DRAFT

CROP PROTECTION PROGRAMME

Development of sustainable weed management systems in direct seeded, irrigated rice.

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FINAL TECHNICAL REPORT

1 April 1999 – 31 December 2002

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FINAL TECHNICAL REPORT

Title of project:	**Development of sustainable weed management systems in direct seeded, irrigated rice.**
R Number:	R7377
Project leader:	Dr David E Johnson
Institution:	Natural Resources Institute
CPP Production System:	High Potential
CPP Purpose:	Yields improved and sustainably enhanced in high potential cropping systems by cost-effective reduction in losses due to pests.
Commodity base:	Rice
Beneficiaries:	Rice growers in the high potential irrigated systems.
Target Institutions:	G. B. Pant University of Agriculture of Agriculture and Technology, Pantnagar, Uttaranchal; International Rice Research Institute as a partner of the CG Inter-Centre Rice Wheat Consortium and convenor of the Weed Ecology.
Geographic focus:	Gangetic Plains, Uttaranchal and Uttar Pradesh States, India.

	Planned	***Actual***
Start date:	1 April 1999	1 April 1999
Finish date:	31st March 2002	31st December 2002
Total cost:	£186,100	£186,100

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Executive Summary

The project has been undertaken through collaborative links between the International Rice Research Institute, Philippines, G.B. Palla University of Agriculture and Technology, Pantnagar, India and the Natural Resources Institute, UK.

Detailed household-level studies were completed in five villages spanning three agro-ecological areas, the hill, Terai and plain zones. Farmers use, on average, between 25 and 50 % of their own land for cultivating rice/wheat and the average income derived from rice relative to income from other crops is between 28 - 50%. In the plains and Terai areas, many farm households were found to be highly dependent on hired labour for land preparation, irrigation, spraying of herbicides and pesticides, hoeing, weeding, transplanting and harvesting.

Successful adoption of direct seeding of rice is contingent upon weed control early in the life of the crop and the weed flora is a consequence of the method of crop establishment. A range of crop establishment and weed management methods has being tested in on-station experiments. Results clearly indicate that direct seeding in rice can give similar yields to those using conventional practices, but at a reduced cost. On-farm trials, with farmer management, also show that rice yields under direct seeding can be similar to those from transplanting and with good weed control, wet seeded rice gave the best yield. Yields of drill seeded rice however were substantially reduced where weed management was limited to one hand weeding, underlining the critical nature of weed management in direct seeded systems and the importance of chemical weed control. Changes in the weed populations in relation to management practice have been closely followed. Serious weed of rice elsewhere in the world occur in rice in the Indo-Gangetic systems, including *Echinochloa crus-galli, E. colona, Leptochloa chinensis* and *Ischaemum rugosum* and *Fimbristylis miliacea,* and integrated weed management practices are required to provide adequate control. Preliminary results suggest that returns from wet, direct seeding are some 40% greater than transplanting and, further, despite displacement of labour for transplanting and weeding the direct seeded systems are socially profitable.

Initial studies have been conducted for the selection of suitable, weed competitive rice cultivars for direct seeded systems. A collection of rice cultivars (>75) was been compiled at Pantnagar comprising a wide range of traditional and improved cultivars from India and elsewhere in Asia, and O. sativa and O. glaberrima cultivars, and their hybrids, from West Africa.

The potential for the evolution of herbicide resistant weeds in direct seeded rice has been evaluated and methods for its prevention have been identified. Recommendations for herbicide use in India will take account of studies conducted elsewhere to reduce the risk resistance emerging.

Decision tools are being developed as a result of the on-farm and station experiments conducted in 2000 to 2002, combined with information from the household surveys. Weed management practices will be promoted together with information on factors including water control and pesticide use. A promotion phase of this work has been planned with the current partners and linking with agricultural universities in Patna and Faizabad to expand activities in further regions of the Indo-Gangetic plains.

Background:
The Indo-Gangetic Plains (IGP) occupy almost 20% of the total land area of India, Pakistan, Nepal and Bangladesh. In these countries the rice-wheat cropping system occupies 13,500,000 ha and in India contributes 40% of the nation's grain (Singh & Paroda, 1994; Sinha *et al*., 1998). The majority of the rice is transplanted but, as in many parts of Asia where there are water and labour shortages, there is increased interest in direct seeding (Pandey & Velasco, 1999). Transplanted rice grown in the wet summer season (June – October), followed by dry seeded wheat in the cooler drier winters (November – May), is a cropping system widely practised in India, Pakistan, Bangladesh and Nepal. Since the 1960s, significant increases in cropped area and productivity in rice-wheat have occurred with the introduction of improved cultivars and agronomy in both crops (Hobbs & Morris, 1996).

Hobbs *et al*. (2000) described the emerging issues of sustainability due to cropping intensification. These include the need to improve water-use efficiency, soil structure and weed management against a background of increasing labour scarcity for agriculture. In many areas there is the reliance on tube-well irrigation, particularly for land preparation and crop establishment, that is causing concern due to ground-water depletion. Direct seeding does not require the large quantities of water required for "puddling the soil" prior to transplanting but it is not known how great the saving will be over the duration of the crop. Labour requirements for direct seeded rice may also be lower as there is no longer the labour required for transplanting, but the system is likely to encounter greater problems related to weed management. The Rice Wheat Consortium Technical Co-ordination Committee in 1998 stated that "The management of weeds in direct seeded rice" was a crucial factor affecting the systems the performance of the rice –wheat system.

Project purpose and specific objectives of this project:

Purpose:
To develop and promote improved methods for the management of weeds in irrigated rice systems. The project aims to contribute to this purpose by development of sustainable, integrated weed management practices for direct-seeded rice in India.

Specific objective:
Develop an understanding of the weed problems associated with direct seeded rice, test management options in researcher managed trials and assess farmers' perceptions of the practices under test. Formulate weed management decision tools, and make concepts and results available to the wider community in Asia.

Research Activities:
The research activities are based at the G.B. Pant University of Agriculture and Technology (GBPUAT), Uttaranchal State (formerly Uttar Pradesh), that has one of the biggest agricultural faculties in India. G. B. PUAT is the lead institution in the National Agricultural Technology Project (NATP) of the Indian Council Agricultural Research (ICAR) and is a benchmark site of the CIMMYT/IRRI Rice Wheat Consortium (RWC). The principal collaborators in the project were Professors Y Singh and G Singh of the Dept. of Agriculture and Dr R.S.L. Srivastava of the Dept of Agricultural Extension.

GBPUAT staff in conjunction with the extension services in the area has conducted research. In 2000, on farm trials were initiated with "lead farmers" in each of a range of villages conducting an experimental area of 0.4 ha where direct seeding was compared with transplanting. These activities on the farm sites have continued in 2001 and 2002 and been used as a base for farm visits and open days to demonstrate direct seeding technologies. More detailed experiments have been conducted on the research station with a wider range of treatments being tested and the collection of more extensive data sets. The socio-economic studies have taken the form of village and household level studies. These have been conducted in five villages on a transect from the hills to the plains and in 137 households.

The International Rice Research Institute (IRRI) is a partner in the project. Through Dr Mortimer, 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 in UK and has also assisted with funding of meeting of the Weed Ecology Working Group. Dr Mortimer has made frequent visits to Pantnagar and has been closely involved with the planning of the studies and analysis of the data.

Annual visits to the West Africa Rice Development Association, in West Africa, have provided links with the complementary work that is continuing there on integrated weed management systems in direct seeded rice and in the development of competitive cultivars. This link has also enabled the exchange of information on screening methods and improved cultivars.

Project outputs and achievements:

1. *Output 1: Farmer weed control practices and perceptions of constraints and criteria for choice of weed management practices determined.*

For effective promotion of the direct seeding of rice in the Indo-Gangetic Plains to be undertaken, more needed to be understood about existing farmer practices and the key factors influencing these practices. This understanding allows an informed analysis of the opportunities and constraints presented by the introduction of direct seeding in the current context and possible adaptation of the innovations being promoted. An extended social and economic survey was therefore devised. As the information collected was to be used by GBPUAT for future monitoring activities, comprehensive data sets were collected covering a wide range of issues. For the specific purposes of the current project, questions focused on the agricultural practices of farmers in the region, particularly in relation to rice production, and the relative perspectives of small and large farmers. Specific attention was also paid to current weeding practices, given the implications of the introduction of direct seeding for weed management. Farmers' experiences of and views on direct seeding of rice were also explored.

This summary of findings on farmers' resources and constraints, their perceptions and agricultural practices should be read in conjunction with the analysis of the economic costs of production produced by Dr R.S.L. Srivastava (2002).

1.1 Methodology

Five villages were selected in Uttar Pradesh and Uttaranchal states. The locations selected provide a cross-section of farming communities representative of the three agro-ecological zones in the region: the hills, Terai and plains, as follows:

Plains Banskhera village, Rampur district, Uttar Pradesh state
Mirzapur Aurangabad village, Bareilly district, Uttar Pradesh state

Terai Chakarpur village, Udham Singh Nagar district, Uttaranchal state
Narainpur villlage, Udham Singh Nagar district, Uttaranchal state

Hills Dhaniakote village, Nainital district, Uttaranchal state

Within villages, a proportional sample of small (>0-< 2 hectares), medium (2 - 4 hectares) and large (> 4 hectares) farming households were interviewed to establish the extent to which access to resources, cultivation practices and constraints differ. In addition, several farmers were interviewed at each location. A total of 137 households were included in the survey that was conducted through the use of one-to-one and group interviews based on semi-structured questionnaires. Attention was paid to the perspectives of both male and female farm household members. A summary of the village characteristics is shown below in Table 1.

