CROP PROTECTION PROGRAMME

Promotion and decision support for weed management in rice in India.

R 8409(ZA 0641)

FINAL TECHNICAL REPORT

1 April 2005 – 31 January 2006

Project Leader: Charlie Riches

Natural Resources Institute

January 2006

"This publication is an output from a research project funded by the United Kingdom Department for International Development for the benefit of developing countries. The views expressed are not necessarily those of DFID." R8409 – Crop Protection Programme.

Contents

This report was written by Dr David Johnson, Dr Martin Mortimer and Dr Alastair Orr with contributions from Dr Charlie Riches.

Executive Summary

The project's purpose was to develop and validate weed management options for direct-seeded rice in the Gangetic plains of India. Decision support frameworks and information sources on options for direct-seeded rice would be developed and the understanding of the options would be enhanced among extension and research systems.

The project has enhanced the collaborative arrangements among four key Agricultural Universities in India, the International Rice Research Institute, the University of Liverpool and the Natural Resources Institute UK established under R7377 and R8233. This has 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 and widely promote effective weed management options for direct seeded rice to farmers.

On-station experiments in Uttaranchal, Uttar Pradesh and Bihar demonstrated that yields from direct seeded rice (DSR) are broadly comparable to transplanted rice (TPR) providing management of weeds is effective. 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 2005 in three states over 111 farmers' field trials.

Changes in establishment method and management practice were shown to result in changes in species composition of the weed flora. Densities of *Echinochloa crus-galli*, *Cyperus difformis* and *Eragrostis japonica* were not influenced by establishment methods in either crops over the previous 4 years. Conversely population densities of *Echinochloa colona* in rice were dependent on land preparation for wheat with densities being three fold greater in conventionally tilled wheat plots than in zero-tilled wheat plots. The abundance of *Cyperus rotundus* was promoted under dry seeded rice sown after a "stale" seed bed and elevated by zero tillage of wheat. The ingression of annual grasses and perennial sedges are likely to present particular weed management problems with continuous direct seeding.

Farmers and farmers groups 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 years at these sites has demonstrated that direct seeded rice can be successful, giving broadly similar yields and with reduced costs and improved timeliness compared to transplanting. Farmers have expressed considerable interest and the systems are being adopted among lead farmers. In Uttaranchal Uttar Pradesh and Bihar, promotion of the DSR technologies has led to 975 ha of direct seeded rice being grown by farmers in on-farm trials and field scale demonstrations in 2005 where before rice was almost exclusively transplanted. Rapid uptake of these technologies is likely to continue in coming years.

Information on the likely changes in the weed populations over time and in response to changing altered management practices has provided the basis of decision support tools for improving weed management. Further, information on crop establishment and management has been provided in the form of leaflets, bulletins and promoted through presentation and demonstrations. In 2005, a total of 22 farmer field / extension days have been held, with events at each of the partner sites (GBPUAT, CSA, NDUAT and RAU), and these have been well attended by farmers and state officials.

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 date of rice harvest). In collaboration with four universities of agriculture and technology and through liaison with the CGIAR Rice-Wheat consortium, projects R7377 and R8233 (1999-2005) identified that dry (drill) or wet (broadcast) direct seeding of rice is a more profitable alternative to transplanted rice and in addition there were system productivity gains.

Key findings (1999-2005) have been:

- Most farm sizes are less than 2 ha and farmers use 25-50% of their land for cultivating rice/wheat and derive 30-50% of agricultural income from rice.
- 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 .
- Labour shortages at times of transplanting, manual weeding, and harvest occur on most farms. Family labour is supplemented by hiring of contract labour; migrant labourers travel either from eastern Uttar Pradesh, Bihar, Bangladesh, or the local area.
- Most farmers are familiar with herbicide use in wheat and are using herbicides (most commonly butachlor) in transplanted rice.
- In on-station trials in weed free plots, a) equivalent yields were obtained from transplanted and wet-seeded (broadcast) rice; b) yields from drill (dry) seeded rice were lower (0.5 t ha^{-1} or more) than transplanted rice and in drill seeded rice, similar yields were obtained with reduced tillage. A single manual weeding was insufficient to prohibit yield loss in broadcast or drill seeded rice and highest yields were always achieved utilising a post-emergence herbicide (pendimethalin) and one subsequent hand weeding. There are however a range of registered herbicides that are effective for direct seeded rice.
- Farm trials, with extension support, have indicated that direct seeded rice can achieve equivalent yields to transplanted rice across a range of 13 rice cultivars in common use.

- Sensitivity analysis of partial farm budgets has indicated that benefit-cost ratios for direct seeding with herbicides would be equal to transplanting and manual weeding even if rice yields fell (from 5.41 t/ha to 3.4 t/ha for wet-seeding and 2.64 t/ha for dry seeding).
- Social cost-benefit analysis showed that, for the cost-benefit ratio from transplanting to equal that of direct-seeding, the opportunity cost of labour would have to be either zero or negative. This is implausible, since transplanting relies heavily on migrant male labour and real wages rates for peak-season activities like transplanting are near the market rate. Wage rates for farm labour in Uttar Pradesh have risen in real terms in the 1990s, reflecting opportunities for off-farm employment.
- Direct seeding of rice is 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.*
- In R8233, adaptive research and partnerships were extended (and are ongoing) under leadership from GBPUAT to NDUAT (Faizabad, Uttar Pradesh) and RAU (Patna, Bihar) (see Figure 1).
- In the jurisdictions of the states of 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 compared to all land being transplanted at the beginning of the project. An additional university of agriculture and technology (CSA Kanpur) is now independently initiating trials. Approximately. 70 on-farm trials of DS rice are ongoing.
- 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. 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.(see Table 1).
- The technologies have been widely publicized through newspaper press-releases and other media coverage. Leaflets have been developed in English and Hindi on the technologies for direct seeding.

In project R7377 the feasibility of replacing transplanted rice with direct seeding was illustrated by work at GBPUAT (now in Uttaranchal) and in R8233, technology promotion and adoption was extended to the east in Uttar Pradesh and to Bihar. Table 1 and Figure 1 illustrate the pattern of testing and scale of adoption of direct seeding to date. These projects 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, but importantly so is the provision of information to policy makers, advisors and farmers to enable appropriate decision making.

Key publications (2000-2005):

Livelihood gains and policy

Johnson D., Mortimer M., Orr A. and Riches C. (2003) *Weeds Rice and Poor People in South Asia*. Chatham, UK: Natural Resources Institute.

Gautam, P (2004) *Direct seeded rice – a cost effective technology*. Vice-Chancellor's technology release for direct seeding of rice at national level. GBPUAT, Pantnagar, Uttaranchal.

Development of weed management options

Singh G, Singh Y, Singh V P, Singh R K, Singh P, Johnson, D E, Mortimer M, Orr, A (2003). Direct seeding as an alternative to transplanting rice for the rice-wheat systems of the Indo-Gangetic Plains: sustainability issues related to weed management. *Proceedings of the BCPC International Congress on Crop Science and Technology - 2003,* SECC, Glasgow, UK, 1035-1040.

Y. Singh, G. Singh, V.P. Singh, R.K. Singh, P. Singh, R.S.L. Srivastava, A. Saxena M. Mortimer, D.E. Johnson and J.L.White (2002). Effect of different establishment methods on rice-wheat and the implications of weed management in Indo-Gangetic Plains. *Proceedings of the International workshop on Herbicide resistance management & zero tillage in rice-wheat cropping system.* (Eds. R.K.Malik, R.S.Balyan, Ashok Yadav and S.K. Pahwa) March 4-6 Hisar, Haryana, 182-186.

Singh Y, Singh G, Singh V P, Singh R K, Srivastava R S L, Singh P, Mortimer M, White J L, Johnson D E (2001). Direct seeding of rice in the Rice-Wheat Systems of the Indo-Gangetic Plains and the implications for weed management. *Proceedings of the Brighton Crop Protection Conference - Weeds, 2001*, BCPC, Farnham, UK, 187-192.

