program. Probably the most substantial increase in information available to farmers however has come from other farmers who have collaborated on the testing of direct seeding. Over the two years, 115 farmer trials have been completed over a wide area, comprising three states. In addition, in the target areas approximately 250 ha of direct seeded rice was being grown independently by farmers in 2004, where previously none had been grown, as a result of project activities.

At each of the target areas the universities and extension services have made more than 2000 leaflets and posters available in the local languages and these have been made widely available. There has also been a substantial number (46) of articles in local newspapers on the possibilities for direct seeding of rice. The enthusiasm with which direct seeding has been received has generated a considerable demand for further information that is not currently available in accessible forms.

Project output 3: Enhanced knowledge and understanding of weed management among regional extension and research systems

The project has impacted on knowledge and understanding of weed management among research and extension staff at various levels. Firstly there is awareness that there are opportunities for direct seeding with effective weed management as an alternative to transplanting and that it this has been shown to be feasible on farmers' fields. A theme of communications has been that weed management is a more critical component of direct seeded systems than with transplanting. Effective weed control cannot be "taken for granted", species will have to be monitored, and population shifts anticipated if management is to be sustainable. To achieve this farmers and extension staff will need more guidance and information than has previously been available, and this in itself will require new approaches.

The project has extended knowledge and understanding on direct seeding and the related weed management through informal meetings and discussions, site visits, leaflets, presentations and training. The most significant exchanges of information have taken place through interaction between project collaborators and other researchers and extension staff. This has occurred firstly at a personal level and with informal discussions and exchanges and this has then led to the organization of site visits and more formal presentations. As an example of how this succeeded is that the Chandra Shektar Azad Agricultural University at Kanpur (near Lucknow) initiated trials and demonstrations in 2004 independently of project funding. The success of this aspect of the project is also demonstrated by the significant number of presentations that the project collaborators have made (Appendix 2). Leaflets and posters have been produced and widely distributed (see examples Appendix 3) and excellent press coverage of project activities.

It was originally intended that the project would propose weed management options to the the committees of TAR (Technology and Refinement Project) as well as the extension services, however as this project had ceased activities by end of 2003. Instead efforts were targeted at the research and extension staff and meetings held with extension staff in each of the target areas and plans established for field days and information release. This received a greater momentum in March 2004 when the Vice Chancellor of GBPUAT presented, to a meeting of Vice Chancellor's and the Minister, "direct seeding of rice" as a technology ready for national promotion (see Appendix 4). The project has also been able to link with initiatives including the Rice Wheat Consortium. A good example of this exchange occurred in September 2004 when this consortium organized a travelling seminar around farmers' fields in the Pantnagar area for scientists from a number of neighbouring countries to observe direct seeding.

These activities have primarily been undertaken in the target areas but also at a national level with direct seeding being raised at a number of national level meetings. Further weed management in direct seeding was raised at a regional level with Drs Y and G Singh attending meetings of the Weed Ecology Working Group in Thailand and the Philippines where they made presentations.

A major commitment was made to an end of project workshop held at Pantnagar to which almost 100 researchers, extension staff and farmers attended the two day meeting. Presentations comprised 22 papers where a wide range of issues related to direct seeding in northern India were considered. On a second day if the meeting extended discussions were held with farmers who had recent experience of direct seeding. It is planned that the proceedings will be published by IRRI and be made widely available. See Appendix 5 for draft papers.

Socio economics

Socio-economic research to promote this output resulted in two papers presented at the regional Workshop held at G B Pant University, Pantnagar, that will shortly be published in Workshop Proceedings.

Prospects for Direct-Seeded Rice in Eastern India: Socio-economic Perspectives

This paper used data largely from baseline surveys conducted at DSR research sites in Uttar Pradesh and south Bihar in kharif 2003. (Baseline Tables are provided in internal report no 1). These surveys provided plotwise information on farmers' crop management practices for monsoon rice, and allowed an ex ante exploration of potential benefits from DSR adoption for different categories of farmer.

Prospects for DSR are usually based on the Southeast Asian model whereby adoption is driven primarily by rising labour costs. This has led to the view that in India, where labour costs have risen slowly, incentives for DSR adoption are likely to remain weak in the short to medium term. This paper argued that prospects for DSR adoption in eastern India may be brighter than previously believed. This was because:

- Average time of transplanting did not differ by farm size, suggesting that small as well as large farms will benefit from timelier crop establishment.
- Livelihood diversification through seasonal migration has increased incentives for adoption of labour-saving technology, although this is blunted by the "feminisation" of agriculture whereby female family members substitute for men.
- DSR will reduce on pumpsets and tractors for timely crop establishment will benefit poorer farmers.
- Evaluation shows that savings in labour costs were less important for large farmers than savings in the cost of tillage and irrigation.

A full statement of the argument can be found in project internal report no 3.