Detailed information was collected on the following areas:

- General demographics
- Access to resources (land, water, labour, agricultural inputs, technology, credit, social support etc.)
- Farming practices:
  - (i) crops cultivated (including relative importance of different crops; changes in crop cultivation over recent years)
  - (ii) crop calendars (including crop rotation practices)
  - (iii) rice varieties under cultivation (including changes in varieties cultivated over recent years and the reasons behind any changes)
  - (iv) choice of rice farming system (transplanting, and/or direct seeding, and reasons for choice)
  - (v) perceptions of direct seeding in rice
  - (vi) indigenous weed classification system(s)
  - (vii) prevalence of different weed groups/species in relation to agricultural practices
  - (viii) perceptions of relative damage to crop yield caused by different weeds
  - (ix) cultural measures used to control specific weeds, e.g. hand weeding, denala
  - (x) use of herbicide to control weeds
  - (xi) rationale(s) behind weed control measures, including timing of inputs, frequency of activity, source of inputs and perceived efficacy
  - (xii) changes in weed problems over recent years and perceived causes other crop protection measures pursued
  - (xiii) relative involvement of different groups in agricultural tasks (men, women, household members, paid labourers).
  - (xiv) Information sources for agriculture accessed by farmers
  - (xv) Farmers' experiences of utilising new farming practices/technologies)
  - (xvi) Costs and returns of rice and wheat productions

Table 1. Summary Characteristics of Survey Locations

	Banskhera Uttar Pradesh State	**Mirzapur A. Uttar Pradesh State**	**Chakarpur Uttaranchal State**	**Narainpur Uttaranchal State**	**Dhaniakote Uttaranchal State**
Agro-ecological zone	Plains	Plains	Terai	Terai	Hills
Dominant livelihood activities of households interviewed	Agriculture	Agriculture, government service, retailing	Agriculture, government service, retailing, artisan-ship	Agriculture, artisan-ship, government service	Agriculture
Cropping system	TR, wheat and sugarcane	TR , wheat and sugarcane	TR, wheat, lentil, barseem, and mustard	TR, wheat and maize	TR, DSR wheat and horticultural crops
Typology of farms	Cross-section of small, medium and large	Over 50% small farms (< 2 ha)	Predominantly small farms (< 2 ha)		All small farms (< 2 ha)

	Banskhera Uttar Pradesh State	**Mirzapur A. Uttar Pradesh State**	**Chakarpur Uttaranchal State**	**Narainpur Uttaranchal State**	**Dhaniakote Uttaranchal State**
	farms. Large farmers cultivating on greatest scale (up to 19.44 ha)				
Water Supply	Large-scale access to canals, tube-wells and pump sets.	No canals; tube-wells only.	Dependent on canal water.	Canals and tube-wells available.	Canals available.
Sources of labour for farming	Family, exchange and hired labour. Most dependent on hired labour.	Family (in all cases just one household member involved), exchange and hired	Family, exchange and hired labour	Family and hired labour	Family labour (NB. few other livelihood options in the area)
Use of technology	Tractor cultivation Highly mechanised system 50% of large farmers own seed/fertiliser drills	Tractor cultivation No ownership of seed/fertiliser drills	Tractor cultivation No ownership of seed/fertiliser drills	Tractor cultivation Some medium and large farmers own seed/fertiliser drills	Bullock cultivation (e.g. use of locally - fabricated *denala* for ploughing) Very limited access to technology such as sprayers No ownership of seed/fertiliser drills
Weeding methods	Herbicides + hand weeding	Herbicides + hand weeding	Herbicides + hand weeding	Herbicides + hand weeding	Hand weeding only
Farmers' sources of Information	Mainly fellow farmers and commercial distributors	Mainly fellow farmers and commercial distributors	Mainly fellow farmers and commercial distributors	Only location citing support from university and extension agencies	

TR = Transplanted rice, DSR = Direct seeded rice

1.2 Social and cultural background of survey villages

Table 2. Caste and background of farming communities studied

Village	Caste(s)	Farmer Background
PLAINS		
Banskhera	Sikh	Many farmers migrated into area
Mirzapur A.	Kurmi	Native to area
TERAI		
Chakarpur	Ahir, Dhobi, Brahmin, Jat, Gujar, Jatav, Kasyap, Barhai	Predominantly natives to area
Narainpur	Jatav, Harijan, Ahir Brahmim Thakur	Many farmers migrated into area (freedom fighters)
HILLS		
Dhaniakote	Lohar, Barhai Thakeer	Native to area

Table 2 reveals the varying social and cultural backgrounds of villagers in different locations. There are also different patterns of social organisation between and within villages. For example, while in Banskhera and Dhaniakote most households live as a nuclear family, in other locations only around half of the households interviewed were nuclear families while around 50% were composed of joint family groups.

The education level of families and the range of livelihood activities that they undertake vary quite markedly across different locations. Amongst the villages in the plains, illiteracy was rare, except amongst landless families; education up to high school level was relatively common. Narainpur was unusual in that a number of adults in families had been educated to degree level and even, in some cases, to post-graduate level. Correspondingly, this location had the highest number of families also raising income from off-farm activities such as business enterprises, government service and artisan-ship. This may relate to the fact that at this location the majority of farmers were headed by freedom fighters from the war of independence that had been given land by the government and had moved to the region as a consequence. While such activities also appear to be available in all other locations, they are pursued to a much lesser degree. In Banskhera and Dhaniakote agriculture was the dominant livelihood activity, but this is likely to be for very different reasons. In Banskhera there is a relatively high proportion of large farms, with households investing significant resources in agricultural activities, whereas in Dhaniakote farming is on a very small scale and there are limited livelihood options in the hills area where the village is located. Furthermore, in terms of education levels, Dhaniakote was a strikingly different case from the locations surveyed in the plains. A relatively high number of household members in this village were illiterate, although in some cases a number of individuals within households had completed high school.

1.3 Access to resources

(i) Land ownership

The socio-economic endowments of farmers are relatively high in the Northwest region of the IGP where the studies took place. However preliminary group discussions with farmers during the planning of the survey work revealed that access to land and other resources is variable, and farm sizes differ markedly. This finding was borne out by the survey data collected. While it might be expected that many farmers in the hill zone cultivate on a small scale (as exemplified by Dhaniakote village), it was also found that in the villages in the Terai and plains zones, small-scale farmers also pre-dominate (see Figure 1). In Banskhera, however, over 50% of families are farming at a medium or large-scale. If the locations selected can be considered a representative cross-section then across the region there are significantly more small farmers in operation than large farmers, even if the leasing of land is taken into account (see below). This reveals that small, marginal farmers as well as medium and large farmers are significant stakeholders in agricultural production in the region.

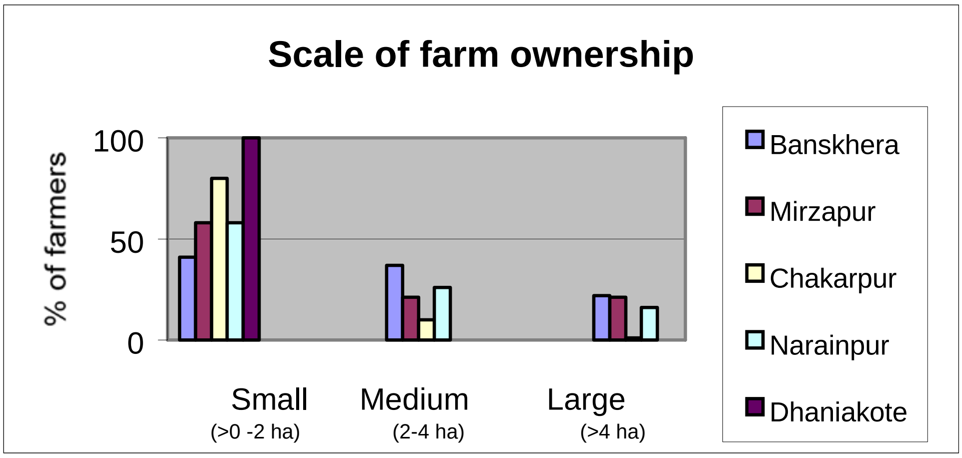


Figure 1. Proportion of small, medium and large farmers in study villages

(ii) Leasing of Land

In some locations farmers are able to lease in land and hence expand the area under cultivation. This practice is to be most common in Banskhera, where it contributes most to expanding the scale of agricultural production, but also takes place in Narainpur, Chakarpur and Dhaniakote. In Mirzapur A., however, none of the sample population leased in land (see Table 3).

Table 3. Total amount of land leased in by farmers

Land leased in (ha)				
	Small	Medium	large	Total
Banskhera	10.11	6.07	12.15	28.33
Chakarpur	0	0	2	2
Mirzapur A.	0	0	0	0
Narainpur	1.61	0	0	1.61
Dhaniakote	1	n/a	N/a	1

No landless families were leasing in land in the villages in the Terai or plains zone. This may reflect the availability of land or the prohibitive costs of renting land and purchasing other inputs for agricultural production. The landless therefore rely on hiring out their labour for agriculture or other activities. In the survey location in the hills, Dhaniakote, however, all landless families were renting land for cultivation purposes.