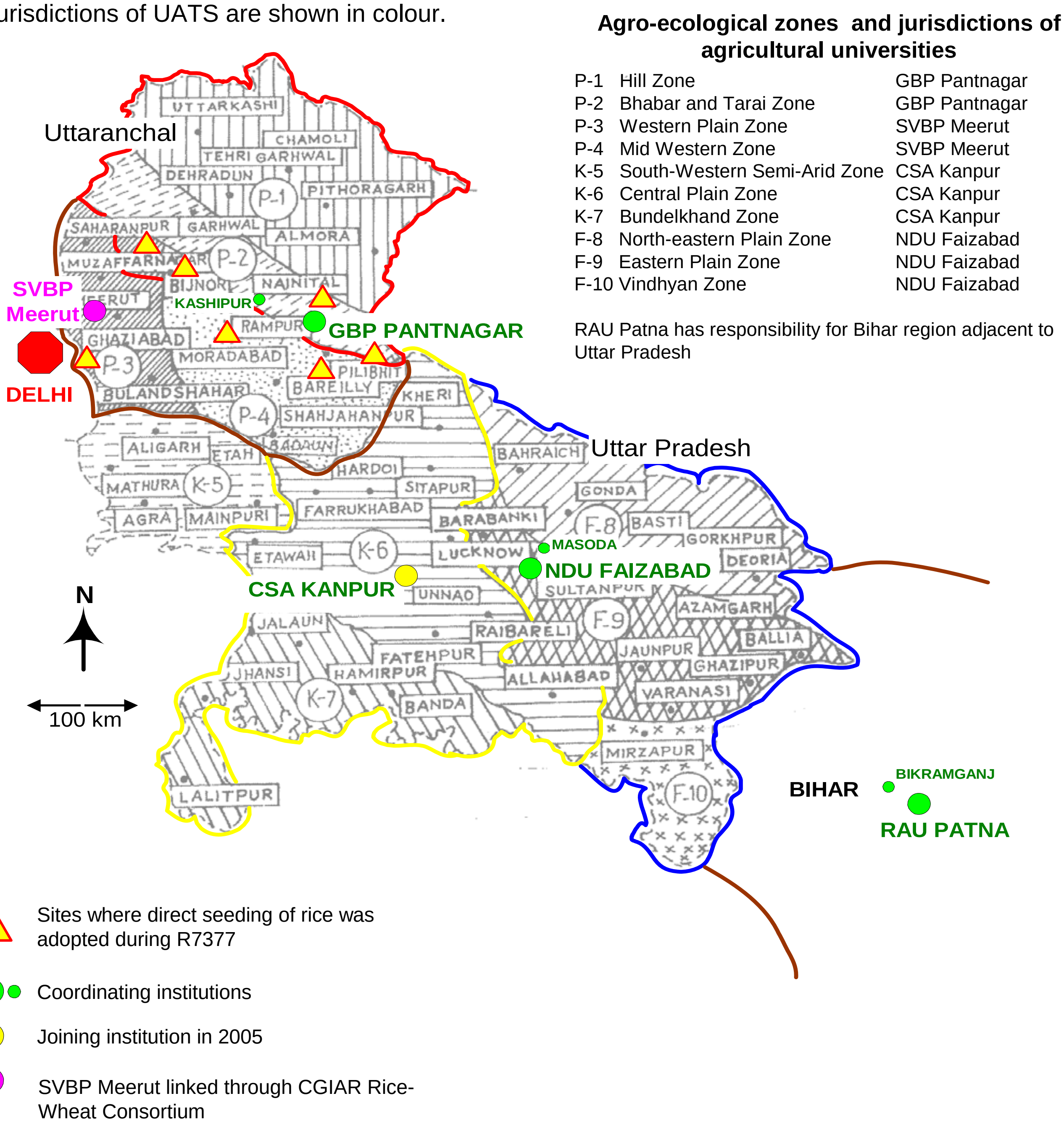
Singh G, Singh Y, Mishra O P, Singh V P,Singh R K, Johnson D E, Dizon M, Mortimer M (2001). Changes in weed community structure in rice-wheat cropping systems in the Indo-Gangetic plains. *Proceedings of the Brighton Crop Protection Conference - Weeds, 2001*, BCPC, Farnham, UK, 193-198.

Table 1. Summary of field activities undertaken with farmers and collaborating institutions.

Institution / Region	R7377 2000 - 2003	R8233 2003 - 2004
GBP Pantnagar	OFT : 15 ECF trials : > 40 ha	OFT : 22 LSFD : 117 ha ADP : > 141 ha
UAT locations	Pantnagar	Pantnagar, Kashipur
NDU Faizabad		OFT : 22 ADP : ~ 40 ha
UAT locations		Kumarganj, Masoda
RAU Patna		OFT : 25 ADP : ~ 60 ha
UAT locations		Bikramganj
CSA Kanpur		OFT : 2 [1]
UAT locations		Kanpur [1]

UAT locations = experimental station trials of Universities of Agriculture and Technology
OFT = number of on farm trials – conducted with collaborating farmers
LSFD = area of large scale farm demonstrations
ECF = area of trials on ‘experimental cultivators fields’, (terminated in 2000).
ADP = area of rice under drill seeded or broadcast rice, through adoption by technology diffusion by farmers
1 = in R8233, activities were funded independently by CSA Kanpur

Figure 1. Locations of collaborating institutions in the Indo-Gangetic plains. Jurisdictions of UATS are shown in colour.



Project Purpose

The project's purpose was to :

1. *Develop and validate weed management options for direct-seeded rice*.

2. *Develop decision support frameworks and information sources on 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 collaborators were Professor G Singh and Dr V. P. 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) and Chandra Shektar Azad Agricultural (CSA) University at Kanpur (near Lucknow) (400 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 infrastructure is less developed.

GBPUAT, CSA, NDUAT and RAU, together with extension services, have been the primary collaborators in India on the research activities. Experiments have been conducted on research stations at Pantnagar, Faizabad, and Patna where the different establishment options have been tested. The project sites of activity are shown in Figure 2. These experiments have been used to gain a detailed understanding of the constraints and benefits of the different methods of direct seeding, and to develop the data sets on crop performance and weed growth on which the recommendations would be based. 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 and through these farmers have undertaken field scale testing of direct seeding after having selected the options from demonstrations / researcher experiments. Researchers have monitored the performance of on-farm trials and the direct seeding methods have been compared to transplanting at each farm.

The International Rice Research Institute (IRRI) is a partner in the project. Through Dr Johnson the IRRI weed scientist, the project has links with the Labor Productivity Working Group of the Irrigated Rice Research Consortium (IRRI) based at IRRI that, in turn, brings together agronomists and weed scientists working in rice in south and south east Asia. Dr Mortimer (ex. IRRI), University of Liverpool has been closely involved with the planning of studies and analyses of the data, and have made visits to India and IRRI. GBPUAT is a benchmark site of the CIMMYT/IRRI Rice Wheat Consortium (RWC) and of the Irrigated Rice Research Consortium of IRRI. The project was linked with IRRI's MTP project "Managing resources under intensive rice-based systems".

Project on-farm activities on direct seeded rice

Figure 2. Sites of project activities in India

Outputs

The project's outputs are:
To exploit the progress made to date by R7377 and R8233 three outputs were proposed :

1. Weed management options for DSR validated across sites in the irrigated rice-wheat rotations of the IGP.
2. Decision support frameworks for weed management options in DSR in the irrigated rice- wheat rotations of the IGP developed and validated.
3. Information sources on weed management in DSR for researchers, extension workers and farmers prepared and disseminated.

Project output 1: Weed management options for DSR validated across sites in the irrigated rice-wheat rotations of the IGP.

Researcher managed trials

Continuing from previous phases of the project, researcher managed experiments were conducted on the experimental stations of GBPUAT, NDUAT and RAU. At each of these sites the major activity was a longitudinal study over cropping seasons designed to measure yield stability in relation to crop establishment method and the response of the weed flora to crop establishment method and weed management. The first experiment was established in 2000 at GBPUAT (with treatments shown in Table 2) which was followed by the similar experiments at NDUAT and RAU in 2003. It is anticipated that 2005 is the last year of these experiments, unless partner institutions continue to fund them themselves. Weed control treatments were either a) intensive weeding - herbicide followed by hand weeding (HW) (once,30DAS/DAT, GBPUAT; once, 30DAS/DAT, and twice,30 and 60DAS/DAT, NDUAT and RAU), b) hand weeding alone (30 and 60DAS/DAT) and c) an unweeded check.

Results are presented for the 2005 rice crop, and wheat yields will be available in 2006 (partner institutes have agreed to complete the rotation themselves).

The grain yields for the interactions of establishment method and weed control are shown in Table 3 a-c for GBPUAT, NDUAT and RAU respectively.

Across establishment methods, more than 70% of grain yield was lost where weeds were not controlled and these losses were usually highest under dry seeding and zero-tillage.

With either dry or wet seeding after cultivation yield losses with no weed control were more than 80% compared to *ca*.15% with transplanting.

Under intensive weed control (Herbicide + HW) yields of dry seeded exceeded that of transplanted rice at GBPUAT and RAU, although this was not statistically significant. Contrastingly this was not seen at NDUAT, however yield differences were small and within the bounds of experimental error.

The addition of a second hand weeding (at 60DAS/DAT) resulted in a yield increase under all crop establishment methods, although not significant statistically in all cases.

These finding confirm earlier project findings in that yields from direct seeded rice plots are similar or slightly lower than from transplanting, (but with the considerable saving of labor inputs as reported previously).

Data on weed abundance in these experiments has been collected and is in the process of collation and verification by partners. These data will contribute to subsequent validation of weed species trends from long term observations at GBPUAT.

Table 2. Summary of experimental details. DAS, days after seeding; DAT days after transplanting.

	Establishment method	Land preparation and sowing	Herbicide used
Rice			
	TP conventionally transplanted	Ploughed, puddled and levelled; hand transplanted 21-day-old plants 20 cm × 20-cm spacing.	Butachlor 1.5 kg a.i. / ha, 2 DAT.
	WS wet (pre-germinated) seeded	Ploughed, puddled and levelled; drum-seeded, 35 kg / ha, 20 cm row spacing.	Anilophos 0.4 kg a.i. / ha, 5 DAS.
	DS dry drill seeded	Ploughed, harrowed; drill seeded, 50 kg / ha, 20 cm row spacing.	Pendimethalin 1.0 kg a.i. / ha, 1 DAS.
	DSf dry drill seeded with stale seed bed treatment	As DS, with a flush irrigation and subsequent 7d glyphosate application prior to seeding; 50 kg / ha, 20 cm row spacing.	Pendimethalin 1.0 kg a.i. / ha, 1 DAS.
	ZR dry drill seeded with zero tillage	Flush irrigation and subsequent 7d glyphosate application prior to drilling; 50 kg / ha, 20 cm row spacing.	Pendimethalin 1.0 kg a.i. / ha, 1 DAS.
Wheat			
	CW conventional tillage	Ploughed, harrowed; drill seeded, 100 kg / ha, 20-cm row spacing.	Isoproturon kg a.i./ ha 35 DAS, follow-up handweeding as required.
	ZW zero tillage	Drill seeded into rice stubbles after paraquat, 0.5 kg a.i. /ha; 100 kg / ha, 20-cm row spacing.	Isoproturon kg a.i./ ha 35 DAS, follow-up handweeding as required.