The Economics of Direct-Seeded Rice in Eastern India

This paper was based on data from on-station trials at GB Pant University, Pantnagar, for the 2003 and 2004 kharif seasons. The paper estimated private and public costs and benefits from adoption of DSR. Results showed that:

- DSR was privately profitable for farmers, giving net returns of 13,350 Rs/ha for dry seeded and 11,592 Rs/ha for dry seeded rice compared to 10,343 Rs/ha for transplanted rice.

- Net labor savings with DSR averaged 27 days/ha.

- A provisional cost-benefit analysis suggests that DSR was also profitable at the national level. TPR was only as socially profitable as DSR if labour was assumed to have zero opportunity cost, or if yields were halved, or if environmental and health-related costs were twice as large as private costs.

DSR was also profitable according to the compensation principle of welfare economics.

- However, these analyses did not take account of equity issues. DSR reduces equity because it transfers income from labour to farmers without a compensating increase in output. Gender segmentation in the labour market and the absence of alternative employment impose social costs. At the local level, therefore, DSR adoption is likely to have adverse effects on equity.

Full details of the economic analysis may be found in project internal report no 5.

Contribution of Outputs to developmental impact

The projects R7377 and R8233 have provided clear insights into the opportunities that direct seeding will bring in terms of labour requirements, system productivity and the use of herbicides. The local uptake of direct seeding (both wet and dry, depending on circumstance) in the areas of project activity has been considerable and the institutions promoting it have been enthusiastic, in turn being encouraged by farmer response. These management options have however only been validated in a relatively small portion of area occupied by the rice wheat system, that is itself very variable in its nature. Further validation and data collation is required, as also importantly is the provision of information to policy makers, advisors and farmers to enable appropriate decision making.

There is considerable scope for a synthesis of findings from the India (R7377 and R8233) with those of R7471 and R8234 (Bangladesh) into a decision support framework for integrated weed management for direct seeded rice in irrigated and rainfed rice. A substantial knowledge base has `been established on weed management in three of the most widespread rice-based cropping systems in the region. These systems are diverse in terms of agronomic practices, productivity, water regimes and farming systems. However they have considerable commonality in the baseline weed flora at the regional level; but variability at the field level, primarily due to crop establishment method and water regime, and farming practices. In Bangladesh, direct seeding has the potential to increase the productivity of rainfed rice-systems in the Barind, whereas farmers in India are interested in direct-seeding to overcome labour and water shortages in irrigated agriculture. Thus whilst adoption of direct seeding may be driven for different reasons, weed species shifts are therefore to be expected as a consequence of change in crop establishment method and of weed control method. Future work will allow the research findings from India and Bangladesh to be distilled to establish decision-tools for improved weed management for transplanted and direct seeded rice and for transition between the two. This would allow knowledge to consolidated and make it accessible in a form that enhances understanding of the new technology, promotion by extension, and adoption by farmers.

The enthusiasm with which direct seeding has been received, has generated a considerable demand for further information that is not currently available in usable / accessible forms. Future activities will address this “information gap” as it is crucial that farmers, advisors and policy makers are able to make informed choices based on their knowledge and the best information available.

The pathways for the uptake of project outputs have been through the informal channels of farmer groups focussing on progressive/lead farmers, the agricultural input supply, with leaflets and posters, and through the agricultural universities that are based on the land-grant system and closely linked with the extension services and farmers. It is expected that this will continue. The information will also be available through the "India node" of the IRRI rice knowledge Bank and also through the Irrigated Rice Research Consortium.

A further phase of funding has been agreed with CPP to allow the above activities to be undertaken using the existing project partnerships.

Biometricians Signature

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

Signature:

Name (typed): Dr A. M. Mortimer
Position: Biometrician, School of Biological Sciences, University of Liverpool
Date: 29 March 2005

Project LogFrame:

Narrative Summary	**Indicators of Achievement**	**Means of Verification**	**Risks and Assumptions**
Goal			
The goal is given by DFID: Livelihoods of poor people improved through sustainably enhanced production and productivity of RNR systems.	*These are under discussion with DFID. Leave blank.*	*These are under discussion with DFID. Leave blank.*	
Purpose			
"Yields improved and sustainability enhanced in high potential cropping systems by cost-effective reduction in losses due to pests".	1.1 Weed management options for direct seeded rice demonstrated on farmers' fields at four key sites in the Indo-Gangetic plains by July 2003. 1.2 Successful weed management strategies for direct seeded rice identified for four key sites in the Indo-Gangetic plains by September 2004. 1.3 Farmers seeking to adopt direct seeding of rice at one key site by end of Kharif 2003 and at three further key sites by end of Kharif 2004.	1.1 Project reports 1.2 Project reports and workshop proceedings 1.3 Field survey, project reports	Co-operation of farmers Institutional support for the project from IRRI and within India Political stability
Outputs			