Total Areas Cultivated

The study areas showed some variation in the average areas of land cultivated at different locations. Farmers interviewed at Banskhera in the plains zone were farming by far the largest total area and had the highest level of medium and large farmers, and largest individual farms (see Table 4). Interestingly, this is a location where a high number of farmers have migrated (see Table 2).

Table 4. Average and total land area operated by location

Average land area operated (ha)	**Banskhera**	**Mirzapur A.**	**Chakarpur**	**Narainpur**	**Dhaniakote**
Small (>0 – < 2)	1.58	1.22	0.89	1.23	1.75
Medium (>2 – 4)	3.26	2.54	2.59	2.42	N/a
Large (>4 ha)	8.57 (range: 4.8 – 19.44)	6.28 (range: 4.02 - 10)	4.95 (range: 4.43 - 6)	5.54 (range: 5.87 – 6.07)	N/a
Total area cultivated (ha)	800	116	186.23	156.3	98

(iii) Access to water

Important differences among farmers were found both between and within locations in terms of access to water. From Table 5 it can be seen that the village of Mirzapur A. is lacking in canal water. The qualitative data collected revealed that farmers throughout this village have problems in accessing water and spend significant resources hiring labour, pumps and tube-wells to irrigate their land. There were also found to be serious problems of water availability in Chakarpur village. In both locations farmers were concerned about the deepening water table. Problems in water supply at both locations are affecting small farmer more severely. At Chakarpur, for example, small farmers described how more powerful people had privileged access to canals. This prevented poorer farmers from controlling the timeliness of irrigation. Furthemore, the analysis of economic data gathered at both Chakarpur and Mirzapur A. and also Narainpur revealed how smaller farmers in these villages were spending proportionately more money on irrigation than larger farmers. While this may partly relate to economies of scale, it also appears likely that small farmers are not only at a disadvantage due to their limited ownership of private resources such as tube wells (hence their need to pay for access to water and labour for water transportation), but also the hierarchical nature of their communities places them at a disadvantage in relation to common resources.

Table 5. Sources of water and area irrigated by location

Source of Irrigation	**Banskhera**	**Mirzapur A.**	**Chakarpur**	**Narainpur**	**Dhaniakote**
Canal	250 ha	0 ha	Data not available	71 ha	98 ha
Private Tubewell	450 ha	111 ha	Data not available	83 ha	0 ha
Pump Set	100 ha	111 ha	Data not available	0 ha	0 ha

(iv) Capital Assets:

All farmers in both the plains and Terai engage in tractor-based cultivation. Even where farmers do not own their own machinery it is usual practice for small, medium and large farmers to hire tractors and other equipment for land preparation purposes. Banskhera and Narainpur are the locations where farming appears to be the most mechanised, with widespread access to tractors, trailers and sprayers. As would be expected, small farmers are generally least likely to own technology but in Banskhera even small farmers were often owners of equipment such as harrows, cultivators, trailers and tube wells.
In contrast, villagers in Dhaniakote in the hill zone are dependent on bullock-driven cultivation and use locally fabricated technologies such as *denala*, used for ploughing. Dhaniakote also has the most limited access to technology. The village as a whole owns two sprayers, eighteen bullock-drawn implements and no other heavy machinery.

Certain technologies are more common at certain locations than others. The proportion of sprayers owned by all farmers at Narainpur, for example, is striking and can be related to the frequency of herbicide use at this location (see below). In another example, seed/fertilizer drills are currently only utilised in the villages of Banskhera and Narainpur where they are owned by a number of medium and large farmers respectively. The availability of technology clearly has implications for the introduction of new technology. For example, seed/fertilizer drills, which are commonly promoted for use in the direct seeding of rice, are currently only utilised on a limited scale. Similarly, the promotion of sprayers to tackle weed problems in direct seeded rice may require a change in approach for some farmers.

1.4 Rice cultivation practices

(i) General Findings

Table 6 summarises the dominant crop production systems at each location. As would be expected in the rice-wheat system, the dominant crops in all locations are rice and wheat, which are cultivated across all agro-ecological zones. However, different supplementary crops are important at various locations. While in the plains sugarcane is cultivated quite widely, in the hill zone farmers have diversified into a wide range of crops and are increasingly dependent on horticultural production for home consumption and income.

While farmers in the plains and Terai transplant rice, all farmers in Dhaniakote, the village in the hill zone which was surveyed, carried out direct seeding of rainfed rice, a method that has traditionally been used in this area due to limitations in water and labour supply. Families who own suitable land in the hill zone also transplant rice.

Table 6. Main crops cultivated at each location

Village	Crops
Banskhera (plains)	Majority of farmers: Transplanted rice, wheat Some farmers: sugarcane
Mirzapur A. (plains)	Majority of farmers: Transplanted rice, wheat Some farmers: sugarcane
Narainpur (Terai)	Majority of farmers: Transplanted rice, wheat Some farmers: sugarcane, maize
Chakarpur (Terai)	Majority of farmers: Transplanted rice, wheat, sugarcane Some farmers: lentil, barseem, mustard
Dhaniakote (hills)	Majority of farmers: Direct seeded rice, wheat, millet, cabbage, potatoes, Some farmers: Transplanted rice, onion, tomato, chiles, soyabean, gahat, peas

Farmers use, on average, between 25 and 50 % of their own land for cultivating rice/wheat and the average income derived from rice relative to income from other crops extends over a similar range (28 - 50%). However, the percentage of total income derived from rice cultivation is, in a number of cases, markedly lower, highlighting relative dependence on other sources of income in locations such as Chakarpur and Dhaniakote (see Figure 2).

In terms of costs, preliminary analysis has revealed that puddling (land preparation), transplanting and weeding in rice production account for the majority of the total resources used in terms of both material and operational costs. This suggests that substantial savings could be made through the introduction of direct seeding of rice in the Terai and plains areas, particularly in terms of labour costs for transplanting. The costs saved through weeding would, however, depend on the weed management practices necessary for direct seeded rice.

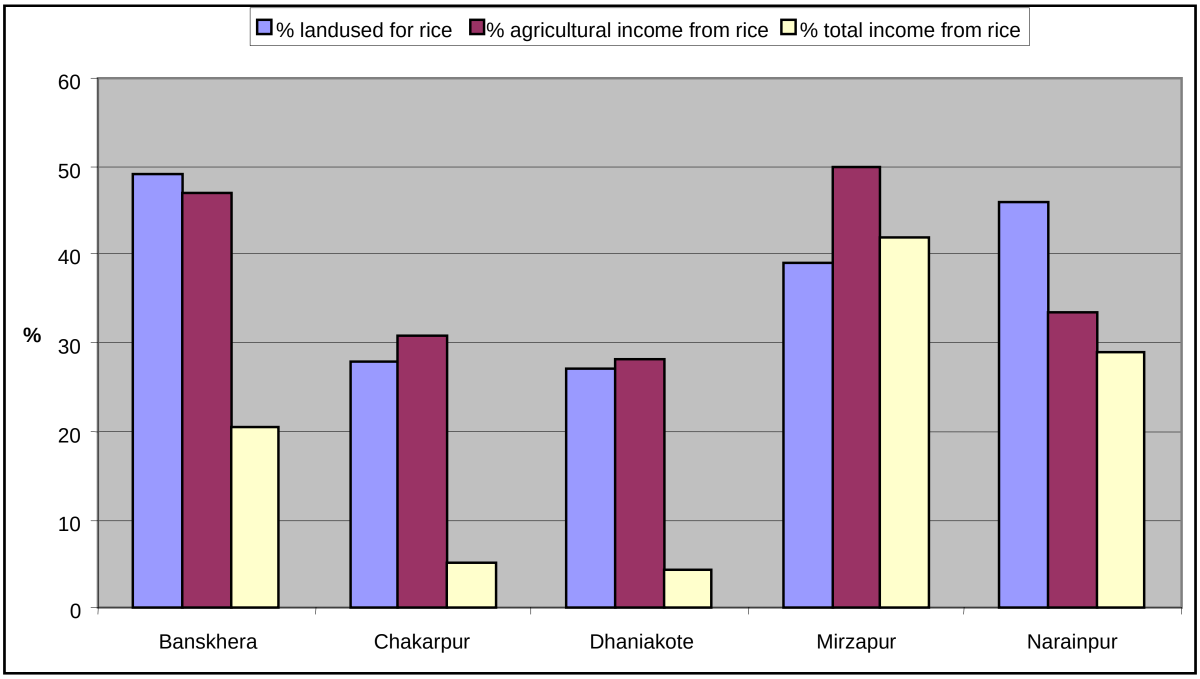


Figure 2. Relative importance of rice in terms of land use and income

(ii) Weeds and weeding practices

All farmers were able to cite the most common weeds in the different locations and indicated those considered most damaging. There was considerable variation in weed species across locations (Table 7). Most farmers associated the frequency of weeds with water supply. In the Terai and plains areas, for example, it was understood that low rainfall/low water levels through irrigation led to an increase in weed growth.