Table 3 a. The effects of establishment method and weed control on grain yield (kg ha^{-1})at GBPUAT. HW = hand weeding (see text for details). Significant sources of variation : rice establishment, p = <0.001; weed control, p = <0.001; interaction, p = <0.001.

Rice establishment	**Weed control**	**2005**
Transplanting	2 HW	6269
	Herbicide + 2HW	6356
	No control	5394
Wet seeding	2 HW	5162
	Herbicide + 2HW	5969
	No control	931
Dry seeding	2 HW	5769
	Herbicide + 2HW	6462
	No control	962
Dry Seeding + flush irrigation	2 HW	5519
	Herbicide + 2HW	6687
	No control	1081
Zero tillage	2 HW	4112
	Herbicide + 2HW	5619
	No control	56
S.E.M.		349

Table 3 b. The effects of establishment method and weed control on grain yield (kg ha^{-1}) at NDUAT. HW = hand weeding (see text for details). Significant sources of variation : rice establishment, p = <0.001; weed control, p = <0.001; interaction, p = <0.001.

Rice establishment	**Weed control**	**2005**
Transplanting	2 HW	2520
	Herbicide + 2HW	2790
	Herbicide + 1HW	2500
	No control	1249
Wet seeding	2 HW	2434
	Herbicide + 2HW	2663
	Herbicide +1 HW	2184
	No control	1313
Dry seeding	2 HW	2231
	Herbicide + 2HW	2541
	Herbicide + 1 HW	2100
	No control	173
Zero tillage	2 HW	2519
	Herbicide + 2HW	2769
	Herbicide + 1 HW	2212
	No control	171
S.E.M.		9.1

Table 3 c. The effects of establishment method and weed control on grain yield (kg ha^{-1}) at RAU. HW = hand weeding (see text for details). Significant sources of variation : rice establishment, p = <0.001; weed control, p = <0.001; interaction, p = <0.001.

Rice establishment	**Weed control**	**2005**
Transplanting	2 HW	2277
	Herbicide + 2HW	2459
	Herbicide + 1 HW	2365
	No control	2135
Wet seeding	2 HW	2237
	Herbicide + 2HW	2362
	Herbicide + 1 HW	2226
	No control	0
Dry seeding	2 HW	2301
	Herbicide + 2HW	2590
	Herbicide + 1 HW	2347
	No control	0
Zero tillage	2 HW	2207
	Herbicide + 2HW	2329
	Herbicide + 1 HW	2274
	No control	0
S.E.M.		8.7

Farmer managed trials

Trials on farmers' fields were categorised as those where direct seeding areas of about 0.4 ha were compared with the farmers' transplanted rice, termed "farmers field trials" and "large area demonstrations" where the direct seeded areas exceeded 1 ha and including much larger contiguous areas. There has been a progression as farmers who had initially grown small areas of direct seeded rice then expanded the areas in subsequent years and continued to receive guidance from project staff. The numbers and area under project trials from 2000 to 2005 are shown in Table 4.

Table 4. On-farm trials conducted and area under DSR in Uttaranchal (GBP), Uttar Pradesh (NDU, CSA) and Bihar (RAU).

	No. of Trials					**Area covered (ha)**				
Year	**GBP**	**NDU**	**RAU**	**CSA**	**Total**	**GBP**	**ND**	**RAU**	**CSA**	**Total**
2000	4	-	-	-	4	1	-	-	-	1
2001	9	-	-	-	9	2	-	-	-	2
2002	6	-	-	-	6	1	-	-	-	1
2003	21	13	14	-	48	78	5	6	-	89
2004	22	30	26	3	81	179	15	13	1	208
2005	31	23	40	15	111	827	117	25	6	975

Yields from trials in farmers' fields in 2005 are shown in Table 5 a – d . At four out of the 5 sites, direct seeded rice yields were similar to that from transplanted, yield advantage from transplanting being only observed at NDU.

Table 5 a. Grain yield (t/ha) in farmers' field trials (n=30), effects of establishment method and weed control; GBP, Uttaranchal 2005.

	Weeds controlled	No Weed control
Dry seeded rice	5.37	2.83
Transplanted rice	5.28	3.81
SEM	0.112	

The yields from the Kanpur (CSA) area in 2005 are shown in Table 5 b. Where the weeds are controlled the yields were similar for dry or wet direct seeded or transplanted rice. Where weeds are not controlled however the losses were almost 50% for dry seeded compared to 12% for wet seeded of transplanted.

Table 5 b. Grain yield (t/ha) in farmers' field trials (n=11), effects of establishment method and weed control; CSA, Uttar Pradesh 2005.

	Weeds controlled	No Weed control
Dry seeded rice	5.50	2.67
Wet seeded rice	5.70	4.39
Transplanted rice	5.48	4.38
SEM	0.109	

Table 5 c. Grain yield (t/ha) in farmers' field trials (n=23), effects of establishment method and weed control; NDU, Uttar Pradesh 2005.

	Weeds controlled	No Weed control
Dry seeded rice	3.14	0.55
Transplanted rice	3.76	-
SEM	0.108	

In Bihar, 40 farmers field trials were planned but poor rainfall only allowed 30 to be established and over an area of 6 ha in 7 villages. Field scale areas of direct seeding with farmers using the project direct seeding technologies, as distinct from traditional direct seeding, extended to a total of 66 ha.

Table 5 d. Grain yield (t/ha) in farmers' field trials (n=23), effects of establishment method and weed control; RAU, Bihar 2005.

	Yield
Dry seeded rice	5.31
Transplanted rice	5.29
SEM	0.44

Management of pernicious weeds

A trial was initiated at GBP in 2004 to examine the efficacy and timing of stale seed bed techniques (cultivation followed by glyphosate) for control of *Cyperus rotundus*. Populations were artifically established from tubers and treatments examining glyphosate dose and timing were imposed. Tuber census counts have been taken at the end of the rice and wheat season in 2004 and 2005. Data analysis is yet to be completed.

Farmer and extension agency evaluation of direct seeded rice.

The following report has been compiled by Professor Y Singh, Dr DS Yadav, Dr RK Sinha, Dr BK Singh and Dr A N Tiwari

The farmers who have practiced direct seeding (DSR) or seen it in practice are very enthusiastic. Many of them have now converted their entire holding to DSR. Among the forerunners are those who mostly hire the labour for transplanting since they cannot obtain the labour for timely transplanting and wages are rising. Farmers also see advantage of time saving due to faster crop establishment and reduced maintenance of farm machinery. The extension services have been slow in promoting the technologies for direct seeding, however, now at every level there is talk of promoting this technology. Recently India Council of Agricultural Research (ICAR) has announced a big programme of promoting "conservation technologies" which includes DSR.

The state of Uttaranchal has initiated a new project namely Agriculture Technology Management Agency (ATMA) which is identifying the deficiencies in the current extension programme. In the future programme of ATMA, DSR has been included in the plains of Uttaranchal. The activities of this project will include training the extension staff about DSR, on–farm trials, development of literature / leaflets and development of technology package in electronic form to be shared through IT network. For IT networking, nearly 100 *Farm Information and Advisory Centres* are being opened in Uttaranchal where farmers have access to agricultural technologies on internet.

DSR technologies have been developed at Pantnagar over the past five years in collaboration with IRRI and NRI. These technologies are now having an impact in all of India. Once the technologies became available a number of research organizations/Institutes/ NGOs/Private organization have adopted these for on- farm testing and promotion. The impact has been more around Pantnagar where in the last season DSR was practiced over nearly 800 ha with technical support from University at Pantnagar. In addition, many farmers have taken up the technologies without direct support. In this area, the stage has come where technology is being passes from "farmer to farmer". In Uttaranchal, the plain areas are in the districts of Udham Singh Nagar, Hardwar, Nainital and Dehradun. The technologies for direct seeding have reached in first three districts. In the neighbouring state of Uttar Pradesh. which has been largest area under rice (5.5 m ha), all the state universities and ICAR institutes are promoting DSR. In western Uttar Pradesh, Project Directorate for Cropping Systems Research and ICAR Institutions have conducted many demonstrations during 2005 and many farmers have started direct seeding. In Central Uttar Pradesh, CSAUA&T, the university at Kanpur has conducted on-farm trials in district of Kanpur, Unnao and Raibareilly. In Eastern Uttar Pradesh, the University at Faizabad, NADA&T, Kumarganj conducted on – farm trials and demonstration in practically all the districts (25) in their area of jurisdiction. The promotional work here has been taken here under the project of G.B.P.U.A&T., Pantnagar and much more than that by the Directorate of Extension in the university through its Krishi Vigyan Kendra (technology outreach centres) networks. In Eastern Uttar Pradesh, another university at Varanashi (BHU) has been promoting DSR with support from rice-wheat consortium and NGO's in district Pratapgarh has been promoting DSR activities. Further east, in the state of Bihar, promotional activities under the G.B.P.U.A &T., Pantnagar and IRRI project had been taken up in district Bikramganj, the "*rice bowl"* of Bihar and in Patna District. In the same district of Bihar, the rice-wheat consortium has also been promoting DSR. Thus in the entire length of Indo Gangetic Plains (IGP) from west to east promotional activities have been initiated at many locations. Machines, drills and drum seeder are also been manufactured at a number of locations in small workshops and these are now locally available.