These are chosen by the proposer. *Outputs should be either* *a) Discrete pieces of new knowledge generated by the project, which are designed to contribute to the resolution of a specific problem for a target group of poor people.* *b) Changes in knowledge levels or attitudes resulting from the promotion of knowledge.* *List your Project Outputs here and number them (1, 2, 3, etc).* 4. Weed management options for direct-seeded rice tested and widely promoted on farmers' fields 5. Improved information for farmers on weed management options for direct-seeded rice 6. Enhanced knowledge and understanding of weed management among regional extension and research systems	*Enter indicators of your choice for each output.* *Indicators should make reference to quantity, quality, time-scale and location. They should be cross-referenced to the relevant outputs (1.1, 1.2.; 2.1, etc).* *These are used by project leaders to monitor the achievement of outputs.* *You may wish to revise these later in discussion with stakeholders.* 1. Weed management options for direct seeded rice demonstrated on farmers fields in four regions in Uttaranchal, Uttar Pradesh and Bihar in 2003 and 2004. 2. Publications for farmers on direct seeded rice developed and made available to farmers through 2003 and 2004. Weed management options proposed to the TAR committees and the extension services by end of 2003. 3. Regional workshop on weed management in direct seeded rice held 2004/5 and attended by local and regional representatives of research and extension services.	*Enter appropriate means of verification for each indicator. These are the sources of information you will use to measure your indicator.* *They should be cross-referenced to the relevant indicator (1.1, 1.2., 2.1 etc).* *You may wish to revise these later in discussion with stakeholders.* Project reports and data - sets. Project reports Project reports	*Identify factors which lie outside the control of the project but which affect the ability of the project outputs to contribute effectively to the project purpose(s) eg behaviour of global markets, national policies.* *We ask for these so reviewers can assess the likelihood of the project outputs contributing to its purpose. The programme may be able to advocate for these factors to be addressed by a third party.* *We will ask you to review them each year.* Universities, extension services and farmers willing to work with the project. Good collaboration with RWC and IRRI. Favourable weather for crop establishment.
Activities			

Enter a summary of project activities. These must be agreed with all institutions collaborating on the research work.These should include a time-scale for achievement and will normally form the basis for establishing milestones against which annual spending forecasts will be required, invoices will be paid and progress will be reported and monitored. *Activities should be cross-referenced to the relevant project outputs: (1.1, 1.2.; .2.1, etc).* 1.1 Evaluation of existing baseline data at the regions, design of farmer survey and training of staff. 1.2 Farmer selection and focus group discussions. 1.3 Identification of appropriate weed management options. 1.4 Testing and participatory evaluation of weed management options in researcher managed trials and on farmers' fields. 2.1 Weed management options proposed to extension service and TAR committees. 2.2 Promotional materials developed and produced as pamphlets and posters. 3.1Information on findings exchanged with national and regional institutions including WEWG. 3.2 Regional workshop held to present the project's findings and evaluate these alongside the work of others.	*Enter indicators of your choice for each activity.* *Indicators should make reference to quantity, quality, time-scale and location. They should be cross-referenced to the relevant activities (1.1.1, 1.1.2; 1.2.1, 1.2.2, etc).These are used by project leaders to monitor the achievement of activities.* 1.1 Meetings held with project collaborators and links established with farmer groups at Patna, Haridwar and Faizabad, outline of activities designed and training needs identified by March 2003. 1.2 Farmer meetings conducted by April 2003, farmer selections made by May 2003. Demonstration sites in each of the regions by May 2003. 1.3 Weed management options for on-farm testing identified by May 2003. 1.4 Demonstration trials established on farmers' fields by June 2003 in four regions of the Indo-Gangetic Plains. Evaluation on farmers' fields continues through 2003/04. 2.1 Management options proposed to TAR committees by December 2003. 2.2 Initial promotional materials prepared for printing as pamphlets by July, 2003 and final promotional materials prepared by January 2005. 3.1 Results and information exchanged by February 2003. 3.2 Regional workshops held.	*Enter appropriate means of verification for each indicator. These are the sources of information you will use to measure your indicator.* *They should be cross-referenced to the relevant indicator (1.1, 1.2, 2.1 etc).* 1.1 Meeting and project reports. 1.2 Initial report on farmer discussions and selections available by September 2003. 1.3 Descriptions of weed management options for farmers' field testing in leaflets and project reports. 1.4 Project report. 2.1 Proposal to TAR on technologies for weed management in direct seeded rice available. 2.2 Draft and final copies of promotional materials available 3.1 Meeting and workshop reports. 3.2 Workshop report	*Identify factors which lie outside the control of the project but which affect the ability of the project activities to contribute effectively to the project outputs.* *We ask for these so reviewers can assess the likelihood of the project outputs contributing to its purpose. The programme may be able to advocate for these factors to be addressed by a third party.* *We will ask* you *to review them each year.* Institutional links can be established Farmers willing to co-operate. Timely access to existing socio-economic databases.

Project on-farm activities on direct seeded rice

Fig 1. Project activities in northern India.