Table 7. Farmers' Perceptions of dominant weed problems in rice

Banskhera *(TR)*	**Mirzapur A.** (TR)	Chakarpur (TR)	Narainpur (TR)	Dhaniakote (TR)	Dhaniakote (DSR + some TR)
Motha/deela *Cyperus sp.*	*Motha* *Cyperus sp.*	Batt *Caesulia axillaris*	*Sanyi* *Echinochloa colona*	*Motha* Cyperus sp.	*Motha* *Cyperus sp.*
Sambak/sanyi *Echinochloa colona*	*Doob* *Cynodon dactylon*	*Jhirwa* *Fimbristylis miliacea*	Jhirwa *Fimbristylis miliacea*	*Jhumaria* *Fimbristylis miliacea*	*Jhumaria* *Fimbristylis miliacea*
Marchia *Eclipta alba*		Motha *Cyperus sp.*	*Doura* *Cyperus sp.*	*Pahar* *Trianthema monogyna*	*Chalmoda* Oxalis latifolia
Batt/Huckwa *Caesulia axillaris*		Kunmar Commelina sp.	Huckwa *Caesulia axillaris*	*Doob* *Cynodon dactylon*	*Doob* *Cynodon dactylon*
Doob *Cynodon dactylon*		Doob *Cynodon dactylon*	Doob *Cynodon dactylon*	*Chalmoda* O*xalis latifolia*	Pahar *Trianthema monogyna*
Jhirwa *Fimbristylis miliacea*		Sanyi *Echinochloa colona*	Kena *Commelina sp.*	*Badela* *Ammania baccifera*	Chapakia *Rumex spp.*
		Narai ?	Katili Saccharum spontanium	*Tipatia* *Coronopus didymus*	
			Mutmoor I*schaemum rugosum*		

TR= Transplanted Rice, DSR = Direct Seeded Rice   __ = most damaging

All farmers use some method of weed control in rice. In the transplanted rice system widespread in the Terai and plains and direct seeded rice system, hand weeding is a universal method for controlling weeds, though this weed management method is carried out with varying frequency across locations (Table 8).

Different labour patterns for weeding were identified. In Banskhera, for example, cultural norms meant that only hired labour was used for manual weeding, whereas in the other villages in the plains and Terai a mix of both family and hired labour were utilised. The timing of weeding was very variable between households, depending on the stage of the crop in the field and labour availability. In the hill zone, where farmers have more limited resources, household labour alone was used for hand weeding. No correlation was found between farm size, labour availability and frequency of manual weeding. As can be seen in Table 7, only farmers in Narainpur considered labour availability to be a significant problem for manual weeding. They described how they face particular problems in finding appropriate labour at the right time. In other locations the inconvenience and discomfort of weeding in hot conditions was considered more of a problem.

Table 8. Manual weeding practices and constraints by location

Location	Most common frequency per year	Timing of weeding*	Weeds controlled by manual weeding	Problems cited
Banskhera	2 times	30-60 DAS	Motha (C*yperus sp.*) Sambak (*Echinochloa colona*)	Exposure to heat
Chakarpur	1 or 2 times	30-60 DAS	Jhirwa *(Fimbristylis miliacea)* Batt *(Caesulia axillaris)* Motha (*Cyperus spp.*)	Exposure to heat
Mirzapur A.	2 times	20-40, 40-60 DAS	None	None
Narainpur	2 or 3 times	20-30-60, 30-60, 20-60-90 DAS	Batt (*Caesulia axillaris)* Sambak (*Echinochloa colona*)	Hired labour unskilled Hired labour not available at right time Hired labour costly
Dhaniakote	2 times**	Transplanted rice: 30-40, 50-70 DAS Direct seeded rice: 30-50, 55-70 DAS	Transplanted rice; Marchia (*Eclipta alba*) Motha (*Cyperus spp.*) Direct seeded rice: Chalmoda (*Oxalis latifolia*) Doob (*Cynodon dactylon*) Marchia (*Eclipta alba*)	Exposure to heat and rain Damage inflicted on crops

*NB. Various ranges were cited. The most commonly reported ranges are detailed here.
**For both transplanted and direct seeded rice

In addition to manual weeding, most farmers interviewed in the Terai and plains and all large farmers in these agro-ecological zones also herbicides used to manage weeds in rice. The only exceptions were two small farmers in Narainpur. Both were very small households with limited access to resources, and one was a female-headed household. This suggests that poorer households may have difficulty in accessing herbicides to control weeds in rice. This is further reinforced by the fact that none of the households interviewed in the hill zone applied herbicides for weed control in either direct seeded or transplanted rice.

The different chemical treatments used for the control of particular weeds are detailed in Table 9. Farmers in Narainpur are applying herbicides more frequently and using a wider range of treatments than at other locations. It is also notable that economic analysis has shown that small farmers at this location are spending the most of all farmers on herbicides (see report by Dr R.S.L Srivastava of GBPAUT, 2002). This reveals a high level of awareness of weed damage and weed control and a willingness to invest significant resources for weed management which may be related to the fact that farmers in this village appear to have more exposure to staff from local extension agencies and GBPAUT for advice on weed control (see below).

Table 9. Herbicides use by location

Village	Herbicide	No. of treatments	Weeds controlled
Banshkera	Machete	1	Sambak, Deela
Mirzapur A.	Butachlor	1	Motha, Doob
Chakarpur	Butachlor, Machete	1	Batt,Jhirwa, Motha
Narainpur	Machete, Gamaxone,Arigin Topstar 800,Rifit, Roundup	3-4*	Sanyi, Jhirrwa, Doura
Dhaniakote	n/a	n/a	n/a

* Depending on which herbicide used

Despite their dependence on herbicide technologies, many farmers do not consider herbicides to be fully reliable, with some stating that herbicides can be as little as 50% effective. Farmers are aware of increasing weed resistance to certain herbicides, and over recent years have observed changes in the efficacy of the treatments that are traditionally used for various crops. This problem has led farmers in a number of locations to change herbicide treatments over recent years and experiment with new products.

Another problem raised by farmers in relation to herbicide application was the potential damage that such chemical applications may cause to human health. While this perception clearly has not stopped farmers from using herbicides to date, any new intervention that involves sustained promotion of herbicides may need to tackle this issue.

(iv). Use of labour in rice cultivation

Most farmers depend on multiple sources of labour. At all locations, a large proportion of family labour is devoted to agricultural activities and in most cases this labour is not sufficient for the range and scale of tasks in hand so additional labour is sought out, by exchanging labour with other families or, where affordable, hiring labour. The range and scale of labour sources used will, of course vary depending on the tasks being undertaken. One surprise finding was the importance of social capital in the form of exchange labour to many households. Exchange labour was commonly used for agricultural production, though not in Narainpur and Dhaniakote. Relatively little is known about exchange labour in the context of rice production, and this may be worthy of further research. Presumably it is under the same strain at certain times of year as other forms of labour as farmers have pressing tasks in hand, such as transplanting.

The hiring of temporary contract labour is the most common means of recruiting paid labour. In the plain and Terai areas, many farming households were found to be highly dependent on hired labour for land preparation, irrigation, spraying of herbicides and pesticides, hoeing, weeding, transplanting and harvesting. Farmers appear to be particularly dependent on hired labour for transplanting which accounts for a high proportion of labour for this task.

The dynamics behind the recruitment of casual workers differs from location to location. At Banshkera, the migrant labourers employed are from eastern Uttar Pradesh, Bihar and immigrants from Bangladesh. In Chakarpur and Narainpur most labour is drawn from the local area or other villages in the same district. In only a few cases was labour brought in from other neighbouring districts or other states. In Mirzapar A. casual labourers are recruited from nearby villages.

Many of the farming families interviewed face labour constraints that can have an impact on agricultural production. Shortages of temporary labour are experienced by the overwhelming majority of farmers, particularly during the season for the transplanting of rice in July and August and also, in many cases, for weeding and harvesting. In Chakarpur a number of farmers also described how they have difficulty in finding the funds to pay for labourers. This was a particular problem amongst large farmers, presumably because of the scale at which labour must be hired. Farmers in Mizapur A. also cited the rates charged by labourers as prohibitive. Dhaniakote was the only location where there were no problems in the availability of labour for rice production.

These findings suggest that substantial savings could be made through the introduction of direct seeding of rice in the Terai and plains areas, particularly in terms of labour costs for transplanting. The costs saved through weeding would, however depend on the choice of weed management practices for direct seeded rice and their associated costs. In the hills zone, the use of casual labour is less common. Also, the fact that farmers in at least one location emphasised the need for skilled labour for weeding (see Table 8) highlights the importance of distinguishing between different types of labour for different tasks - agricultural labour is not a replicable commodity. The introduction of a new technology that makes labour savings in one area may not necessarily signify an overall saving. Labourers for some tasks may not be required to have specific technical knowledge, whereas for certain activities such as weed control and management, particularly on the introduction of new herbicide regimes, a higher level of knowledge and skill may be required, which has financial implications.

(iv). Constraints

Constraints are shown in Table 10 below.

Table 10. Agricultural Constraints in survey villages

Problem	**Banskhera**	**Mirzapur A.**	**Chakarpur**	**Narainpur**	**Dhaniakote**
Water Supply	No major problem	Limited canal water – significant resources spent hiring labour, pumps and tube-wells for irrigation	Smaller farmers have restricted access to canal water	-	-
Labour	Majority of farmers facing problems in availability, esp. for transplanting (July and August), weeding and harvesting	Majority of farmers facing problems in availability esp. for transplanting (July and August), weeding and harvesting High cost of labour	Problems in availability, esp. for transplanting (July and August), weeding and harvesting High cost of labour	Medium and large farmers face problems in labour availability, esp. for transplanting (July and August), weeding and harvesting Problems in quality of labour available	-
Use of herbicides	Efficacy of herbicides declining	-	Efficacy of herbicides declining	-	-

1.5 Farmers' access to information

In all locations, the majority of farmers relied on other farmers for information and advice about agricultural methods and new technologies. The radio, TV, newspapers and dealers selling seeds, herbicides etc. were also considered important sources by some (Figure 3).