The DSR technologies have reached close to the point of “take-off “and at this stage focused efforts are required so that the technologies disseminates at faster rate. Farmers who have practiced DSR are very clear about the advantage in terms of timely sowing, early crop maturity, saving of labour, machinery, water and money. The reduced production cost of DSR, enhances the profitability of rice growing. There are significant possible gains through DSR technologies. In eastern part of Uttar Pradesh and more so in the state of Bihar, every year sizeable area of rice remains un-planted due to lack of rain at right time for transplanting. These are areas that could potentially be cropped using DSR rather than the transplanting as the former requires less water to puddle the land and there is less time required to establish the crop as a the “lead time” for the nursery bed is not required.

The extension agencies of the state, Department of Agriculture, whose main responsibility to promote new technologies have however not yet taken up its promotion in any significance way. There is need to interact with them so that they include DSR in the state wide programme. That will make real impact. Hence, efforts are required at every stage by various agencies public/private to promote the technology which can very well enhance the productivity of rice in India which is nearly stagnant for last 5-6 years.

Farmers’ opinions on DSR.

- Direct seeding saves labor and fuel.
- In direct-seeded fields under water stress, cracks do not develop as quickly as in transplanted fields and hence the crop can be grown with less water.
- Crop diversification may be important for good soil health in the rice-wheat system.
- Sowing must be done in the second or third week of June. Early sowing exposes the crop to scorching summer heat, which could damage young seedlings. Early sowing would also require more irrigation in summer.
- The technology packages need to be site-specific rather than generalized recommendations. There are no deficiencies in the component technologies of direct seeding, but proper implementation is required. Direct seeding requires careful crop management.
- Laser leveling increases water-use efficiency and hence laser levelers should be made more available.
- Seed drills need improvement, particularly the seed-monitoring device. In current drills, the seed rate is not calibrated accurately and some drills break the rice grains during drilling.
- In traditional transplanted systems, farmers use seed treatments before sowing. In direct drilling, where only dry seeds are sown, provision must be made for appropriate seed treatments.
- There are definite financial advantages of adopting direct seeding.

- Direct seeding can be practiced by drilling/drum seeding as well as by broadcasting the seed.
- With proper management, there are no yield differences between direct-seeded and transplanted crops.
- Herbicide efficiency depends strongly on soil moisture. With delayed herbicide application and soil moisture loss, herbicide efficiency is reduced. After sowing, pendimethalin should be applied as early as possible.

Advantages and disadvantages—farmers' views

Farmers who have been partners in on-farm trials around Pantnagar, Faizabad and Patna on direct seeding and are now practicing direct seeding were asked about the advantages of direct seeding and the limitations of the technology. They were also asked to prioritize these. There were similarities in the responses given in different villages, though there were differences among farmers with respect to farm size, availability of tractors, farm machines, irrigation infrastructure and entrepreneurship. Common responses were as follows :

Advantages

1. Time is saved and the direct-seeded crop can be established earlier, which can lead to increased production.
2. The costs of nursery raising and puddling of fields are saved and tillage costs in direct seeding are less. Farmers' priority is to minimize production costs. Direct seeding saves a lot of diesel fuel, which is expensive.
3. There is a savings of labour, particularly on labour employed in nursery raising, uprooting of seedlings and transplanting.
4. Savings of water in field preparation and later in the crop season can be achieved. The transplanted crop cannot be left dry for more than 1–2 days, whereas a direct-seeded crop can be left dry for 8–10 days or even more.
5. Savings in tillage, labour and water reduce production costs and increase net returns.
6. Direct-seeded rice crops mature earlier than transplanted ones by nearly 10 days and subsequent crops of potato, green peas, or rapeseed can benefit. Direct seeding may facilitate triple cropping and crop diversification such as rice-potato-onion in Bihar.

7. After direct-seeded rice, the residual soil moisture is high and the soil physical conditions may be better, which is advantageous to the following *rabi* crop—wheat, lentils, or chickpea.
8. Savings of seed : in Bihar, farmers use up to 80 kg ha^{-1} of seed for transplanting because of risks involved with nurseries. Direct-seeded crops use only 30–40 kg ha^{-1} of seed.
9. Fertilizer-use efficiency may be greater in direct seeding as the fertilizer is placed close to the seed by a drill.
10. The yield of the direct-seeded crop is more than with transplanting as contract labourers may do a poor job of transplanting, resulting in a poor crop stand.
11. Framers in Bihar reported that the direct seeded crop tolerate drought to a greater extent than transplanted crops.
12. Insect and pest infestations in direct-seeded rice are fewer.
13. The following wheat crop has fewer weeds.

Disadvantages

1. There are more weeds in direct-seeded crops than in transplanted rice and, after the first irrigation, new flushes of weeds emerge.
2. The cost of manual weeding is high.
3. If fields are not uniform and well prepared, sowing and the plant stand is uneven.
4. High summer temperatures may damage young rice seedlings.
5. Direct seeding is done in June and the first weeding is required in July. At that time, weeding coincides with rice transplanting and labor availability is a problem and wages are high.
6. Irrigation is needed for direct-seeded rice sown early; temperatures are very high and maintaining moisture in the soil is very difficult and costly. There is no moisture problem once the monsoon comes.

Project output 2: Decision support frameworks for weed management options in DSR in the irrigated rice- wheat rotations of the IGP developed and validated.

Information on crop establishment and management has been provided in the form of leaflets, bulletins and promoted through presentation and demonstrations. Farm and research station field days and visits have played a key role in the extension and development of these options. Many of the considerations with regard to crop establishment concern farm size, resources, soil type and infrastructure and often involves considerable local knowledge. An example of a "decision tree for farmers considering the adoption of direct seeding options" is shown in Fig 3 and this was promoted through a GBPUAT publication in 2005. The decision tree firstly addresses the primary considerations which in this case is whether "water or labour are in short supply or costly?". The subsequent question guides the choice or wet or dry seeding based on the costs of water and the degree of water control available to the farmer. Choice of weed management will be guided by the establishment method adopted and whether the rice was broadcast or row seeded and the weeds problems likely to occur. Some of the information required to answer the questions will be specific to locality such as soil type for zero-tillage. Other information including herbicide rates and timing of application, machinery and seed rates tends to be more generic and this has been made available in the form of leaflets.

The value of the long term studies on weed populations lies in the ability identify shifts in weed populations over time which in turn enables the prediction of the likely shifts that will occur with altered management practice. This knowledge provides the basis for a decision support system to determine the likely problem weeds and appropriate management responses. In the study at Pantnagar, fourteen principal species were recorded over the four cropping seasons: *Caesulia axillaris, Commelina diffusa, Cynotis* spp, *Cyperus difformis, Cyperus iria, Cyperus rotundus, Echinochloa colona, E. crus-galli, Eragrostis japonica, Fimbristylis miliacea, Ischaemum rugosum, Leptochloa chinensis* and *Paspalum distichum.* At the start of the trial in 2000 in unweeded plots *E. colona, C. axillaris,* and *F. miliacea* were the most abundant weeds in both the transplanted and dry-seeded rice plots. Differentiation in the flora according to rice establishment method was noticeable (Figure 4) by 2003 with *Ischaemum rugosum* being dominant in wet seeded plots, *E. colona* dominating in dry seeded plots and *Cyperus iria* and *E. colona* being most abundant under transplanting ($P < 0.001$, multivariate analysis not shown). Four years after the initiation of the trial, *L. chinensis* and *Cyperus rotundus,* were present in all direct seeded plots. Table 6 summarises the responses of selected species to rice and wheat establishment as indicated by density 28 d after crop establishment in 2004 in unweeded rice plots. Densities of *E. crus-galli, C. difformis* and *E. japonica* were not influenced by establishment methods in either crops over the previous 4 years. Conversely population densities of *E. colona* and *C. axillaris* in rice were dependent on land preparation for wheat. In conventionally tilled wheat plots, mean *E. colona* densities were three fold greater than in zero-tilled wheat plots, a two fold difference being measured for *C. axillaris*, the higher abundance occurring under zero tillage. Rice establishment methods selectively influenced recruitment and in particular, direct seeding with a prior stale seed bed (DSf) reduced densities of *C. axillaris, L. chinensis* and *C. iria.* The abundance of *C. rotundus* was promoted under DSf rice and elevated by zero tillage of wheat. The selective effects of land preparation and of crop establishment on recruitment of rice weeds and by implication soil seed banks are well known and these results highlight the responsiveness of major rice weeds. As a single observation in time, they suggest that underlying weed succession may result from to cultural practices. Further analysis (not shown) of population dynamics support the hypothesis of succession for *C. axillaris* and *E.*

colona since monotonic increases in density were seen over years at comparable census points, despite seasonal climatic variation. Similar increases occurred for *C. rotundus*, although spatial heterogeneity over plots precluded statistical significance. Whilst substantially reducing weed biomass, hand weeding alone did not alter the dominant weed species in residual biomass (comparison of curves, Figure 4) in most instances. Mechanistic processes underlying the dynamics of germination, seed longevity and dormancy for many of these species remain poorly understood.