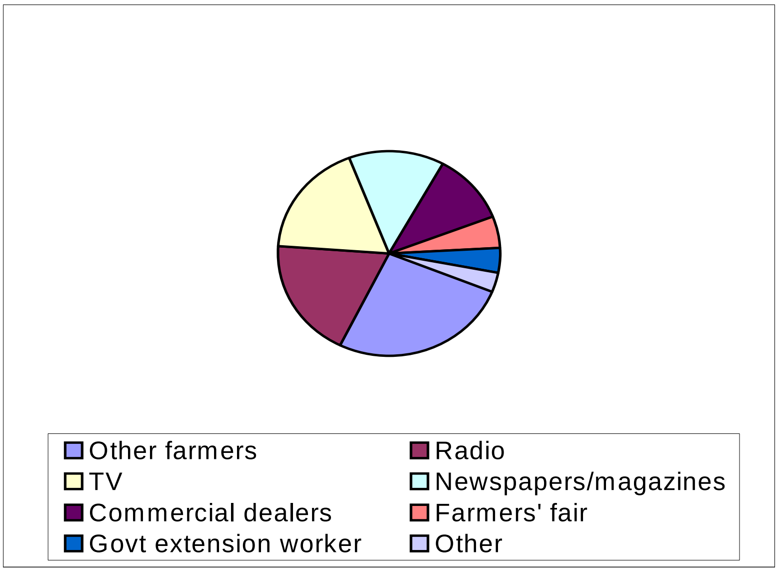


Figure 3. Most common sources of information on agriculture sought out by farmers

If sources of information are analysed by location then important differences can be seen. For example, when farmers were asked where they obtain information on weed management, (specifically herbicide use) commercial dealers and distributors emerged overall as the dominant source of information in most locations, followed by fellow farmers. At Banskhera, however, reliance on commercial operators predominated and communication with fellow farmers was rarely reported. Narainpur was a different case again and farmers in this village cited commercial dealer, fellow farmers, university staff and extension agents as key sources of information (Table 11). Dhaniakote was unique in that no farmers reported receiving information on herbicide use as chemical inputs are not used for agricultural production at this location.

These findings reveal the range of communication sources which are normally accessed to farmers at different locations and which are likely to influence chemical weed management practices. Any initiative aimed at improving current weed management practices may need to pursue similar communication channels.

Table 11. Sources of information on herbicide use

	Dhaniakote	Chakarpur	Banskhera	Narainpur	Mirzapur
Herbicide manufacturer	0	0	0	0	0
Dealers	0	22	1	4	19
Distributors	0	0	23	22	1
University	0	0	0	2	0
Extension agencies	0	0	0	1	0
Fellow farmers	0	18	2	14	15
Other (TV, radio etc)	0	18	0	3	0

*Note: no discernible patterns for farm sizes, so totals given

1.6 Perceptions of direct seeding for rice production

Farmers in different locations had a range of experience in direct seeding rice. In all but one of the sample villages in the plains and Terai a number of farmers had used direct seeding in the past. In every case, however, farmers had subsequently reverted to transplanting due to problems with weed management and poor yields. Partly based on these experiences, the views of farmers in these agro-ecological zones towards direct seeded rice compared with transplanted rice were as shown in Table 12.

Table 12 Views of farmers on direct seeding – plains and Terai villages

	Cost of cultivation	Weed infestation	Irrigation Requirements	Resistance to pests and diseases	Yield
Higher	27%	96%	61%	60%	6%
Lower	73%	4%	39%	40%	94%

It is significant that the farmers in the plains who had employed direct seeding in the past stated that low yields, the crop's susceptibility to diseases and insects and increasing needs for weeding, particularly hand weeding, were the main reasons for their abandoning this practice. These constraints should probably be understood in relation to the historical context in which many farmers were experimenting with direct seeding when they first settled in the region and would have had limited technology and support.

In the hill village of Dhaniakote, where farmers continue to cultivate transplanted rice and direct seeded rice in parallel, perceptions of direct seeding were slightly different, and may relate to the scale of cultivation and different agricultural system in this zone (Table 13). Farmers in the hills who are already direct seeding were keen for new methods to ensure higher production of their crop in a short time. One farmer suggested the introduction of hybrid seeds.

Table 13 Views of farmers on direct seeding – hills

	Cost of cultivation	Weed infestation	Irrigation Requirements	Resistance To pests and diseases	Yield
Higher	6%	76%	53%	24%	41%
Lower	94%	24%	47%	76%	59%

In the majority of cases in all locations, farmers thought that direct seeded rice was easier to cultivate than transplanted rice but weed problems and consequent low yields were a deterrent to continuing this practice. Farmers in the plains and Terai described how they would only be interested in returning to direct seeding in rice if methods could be found of controlling weeds and sustaining higher yields.

2. *Output 2: Weed shifts in response to the changes in crop establishment methods associated with direct seeding and herbicide use described*

In comparison to transplanted rice, early protection of yield from competition from weeds is essential in direct seeded (wet or dry) because of the absence of standing water. Successful adoption of direct seeding is contingent upon weed control early in the life of the crop and the target weed flora is a consequence of the method of crop establishment (Hill et al., 2001). Moreover in direct seeded crops both transient weed species shifts during the life of the crop may occur with the occurrence of late season species and, in the longer term, changes in the weed flora with the exclusion of obligate aquatic weeds. In both instances, competitive grass weeds have been recorded as problematic.

Four activities were followed to quantify the response of the weed flora to direct seeding: 1) detailed analysis of available existing data sets, 2) conduct of a long term, on-station field experiment comparing yields under different methods of crop establishment and weed control, 3) comparative on-farm studies, 4) comparative studies of herbicide efficacy for direct seeded rice.

2.1 Changes in weed community structure in rice-wheat cropping systems in the Indo-Gangetic plains

Changes in weed communities under traditional crop rotations and cropping practices used in rice-wheat production in the Indo-Gangetic plains were analysed from data sets arising from two long-term on-station trials, conducted over the past 10 years. In the Terai in western and central Uttar Pradesh, sugar cane and its ratoon crops are traditionally seen as an integral component of rotations, especially in light textured soils. The trials included a comparison of the effect of sugar cane in a rice-wheat rotation.

Seasonal variation (1.3 – 6.6 t/ha) in rice yields was greater than in wheat (2-5.75 t/ha) and rice yield losses due to weeds were greater than in wheat (70% in rice; 28% wheat). Weed communities at 60 days after planting were distinctive of each crop. Major weeds of rice were *Echinochloa* spp., *Cyperus iria*, *C. difformis*, *Ischaemum rugosum*, *Commelina* spp., *Fimbristylis miliacea* and *Caesulia axillaris*. *Phalaris minor* was the major weed of wheat, accompanied by *Chenopodium album*, *Avena fatua*, *A. ludoviciana*, *Melilotus alba*, *M. indica*, *Anagalis arvensis*, *Medicago denticulata* and *Lathyrus aphaca*. Common weeds of sugar cane were *Brachiaria ramosa*, *Cynodon dactylon*, *Cyperus rotundus*, *Echinochloa colona*, *Parthenium hysterophorus* and *Sorghum halepense* The introduction of sugar cane in rotation between rice and wheat posed the threat of *Cyperus rotundus* in the following rice crop, if direct seeded, but was effective in suppressing of *Phalaris minor* in wheat. A survey of farm methods of weed management (Kauraw & Singh, 1999) indicated that principal weed control methods were manual hoeing in sugar cane (all farmers), and butachlor and anilofos (broadcast with urea after transplanting) being used in rice (20% of farmers using the herbicide alone, and 60%, herbicide with one manual weeding later). Various formulations of isoproturon, 2,4-D and pendimethalin were commonly used as the sole method of weed control in wheat (70% farmers). Trials showed that isoproturon reduced weed densities in wheat in comparison to two manual weedings whereas equivalent weed control was achieved by either a single application of butachlor or two manual weedings in transplanted rice.

2.2 Comparisons of five different methods of crop establishment combined with weed management

In Kharif 2000, an on-station field experiment was initiated on land previously in commercial rice-wheat. The aims were to :

- Compare rice yields under different crop establishment methods involving transplanting (TPR), wet direct seeding (WS) and dry direct seeding (DS) in a rice-wheat rotation.
- Measure the yield gap in relation to crop establishment methods and weed management practices.
- Investigate over a minimum of three rice seasons, the potential weed species shifts that may occur in the absence of effective weed control, in relation to crop establishment.
- Test the hypothesis that zero tillage in rice improves soil structure resulting in yield gains in wheat and reduces the need for post-emergence weed control interventions in rice.
- Test the hypothesis that a stale seed bed in land preparation is as effective as zero-tillage and glyphosate in weed management in dry seeded rice.

In the rice crop, treatments compared rice establishment methods as main plot treatments (5) with subplots of weeding intensity treatment (3) in a split plot design with four (randomised block) replications.

Main plots (rice establishment) were :

1.) TP conventional transplanting after puddling.
2.) WS wet seeding (broadcast) after puddling.
3.) DS dry seeding (drill) after conventional tillage.
4.) DSF dry seeding (drill) after conventional tillage but with the last tillage following a flush irrigation.
5.) ZT dry seeding (drill) zero-tillage after flush irrigation and glyphosate.

Sub plots were :

a) unweeded
b) one hand weeding 30 days after planting
c) weed free (early post-emergence and 2 hand weedings) : TP - Butachlor plus two hand weedings; WS - Anilofos plus two hand weedings. DS, DSF, ZT - pendimethalin plus two hand weedings.

In the wheat crop, the split plot design is incorporated within a strip plot design, with two treatments for wheat establishment, conventional tillage and zero tillage. In wheat, full weed management is applied to all plots with an application of isoproturon followed by one hand weeding.

Summary results

Rice yield 2000, 2000 ,2002

In 2000 the establishment of the experiment was delayed by late monsoon rains until July and yields were low (Fig 4). In 2001, substantially higher yields were obtained with planting in June. Equivalent yields were obtained from weed-free plots of transplanted and wet-seeded rice. Yields from dry-seeded rice were lower than transplanted rice and similar yields were obtained from zero-tilled and conventionally tilled plots. A single manual weeding was insufficient to prohibit yield loss and highest yields were always achieved in weed free plots utilising a post-emergence herbicide and hand weeding.

A similar pattern of yields was observed in 2002, although they were lower than in 2001 in intensively weeded plots and under direct seeding, zero-tilled plots yielded less than those conventionally tilled. A single hand weeding was again inadequate in protecting yields but higher yields were observed than in the previous season.

Wheat yield 2000, 2001

Yields of wheat were not related to rice cropping methods, and yields were similar under zero tillage and conventional tillage in either 2000/01 or 2001/02, averaging 4 t/ha (Fig. 5).

Weed community responses in rice 2000

Although unseasonable conditions delayed crop establishment in 2000, establishment methods resulted in major differences in the competitive weed flora that established in the initial 28 days after planting and reflects findings elsewhere in the region. *Echinochloa colona, Ischaemum rugosum, Eragrostis japonica, Cyperus iria, C. difformis, C. rotundus, Fimbristylis miliacea, Caesulia axillaris* and *Commelina diffusa* were the most common species.

Figures 6 – 8 illustrate the responses for selected species to crop establishment and subsequent dynamics in relation to weed control. Lowest weed infestations always occurred in transplanted rice (TP), the highest occurring after wet seeding (top right plot, Figs 6-8). However relative recruitment varied amongst species. *E. colona* was the least sensitive to method of establishment, whereas dry seeding promoted *Cyperus* species and wet seeding, *I. rugosum*. The impact of herbicide coupled with dry seeding and flush irrigation (DSF) was effective in reducing weed densities to those observed under transplanting with herbicide with the exception of F. miliacea. Changes over by 56 DAP generally resulted in a reduction of numbers (and corresponding increase in biomass, data not shown) although under DSF further recruitment of *I. rugosum* occurred and *Cyperus* species increased in TPR. Weed populations generally declined subsequently to 84 DAP.

Weed community responses in rice 2001

The weed community (28 DAT/DAS) was similar in the 2001 season (Figure 9) although *C. rotundus* was largely absent and *C. diffusa* was rare. Under transplanting, recruitment of all weed species was substantially delayed due to earlier crop establishment but under direct seeding all major weed species were abundant. The use of a stale seed bed for drill seeding through flush irrigation and tillage (DSF) reduced most species except *C. difformis* and *C. diffusa. I. rugosum* and *C. difformis* were abundant under zero-tillage.

Weed community responses over seasons

Figures 10 – 13 show the changes in the weed flora over seasons in transplanted, wet seeded, direct seeded and zero tilled plots in unweeded plots over the three seasons. Data are the dry biomass by species per m2 present at 56 DAS/DAT and species are ranked in terms of abundance on a logarithmic (x+1) scale. Not all species were identifiable due to die-back. *Cyperus* spp refers to *C. rotundus* and other *Cyperaceae* and 'others' to unidentified dicotyledenous species.

These data illustrate the potential changes that may occur in the weed flora as a result of changes in crop establishment method, in the absence of weed management. The initial (2000) composition of the weed seed bank of the experimental site may be expected to be uniform due to past routine cropping of transplanted rice under research farm production (although not necessarily representative of surrounding farms). Diversification of the weed flora had occurred in all systems but the structure of the weed community at 56 DAS/DAT (~ panicle initiation in rice) varied in relation to establishment method. The grass weeds *I. rugosum* and *L. chinensis* dominated the flora with *F. miliacea* and *Commelina diffusa* being abundant under transplanting. In wet seeded rice, *Paspalum* spp, *Cyperus* spp and *Eragrostis japonica* were most abundant whereas dry direct seeding promoted *I. rugosum* and *L. chinensis* to high abundance together with *E. japonica* and substantially relegated *Paspalum* spp and *Cyperus* spp. Under zero tillage, *Commelina diffusa* was the dominant species, reducing the abundance of all others.

Statistical analysis (Philippi *et al.*, 1998; not shown) indicates that whilst there were significant differences in community structure, systematic directional changes in time of individual species abundance were rarely significant. Three cropping seasons represents a short time span over which directional changes in weed species abundance may be discerned and the trial will be continued for a further two seasons to test this hypothesis (Project R8233).

On the basis of results reported elsewhere, *I. rugosum* and *L. chinensis* represent a significant threat to yield in both transplanted and wet seeded rice. These results support this conclusion for transplanted rice and indicate a similar threat to direct seeded rice. In contrast in zero-tilled plots, *L. chinensis* was rare.

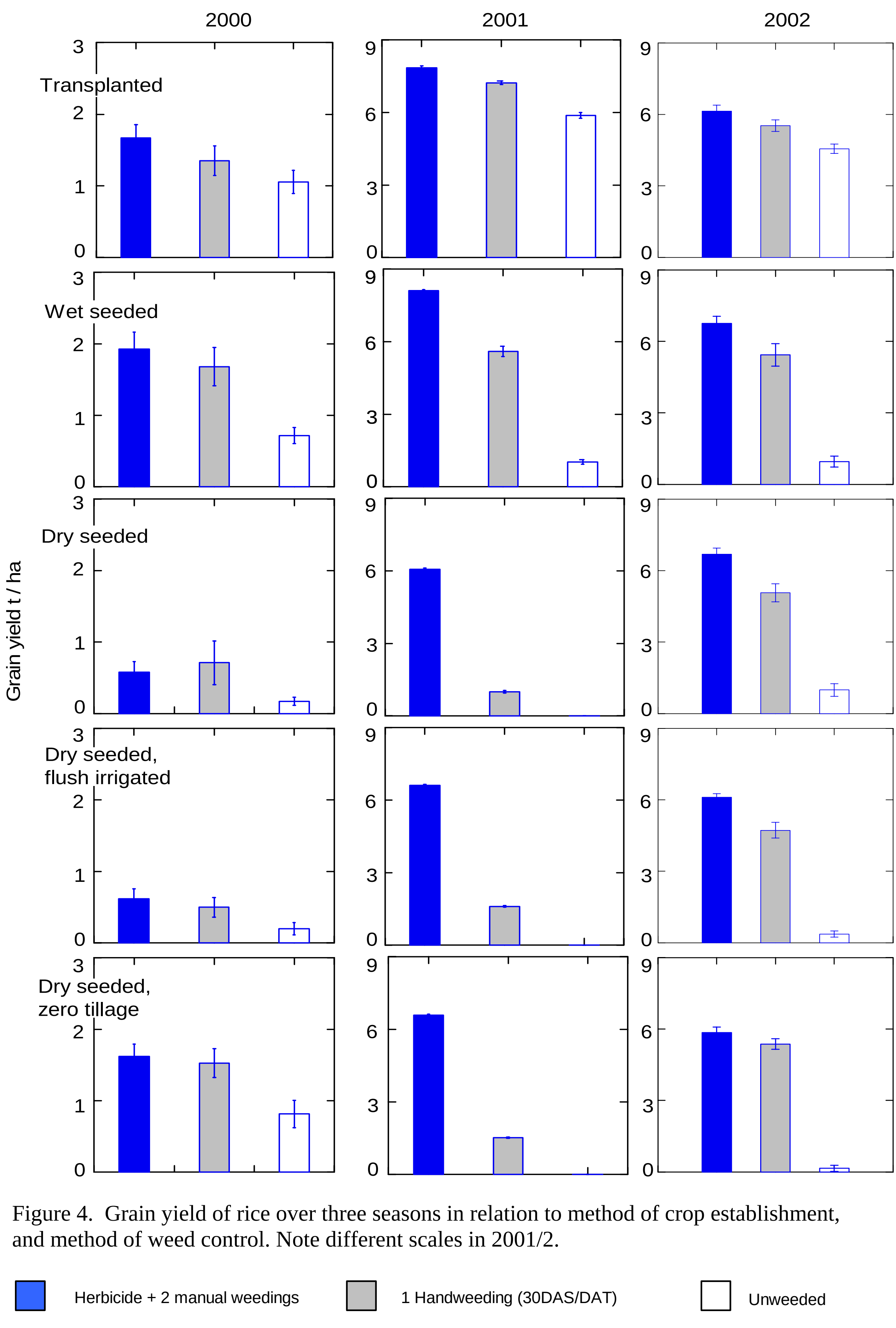


Figure 4. Grain yield of rice over three seasons in relation to method of crop establishment, and method of weed control. Note different scales in 2001/2.