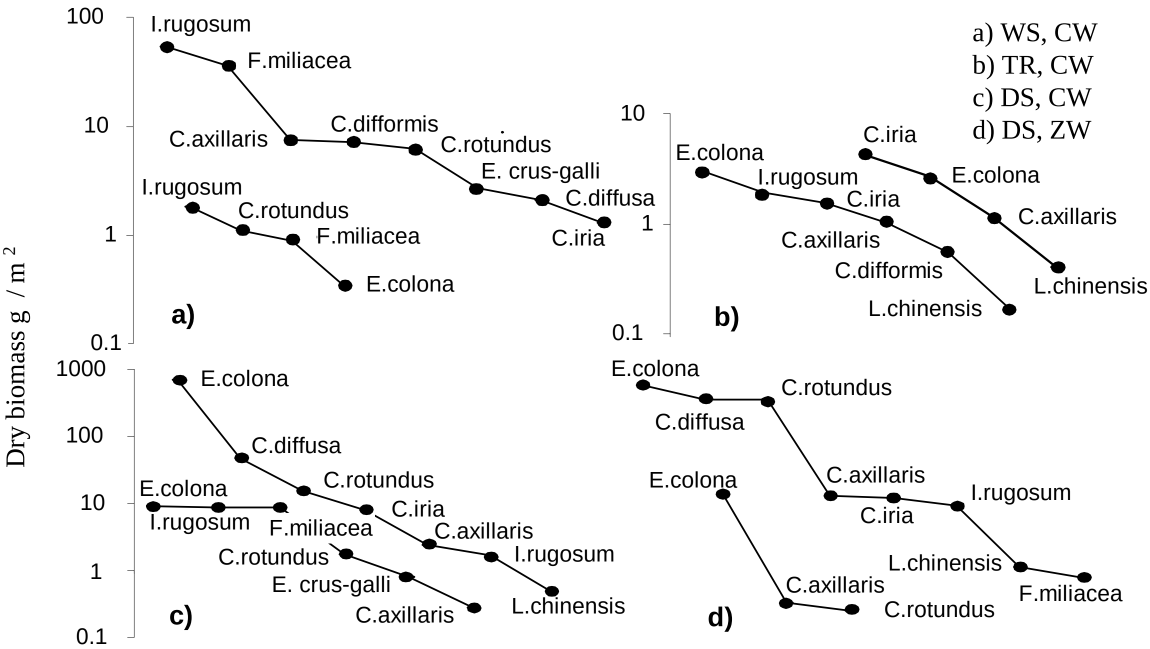


Figure 6. Log rank curves of weed dry weight, 56d after establishment for selected treatments. The upper curve of each pair is from unweeded plots, the lower from manually weeded plots (Singh et al. 2005).

Successful yield protection from weed competition in direct seeded rice relies on effective early chemical control followed by manual weeding, the latter to remove aggressive late emerging species not adequately suppressed by the developing rice canopy. Understanding the underlying dynamics of weed communities underpins decision support systems that identify important target weeds and potential shifts in populations, and determines appropriate control measures. In rice-wheat a change to zero-tillage for improved wheat productivity has the potential to reduce time and costs spent hand weeding for *E. colona* in rice especially if coupled with wet seeding but may increase the risk of ingress of *C. rotundus*.

Table 6. The influence of rice and wheat crop establishment methods on abundance (mean plant density, m^{-2}) 28 DAS / DAT of selected weed species in unweeded plots of rice in 2004. The lowest and highest abundance is indicated by method of establishment for each crop (Singh et al. 2005).

Species	Response to crop establishment method										
	Rice					Wheat					
	Abundance					Abundance					
	Low		High		S.E.D	Low		High		S.E.D
Caesulia axillaris	DSf	16.0	ZR	21.5	5.5	CW	9.3	ZW	19.4	2.26
Commelina diffusa	WS	1.8	ZR	84.2	12.8					
Echinochloa colona	WS	5.2	ZR	22.0	8.7	ZW	5.9	CW	20.0	5.86
Ischaemum rugosum	ZR	0.0	WS	7.8	2.7					
Leptochloa chinensis	DSf	0.2	WS	8.8	2.0					
Fimbrystilis miliacea	DS	4.2	WS	37.2	12.6					
Cyperus iria	DSf	8.8	ZR	68.5	27.4					
Cyperus rotundus	WS	4.0	DSf	175.0	37.0	CW	42.0	ZW	106.0	36.20

All comparisons significant ($P<0.05$) except CW versus ZW in *Cyperus rotundus* ($P=0.17$). Mean density (m^{-2}) of species not responsive to establishment method : *Cyperus difformis* = 17.9, *Echinochloa crus-galli* = 10.2, *Eragrostis japonica* = 1.1.

Farmers' decision making

Decision-making for crop establishment is a complex process which requires the coordination of tillage, labour, and water management under conditions of unpredictable monsoon rainfall. This means that recommendations for DSR must be conditional, and take account of contingencies. This requires a better understanding of how farmers make their decisions about rice establishment.

The general objective of this study was to produce a decision-tree for establishment of DSR and TPR. The specific objectives were to:

- Interview sample OFT farmers about decisions for rice establishment;
- Identify the main physical, climatic, and socio-economic factors involved in decision-making;

- Analyse the implications for adoption of DSR.

Methods

Decision-making was explored in two rounds. In Round One, OFT farmers were interviewed using a structured questionnaire to capture key activities for each rice plot before and after crop establisment. In Round Two, these farmers and non-OFT farmers were interviewed using a checklist to analyse decision-making. Round Two was conducted just after establishment of the 2005 season kharif rice crop. In total, 22 farmers were interviewed at two research sites in Faizabad, Uttar Pradesh and Rohtas, Bihar. Full results are reported in Working Paper # 6.

Findings

Based on farmers' statements, the major choices made by farmers during rice establishment were captured in three composite decision-trees. The first tree identified 11 possible decisions for adoption of DSR over TPR. The second tree identified 15 possible decision criteria for the choice between wet and dry-seeded DSR. The third tree identified 8 possible decision criteria for the choice between timely and late TPR.

Discussion

The criteria identified by farmers included socio-economic, climatic, and physical constraints on rice establishment. Socio-economic variables included reliance on the markets for water and tillage for farmers who did not own these resources. Generally, tillage markets were competitive and few farmers complained about delays in rice establishment due to draught power constraints. Water-markets were also competitive but where farmers relied on irrigation from privately-owned tubewells, as in Faizabad, some complained that they had no choice between suppliers for some of their plots. Uncertain and limited electricity supply also restricted the command area from private tubewells since owners gave priority to their own fields. Expanding the number of electric tubewells would increase the capacity to supply a pre-sowing irrigation and the potential area under DSR. Labour for transplanting was available, either locally or from migrants, but the transaction costs of hiring labour on separate occasions, feeding them, and supervision in the field added to farmers' costs. The opportunity cost of the farmer's labour, and of his family members, is usually omitted from partial budgets but these are evidently an important consideration for farmers.

The major climatic variable was the unpredictability of monsoon rainfall. Pre-monsoon showers determined the timing of tillage for dry-seeded DSR. In Rohtas, it was common for farmers to give a pre-sowing irrigation to allow timely dry-seeding. Rainfall also dictated the time of application for pre-emergence herbicide which required specific soil conditions. Physical decision-criteria included land type, with farmers choosing to sow DSR on medium land with good water control and where there was residual moisture available for an early rabi crop, and soil type, with farmers preferring to sow DSR on soils less prone to weeds.

All three decision-trees highlighted the importance of irrigation in increasing the range of options for farmers in rice crop establishment. Where irrigation was available, farmers had the option of pre-sowing irrigation to ensure timely tillage for dry-seeded DSR and timely puddling for TPR. This option was available to farmers in eastern India with access to cheap irrigation from electric tubewells and canals. Where irrigation was more expensive, as with diesel-powered tubewells in eastern India, or simply not available, as in Rajshahi (Bangladesh), farmers had fewer options and the process of decision-making was relatively simple.

The economics of DSR

Partial budgets for DSR and TPR were made based on interviews with key informants. Results showed that:

- When costs of DSR omitted the cost of subsidised inputs (herbicide or drill-seeder), net returns from DSR were lower than from TPR in both Rohtas district (Bihar) and Faizabad (Uttar Pradesh).

- The high cost of subsidised inputs for DSR in Faizabad DSR-DS and Rohtas DSR-DS reflected the use of drill-seeding using a zero-till drill (35 USD/ha).

Table 7. Comparative costs of DSR and TPR for selected OFT farmers, *kharif* season 2004 (USD/ha)

	Faizabad		Faizabad		Rohtas		Rajshahi	
	DSR-DS	TPR	DSR-WS	TPR	DSR-DS	TPR	DSR-DS	TPR
Costs that vary								
Tillage	57	70	-	-	35	37	50	43
Pre-sowing irrigation	17	17	43	43	-	-	-	-
Herbicide	64	-			25	-	17	-
Transplanting and nursery	-	76	-	87	-	39	-	54
Weeding	74	52	65	65	35	26	9	26
Other	114	0	58	1	62	17	16	0
Total costs that vary	273	215	166	196	157	119	92	123
Total cost of subsidised inputs	53	-	16	-	64	-	18	-
Gross returns	624	638	359	478	610	610	443	443
Net returns Without subsidy With subsidy	298 351	423	193 209	282	453 517	491	361 379	320

Source: Working Paper # 6.

A closer look at the figures shows that, in farmers' fields, some of the expected cost-savings from DSR evaporated because:

- Dry-seeded DSR did not show much difference in tillage costs over TPR. This was because several ploughings were needed to ensure a weed-free and level seedbed.

- Farmers' real costs were masked by the provision of subsidised inputs like herbicide, seed-drills, drum-seeders, and sometimes seed (in the first year). When these costs are included, net benefits from DSR are lowered significantly.

- Weeding costs for DSR were high because of ineffective application.

- The full cost of herbicides, plus additional costs for manual weeding, generally matched the cost of labour saved by avoiding the need for a rice nursery and transplanting.

Case study: Kumar Shankar Upadhaya, Toromaphy village, Faizabad, Uttar Pradesh.

This budget was obtained from the only OFT farmer in Faizabad who dry-seeded DSR in the 2004 kharif season. The plot was summer ploughed after the harvest of wheat using light rains in the last week of April. The field was ploughed twice by bullocks. A pre-sowing irrigation from an electric tubewell was given in mid-June to bring the field to the 'ba' condition, which required 3.5-4 hours/bigha. The field was then dry-ploughed twice with a tractor and planked twice by bullocks. No interval was left between ploughings. After tillage the field was dry-seeded with Surju 52 on 15th June using a seed-drill provided by NDUAT. Pendamethalin herbicide was applied four DAS. The herbicide was not effective, probably because the soil was no longer wet. The crop was hand-weeded once, and the farmer also gave a beushening with bullocks. The crop received 7-8 irrigations after sowing. Harvest was somewhere between the last week of October and the first week of November. The crop matured one week before TPR but both DSR and TPR were harvested at the same time in order to make it easier to manage hired harvest labour.

This example shows the investment required when farmers plan ahead for dry-seeded DSR. Summer ploughing, a pre-sowing irrigation, dry-ploughing with a tractor, planking with bullocks, were all needed for this strategy to succeed as planned. Farmers who had not given a summer ploughing might have needed more ploughings and a longer gap between ploughings to prepare a weed-free seedbed, which might have delayed sowing. The cost of pre-sowing irrigation for this farmer was minimal since he owned an electric tubewell and paid a flat monthly tariff rather than a variable rate. By reducing dependence on the pre-monsoon rains for tillage, irrigation also reduced the risk of investing in a planned DSR strategy.

Hitherto, economic evaluation of DSR has relied chiefly on on-station trials from Pantnagar (See Working Paper # 5). Results from a small number of key informants suggest that DSR may have no clear cut *financial* advantage over TPR in farmers' fields, where tillage is needed to bring soil into the right condition ('ba) for dry-seeding and where herbicides have been ineffective. There are *management* advantages, however. These include reduced transaction costs hiring and supervising labour for transplanting while reduced demand for transplanting labour allows timelier transplanting on other plots.

A. Orr, S. Saxena, R K P Sinha, M A Jabbar and M A Mazid (2005). Farmer Decision-Making for Rice Establishment in Eastern India and the High Barind Tract, Bangladesh. Working Paper # 6. September.

Project output 3: *Information sources on weed management in DSR for researchers, extension workers and farmers prepared and disseminated.*

1. In the area around GBPUAT, Pantnagar farmers' fairs in March and October 2005 and these included the demonstrations of direct seeding in the rice wheat system. Further field days were held in October 2005 where farmers from various districts were taken to examine direct seeded fields in other districts (see Table 8).

Table 8. Farmers field "direct seeding" days held in Pantnagar, Uttaranchal, 2005.

Date of visit	Areas shown	Farmers from areas	No. of farmers participated
14.10.2005	Narayanpur, Deoria , Bagwara, Kaushal Ganj, Bilaspur & Arafatpur	Radhabangar, Halduchor, Motinagar, Shantipuri, Jawahar Nagar & Kichha	100
18.10.2005	Rudrapur, Gadarpur, Bajpur Doraha, Bajpur & Sultanpur Patti	Lalpur, Narayanpur, Deoria, Phulsungha, Rudrapur, Dineshpur & Gularbhoj	72

To promote the direct seeding technologies and practices a number of meetings were held with extension staff in order to establish plans and coordinate activities. The meetings held by staff in Pantnagar are shown in Table 9

Table 9. Extension meetings held by GBPUAT, Uttaranchal, 2005.

Date	Participants	Places
18-07-2005	Scientists, farmers, extension workers and NGOs	Jahangirpuri (Udham Singh Nagar), Bilaspur (Rampur), Bichpuri (Udham Singh Nagar)
10-09-2005	Scientists, farmers, government officials, private companies and NGOs	Ramnagar, Dist. Horticulture Office
13-09-2005	Scientists, farmers, extension workers and NGOs	Bagwada (Udham Singh Nagar), Bilaspur (Rampur), Deoria (Udham Singh Nagar)
18-09-2005	Scientists, farmers, government officials, private companies and NGOs	Kalagarh, Jila Panchayat office, Nainital
14-10-2005	University staff, scientists, farmers, extension workers, NGOs and pesticides suppliers.	Bagwada (Udham Singh Nagar)
18-10-2005	scientists, farmers, extension workers, NGOs	Motinagar (Nainital), Narayanpur (Udham Singh Nagar), Deoria (Udham Singh Nagar), Abad nagar (Udham Singh Nagar), Bilaspur (Rampur)

2. CSA, Kanpur organized an "*All India Farmers' Fair*" on October 3-6, 2005 at Kanpur where the technologies related to direct seeding was displayed through field demonstrations

and photographs. Farmers' field days were also held in September 2005 at *Etaura bujurg* and *Purenikani* (Raebareilly) villages where large number of farmers visited on farm trials being conducted on direct seeded rice. Around Kanpur, scientists of *Krishi Vigyan Kendra (KVK* - technology outreach centres), Agriculture officers of State Department of Agriculture, Assistant Director (rice) Uttar Pradesh, Deputy Director (Agriculture Extension), District Agriculture Officer, together with television and radio reporters also visited the on farms trials, interacted with scientists and farmers.

3. NDUAT, Faisabad reported that more than 2830 ha area was grown under direct seeding in 2005 Two farmers' fairs were held (March 5-6, 2005 and November 19-20, 2005) together with two field days in Toromafy, Bikapur on September 25, 2005.

A total of 10 extension meetings were held (Table 10) in which the technologies of direct seeded rice was discussed. Two leaflets were disseminated 'Dhan Ki Sidhi Bowai – Kam Lagat Prabhavi Takniki ' and 'Purvi Uttar Pradesh Mei Dhan Ki Sidhi Bowai Karke Laabh Uthai'. Articles also appeared in thelocal newspaper *Janmorcha* on 28-9-2005 and 4-10-2005, entitled Dhan Ki Sidhi Bowai Par Prachhetra Divas and Janmorcha, , Dhan Ki Sidhi Bowai Par Prachhetra Divas Ewam Kisan Gosthi

Table 10 Meetings with extension agency staff in Faisabad region.

Place/ Village	No of Meetings	No. of farmers participating	Scientists involved*
Toromafy, Bikapur	3	35-40	Dr. S.P. Singh, Dr. R.M. Singh, Dr. R.A. Singh, Dr. Brij Lal, Dr.Ram Achal, Dr. Sushant, Sri Birendra Kumar , Sri Vinit Kumar
Kharbaria, Milkipur	2	50-60	Dr. D.S. Yadav, Dr. H. P Tripathi, Dr. Jai Dev Sharma, Dr. J.S. Tripathi, Dr. Sushant, Sri Birendra Kumar , Sri Vinit Kumar
Achhora	1	30-35	Dr. R.D.Vaishya, Dr.Alok Kumar, Dr.R.D.S. Yadav, Dr. Sushant, Sri Birendra Kumar , Sri Vinit Kumar
Ranapur	1	40-50	Dr. G. P. Verma, Dr. Ganshayam Singh, Dr. J.S.Tripathi, Dr. Sushant, Sri Birendra Kumar , Sri Vinit Kumar
Inayatnagar	2	40-50	Dr. H. P Tripathi, Dr. R.D.Vaishya, Dr. Alok Kumar, Dr. R.C. Sharma, Dr. Sushant, Sri Birendra Kumar , Sri Vinit Kumar
Sorawan	1	50-55	Dr. D.S. Yadav, Dr. R.M.Singh, Dr. R.D.Vaishya, Dr.Ram Achal, Dr. Sushant, Sri Birendra Kumar , Sri Vinit Kumar

4. In Bihar, the Department Agriculture has announced a subsidy of Rs 5000 (or about 25% of the cost) on seed drills to promote the technology and two manufacturers in Patna are producing the drills. Meetings on direct seeding with extension services and farmers were co-ordinated with the Department of Agriculture.