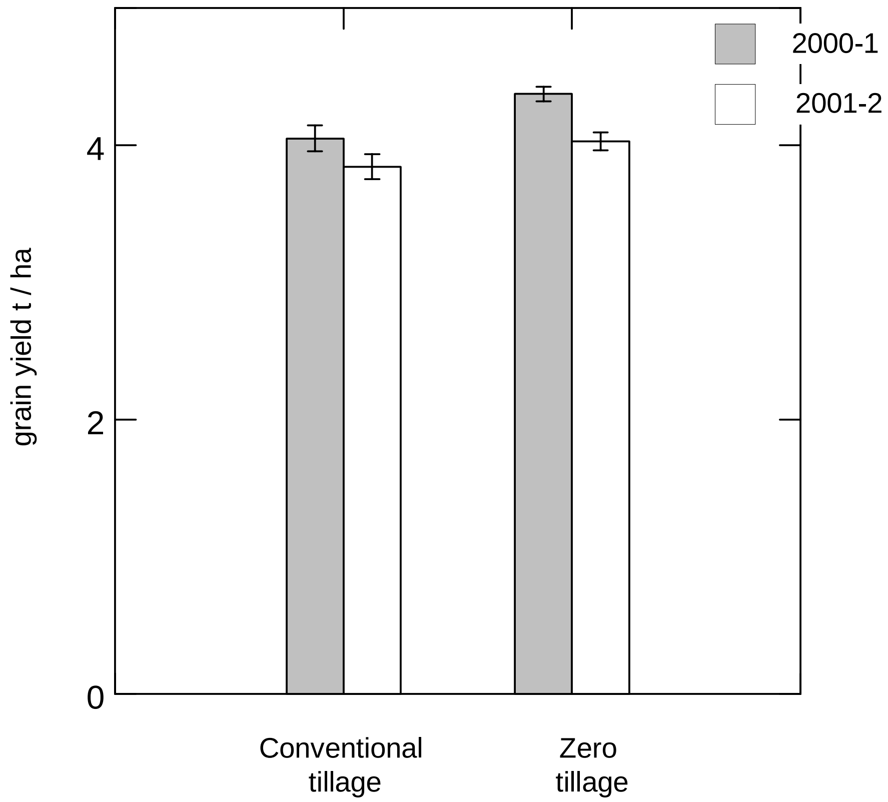
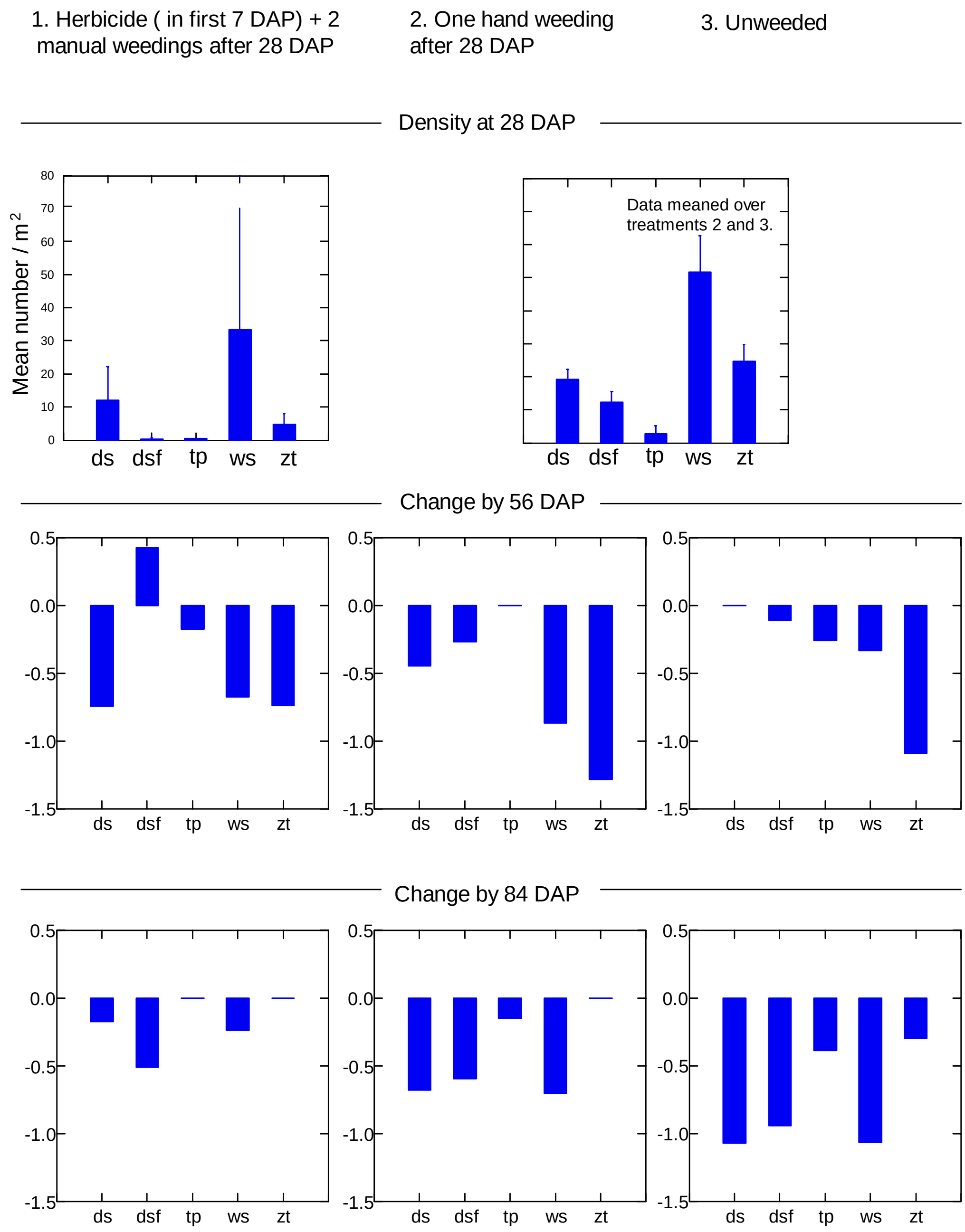
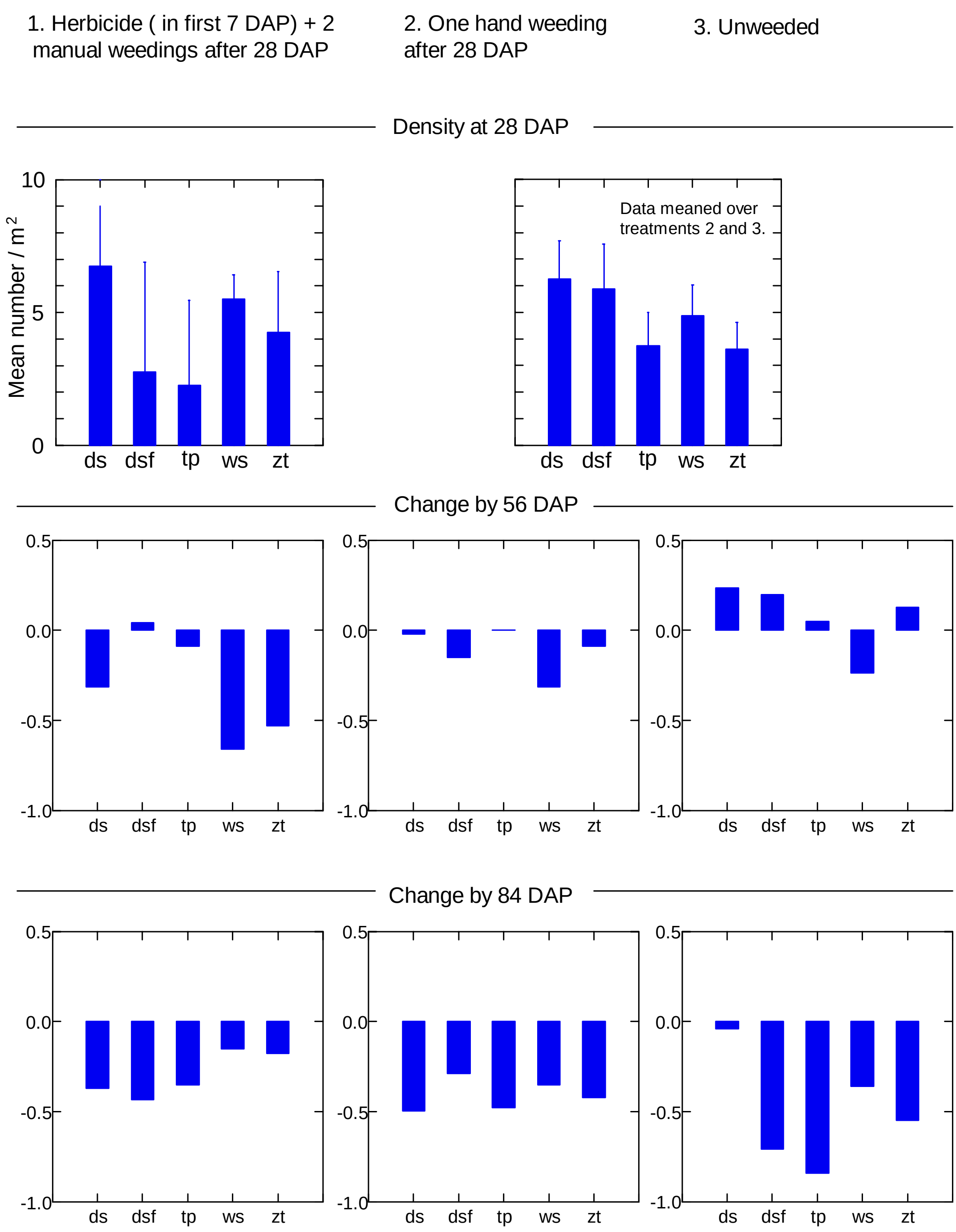


Figure 5. Wheat yields over seasons in relation to tillage practice.