Farmers obtain information on rice production from a diversity of sources in Bihar. This process and opportunities for enhancing knowledge transfer were summarised in a project working paper (Riches and Singh, 2005). In some districts the university runs Krisi Vigyan Kendra (KVK) centres. KVK staff has the mandate for adaptive research, technology development and farmer training. KVK activities have led to some farmers, particularly tractor owners gaining access to zero-tillage drills designed for wheat. These are also being used for direct seeding of rice after conventional land preparation and to some extent direct seeding has become closely associated with drill seeding of rice. Tractor owners commonly operate as tillage contractors and to a limited extent have been extending the use of direct seeding to their clients. At the current time these farmer/contractors have the most knowledge about the practicalities of rice direct seeding. Herbicide use, particularly of butachlor, is common in transplanted rice. Farmers obtain information about herbicides from other farmers and pesticide dealers. The dealers receive variable levels of training and product information from distributors and manufacturers although this is largely restricted to product specific information on doses, time and method of application.

DSR is knowledge intensive. The effectiveness of information flow to farmers on rice direct seeding and herbicide use could be improved by building a partnership between KVKs and the private sector. KVKs should target farmer groups centred on tillage contractors. These should be assisted to evaluate DSR by broadcast and drill seeding of dry seed AND broadcasting or drum seeding of pre-germinated seed once land can be puddled. Appropriate herbicides for each of these DSR practices needs to be evaluated further. Information on DSR and herbicides could then be channelled to farmers via the herbicide supply chain by making posters and flyers available at pesticide dealer's stores in partnership with the manufacturers. To undertake timely DSR effectively farmers need access to all of the components necessary to use the technology i.e. tillage equipment, drills and herbicide in advance of the onset of the monsoon. Further studies are needed to investigate farmer access to these, particularly household liquidity and the role of micro-credit.

5. The project produced 5 has produced bulletins in English and Hindi covering the critical aspects of crop establishment and management (see Appendix 1) and these were primarily intended for extension and research staff rather than as primary extension tools. The technologies for direct seeding were also promoted through radio and television presentations / discussions.

6. Project outputs have been taken up and promoted in Uttar Pradesh with the very active collaboration of Dr CM Singh, Director of Extension, NDUAT. This is described in the following report of activities under the National Agricultural Technology Project (NATP) which is supported by IFAD and USAID programmes.

The Directorate of Extension, NDUA&T Kumarganj in collaboration with *Krishi Vigyan Kendras* and *Krishi Gyan Kendras* (village education centres) has been conducting demonstrations on Farmers' Fields to popularize "Direct Seeded Rice with Zero Till (ZT) drills. The technologies perfected by GBPUA&T Pantnagar were promoted in these demonstrations. These included establishment of rice after one or two harrowing, seeding dry rice seeds with ZT drill; application of pendimethalin for weed management.

Process followed :

(i) Meeting with scientists of KVKs / KGKs at University HQ to discuss in detail the technical aspects and strategy to follow to layout demonstrations and increase awareness among rice growers
(ii) Farmer scientist interaction programme organized by KVKs / KGKs to discuss the usefulness of DSR over conventional transplanted rice. At length the merits and constraints are discussed and finally the farmers willing to try the technique are short listed.
(iii) Technology transfer programme is organized for farmers interested in the DSR technology. The schedule of activities is given to the farmers.
(iv) Layout of field demonstration were undertaken in presence of the scientist, together with farmers from the village and details were again explained to the gathering.

The scientist - farmer collaboration ensured that the required operations were done in timely fashion.
(v) A field day / Kisa Gosthi (Farmers' fair) was organized at each of the demonstration sites to which all the relevant organizations of Agriculture Department, NGOs, farmers of adjoining villages and officers of development departments. Press and publicity people are invited to attend. The gathered group visits the site and discusses with the concerned farmer. The experiences of other farmers are also shared at these meetings. Literature in local language is also made available to the interested farmers and. This process makes the farmers aware and convinces them as - "seeing is believing".

Area covered under Direct Seeded Rice during Kharif 2005 in Eastern Uttar Pradesh

S.No.	Name of District	DSR with ZT machine(Ha)
1	Basti	30.0
2	Sant Kabeer Nagar	2.0
3	Bahraich	194.5
4	Ballia	7.5
5	Gorakhpur	17.0
6	Sonbhadra	4.0
7	Faizabad	1.0
8	Ambedker Nagar	10.0
9	Varanasi	15.0
10	Sidharth Nagar	6.0
11	Chandauli	3.0
12	Maharajganj	6.0
	Total	**296.0**

Results: Based on 236 farmers field data available from different districts during last three years the comparative performance of DSR and Transplanted rice is given hereunder

Year	Farmers	Yield(Kg/ha) DSR	Yield(Kg/ha) TR
2005	44	awaited	awaited
	26	3361	3613
	50	2916	3149

DSR=Direct Seeded Rice with ZT drill.
TR=Transplanted rice as practiced by farmers

Contribution of Outputs to developmental impact

The rice–wheat system is critical to the food security of India and to the livelihoods of the rural communities across the Indo-Gangetic Plains. Rising costs of production and decreasing margins is forcing farmers to seek new production options to maintain profitability. With appropriate weed management options, as developed through the project, direct seeding offers a number of advantages compared to transplanting. These technologies have now been widely tested across the states of Uttaranchal, Uttar Pradesh and Bihar. The local uptake of wet and dry direct seeding has been considerable in the project activity areas and among the institutions involved with the promotion. The project activities have demonstrated opportunities with direct seeding in terms of labour saving, system productivity and the use of herbicides. These management options have however only been validated in a relatively small portion of area occupied by the rice wheat system that is in turn variable by nature.

Farmers' response has, in general, been enthusiastic though the technologies have worked better in some locations than others and factors such has soil type, rainfall, farmers' knowledge and farm infrastructure are critical. In the Western areas of the Indo-Gangetic the technologies have been well tried and tested, this augurs well for significant impact at farm in the near future. Least information and greatest uncertainty with regard to the application of the technologies lies in the eastern areas of the Indo-Gangetic where farms tend to be smaller and with fewer resources that in the west. The project has had only two years of experimental experience on farm in these areas and, in both years, late monsoons and drought caused serious disruption to the establishment of the transplanted and direct seeded crops. In some areas up to half of the rice area failed to be transplanted in 2005. Direct seeding may have substantial potential in these areas not only in terms of time and cost saving but also in terms of risk reduction, but this is an hypothesis to be explored in future work.

Validation and data collation over a wider area and in collaboration with farmers' groups will continue to be required in order to be able to further develop the technologies and to overcome constraints that arise. Provision of information to policy makers, advisors and farmers will continue to be critical to enabling appropriate decision making. Sustained effort is required to meet this need for information as it is crucial that farmers, advisors and policy makers are able to make informed choices based on the best information available.

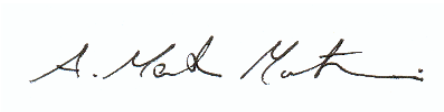
It has been extremely encouraging to witness uptake of project outputs by the NATP program (6. above), which will place the project outputs in reach of all institutions involved in the NATP and allow effective dissemination to occur.

The project has been actively linked with the Irrigated Rice Wheat Consortium at IRRI and also with the Rice Wheat Consortium. These consortia have adopted direct seeding as part of their program of activities and options and technologies form part of the suite of technologies being developed and promoted in south Asia.

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:	30 January 2006

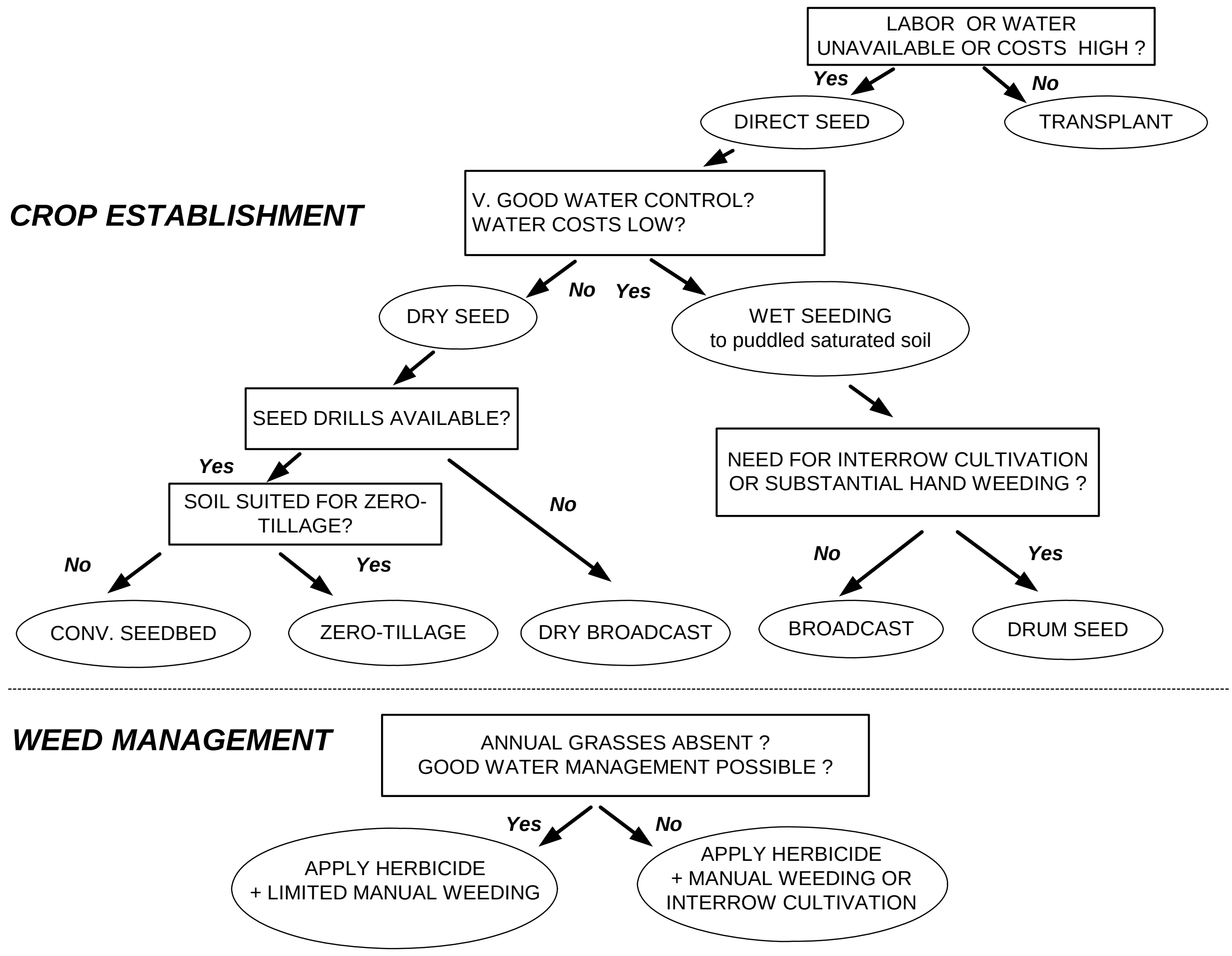


Fig 3 Decision tree for adoption of direct seeding and weed management in irrigated rice wheat system, India. (Singh et al. 2005)

Appendix 1.

PUBLICATIONS SUMMARISING RESULTS FROM R4089

Articles and papers

1. Singh G, Singh Y, Singh VP, Johnson DE, Mortimer M. 2005 .System-level effects in weed management in rice-wheat cropping in India *Proceedings of the BCPC International Congress on Crop Science and Technology* - 2005, SECC, Glasgow, UK, 1, 545-550.

2. Singh Y, Singh Govindra, Singh VP, Singh Pratibah, Hardy B, Johnson DE, Mortimer M. 2005. Direct Seeding of rice and weed mangement in the irrigated rice-wheat cropping system of the Indo-Gangetic Plains. Directorate of Experiment Station, G.B. Pant University of Agriculture and Technology, Pantnagar, India. 39 p.

3. Johnson DE, Mortimer AM. 2005. Issues for integrated weed management and decision support in direct seeded rice. In : Rice is life: scientific perspectives for the 21st century. Proceedings of the World Rice Research Conference held in Tokyo and Tsukuba Japan. November 4 – 7, 2004. Los Baños (Philippines): International Rice Research Institute, and Tsukuba (Japan): Japan International Research center for Agricultural Research. CD. 211-214.

4. Singh Y, Singh G, Johnson DE, Mortimer M. 2005. Changing from transplanted rice to direct seeding in rice-wheat cropping systems in India. In : Rice is life: scientific perspectives for the 21st century. Proceedings of the World Rice Research Conference held in Tokyo and Tsukuba Japan. November 4 – 7, 2004. Los Baños (Philippines): International Rice Research Institute, and Tsukuba (Japan): Japan International Research center for Agricultural Research. CD. 198-201.

Project Working Papers

Orr AW, Sushant Saxena, Sinha RK. Jabbar M A. and Mazid MA. 2005.Farmer Decision-Making for Rice Establishment in Eastern India and the High Barind Tract, Bangladesh Project R4809 Working Paper. Chatham, UK: Natural Resources Institute.

Riches CR, Singh BK 2005. Information flow for rice direct seeding and herbicide use in Bihar. Project R4809 Working Paper. Chatham, UK: Natural Resources Institute.

Bulletins

Direct Seeding and Weed Management, Research Bulletin No. 146 GBPUAT Uttaranchal.

Sinchit Dhan Main Sidhi Boaai Va Kharpatwar Prabhandhan, Research Bulletin No. 147. GBPUAT Uttaranchal.

Direct Seeding of Rice and Weed Management in the Irrigated Rice-Wheat Cropping System of the Indo-Gangetic Plains, Technical Bulletin No. 140. GBPUAT Uttaranchal.

Management of Direct Seeding Rice – An effective approach to reduce cost of production. CSA, Kanpur.

Direct seeding of rice – a low cost technology effective technology (dry method for irrigated ecosystems) – translation from the Hindi. 2/05-06. Department of Agriculture, Government of Bihar.

Newspaper Articles

Date	Newspaper	Title of article (translated from the Hindi)
Pantnagar		
21-07-2005	*Amar Ujala*	Large farms adopting direct seeding of rice
14-09-2005	*Amar Ujala*	Foreign scientists listen to farmers views (Farmers satisfied with direct seeding of rice)
16-09-2005	*Dainik jagran*	Direct seeding of rice is beneficial compared to transplanted rice (A research finding of Agricultural scientists)
09-10-2005	*Amar Ujala*	Possibilities of more profit in the wheat crop
08-10-2005	*UttarUjala*	Foreign scientists view the direct seeded rice techniques of Pantnagar adopted by farmers
11-10-2005	*Amar Ujala*	Direct seeding of rice is profitable for farmers
12-10-2005	*Uttaranchal Darpan*	Less expensive rice cropping is now possible without transplanting
14-10-2005	*Shah Times*	Foreign guests again arrived to see the direct seeded rice (Vice-chancellor, scientists and farmers observe direct seeding)
15-10-2005	*Shah Times*	A farmers meeting organized on direct seeding of rice
16-10-2005	*Uttar Ujala*	Farmers are themselves adopting direct seeding of rice
20-10-2005	*Uttar Ujala*	Scientists and farmers observing direct seeding of rice
Kanpur		
15.09.2005	*DainiK Jagaran*	Foreign scientists give tips for higher production of direct seeding rice
15.09.2005	*Amar Ujala*	More emphasis on direct seeded rice by agricultural scientists
15.09.2005	*Hindustan Times*	Foreign delegation advised for higher production of direct seeded rice with low cost
15.09.2005	*Aaj*	Scientists stressed the need for Direct seeding rice
15.09.2005	*Rashtriya Sahara*	Dialogue on weed management in Direct seeded rice
Patna		
25-6-2005	*Hindustan*	Direct seeding of rice – a low cost technology
14-6-2005	*Smarika - Kharif*	Rice seeding by zero-till drill
28-5-2005	*Hindustan*	More grain yield from direct seeding rice technology
3-9-2005	*Hindustan*	More grain yield obtained from direct seeded rice

Newspaper reporting on DSR were also under taken by CSA, Kanpur, NDUAT, Faizabad and RAU, Patna, Bihar in the local news papers at respective area, the technology was also promoted through radio talks and television.

Logframe Project R4809

Narrative Summary	Objectively Verifiable Indicators	Means of Verification	Important Assumptions
Goal			
Livelihoods of poor people improved through sustainably enhanced production and productivity of RNR systems.	To be completed by CPP Programme Manager	To be completed by CPP Programme Manager	To be completed by CPP Programme Manager
Purpose			
Promotion of strategies to minimise impact of target pests in rice-based Land-Water interface cropping systems, for benefit of poor people.	To be completed by CPP Programme Manager	To be completed by CPP Programme Manager	To be completed by CPP Programme Manager
Outputs			
1: Weed management options for DSR across IGP validated.	2005 kharif trials conducted on farmers' fields and in researcher managed trials in three states; reported by 11/05.	Project reports.	Favourable weather and farmers willing to collaborate.
2. Decision support frameworks for weed management in DSR developed and validated	Decision tools and technical options described and available to institutions by 12/05.	Publications and reports.	Conducive policies and strong collaborative arrangements maintained.
3. Information sources on weed management in DSR prepared and disseminated.	Leaflets, proceeding and guidance notes available as drafts by 8/05 and final copy by 12/05.	Leaflets, proceeding and guidance notes, IRRI web pages	Conducive policies and strong collaborative arrangements maintained

Activities	Inputs	Means of Verification	Important Assumptions
	Total Budget here		
1.1 Conduct farmer and researcher managed trials on direct seeding in the areas of Ghazipur, Kanpur, Faizabad and Patna	100 farmer and researcher managed trials conducted in 3 states and completed by 11/05.	Project reports, data sets	No extreme climatic conditions compromise implementation
1.2 Conduct experimental trials at GBPUAT to fill knowledge gaps	Two experiments conducted at GBPUAT and completed by 11/05.	Project reports, data sets	No extreme climatic conditions compromise implementation
2.1 Technical options evaluated and decision support frameworks developed.	Evaluation of the technical options undertaken and decision frameworks developed and tested in collaboration with NARES partners; completed, by 12/05.	Project reports, information sheets and workshop proceedings.	
3.1 Describe current information sources and extension process	Study of information sources and flow completed by 10/05.	Project reports	