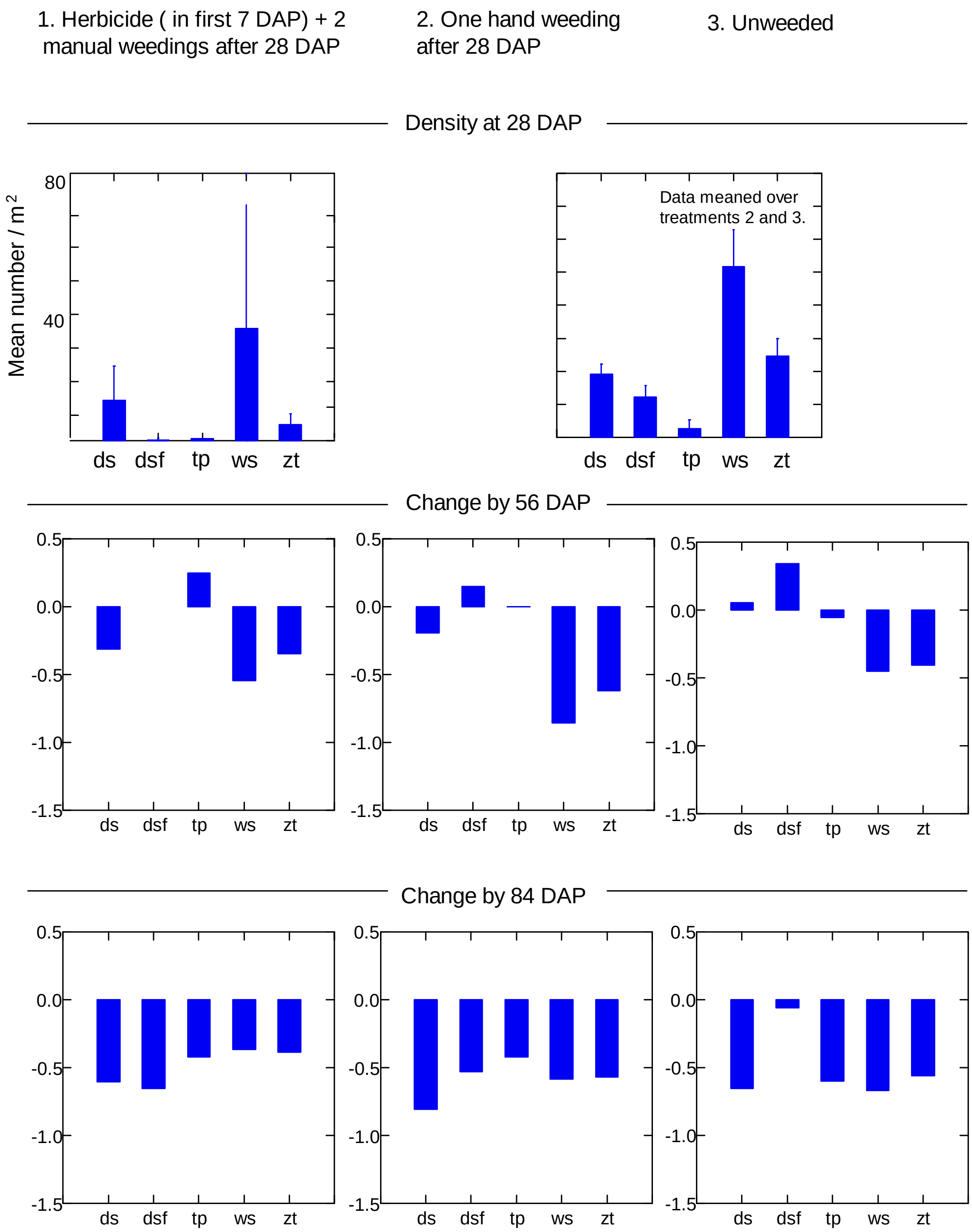
ds - dry seeding after conventional tillage
dsf - dry seeding after conventional tillage with flush irrigation before last tillage
tp - transplanting after puddling
ws - wet seeding after puddling
zt - dry seeding with zero tillage (flush irrigation and glyphosate)

Figure 6. In-season dynamics of *Ischaemum rugosum* in response to crop establishment method and weed control, 2000. For each weed control treatment: the upper plots show the weed density 28 days after planting (DAP); the lower plots show the change in abundance by 56 and 84 days respectively. Rates of change are calculated as the logarithm of the ratio of the number of plants at 28 DAP to those at 56 DAP and 56 DAP to 84 DAP. Left-hand column of plots shows responses under intensive weeding, mid column responses under a single manual weeding and right most, unweeded.



ds - dry seeding after conventional tillage
dsf - dry seeding after conventional tillage with flush irrigation before last tillage
tp - transplanting after puddling
ws - wet seeding after puddling
zt - dry seeding with zero tillage (flush irrigation and glyphosate)

Figure 7. In-season dynamics of *Echinochloa colona* in response to crop establishment method and weed control. See Fig. 5 for explanation.



ds - dry seeding after conventional tillage
dsf - dry seeding after conventional tillage with flush irrigation before last tillage
tp - transplanting after puddling
ws - wet seeding after puddling
zt - dry seeding with zero tillage (flush irrigation and glyphosate)

Figure 8. In-season dynamics of *Fimbristylis miliacea* in response to crop establishment method and weed control. See Fig. 5 for explanation.

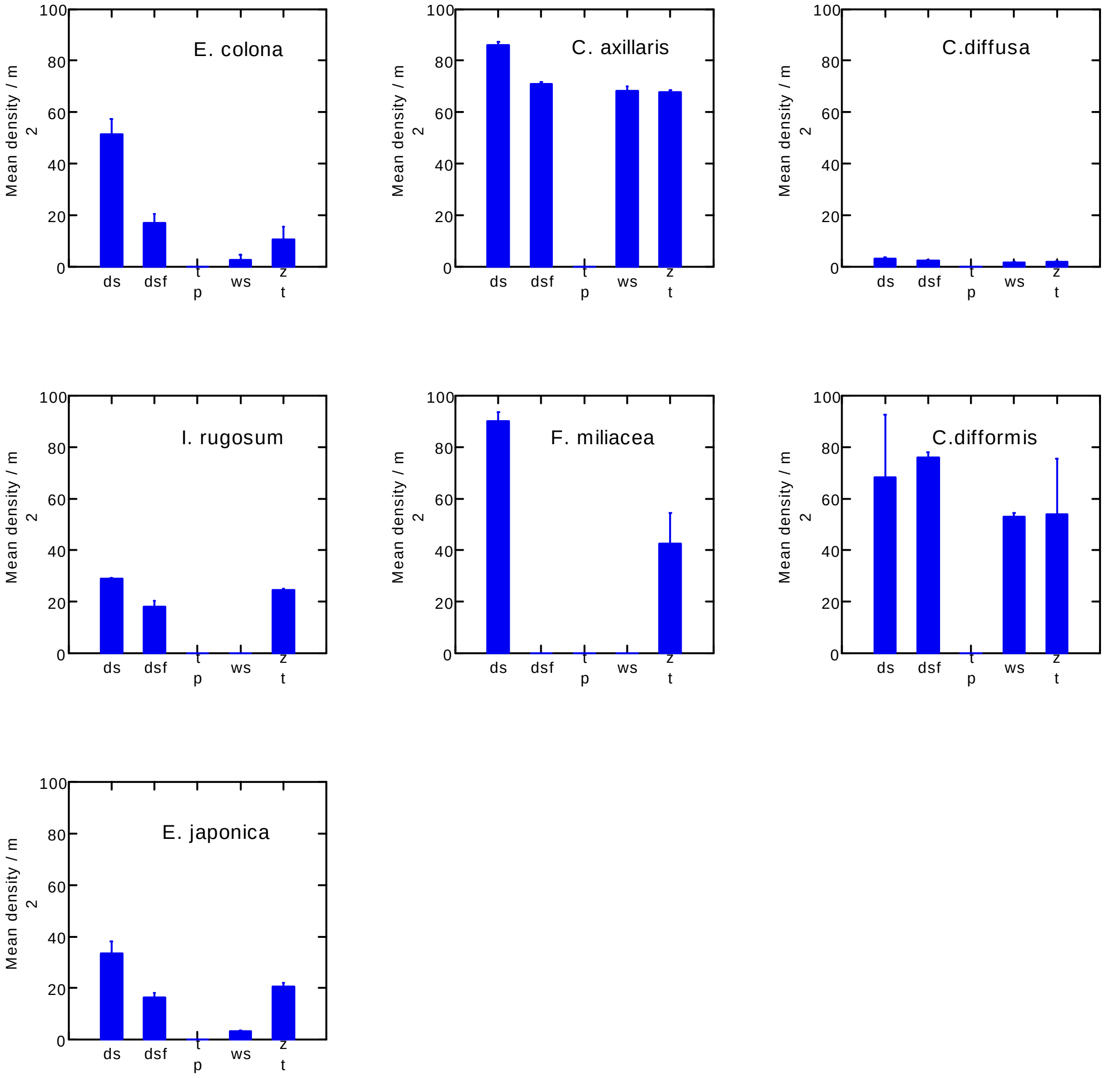


Figure 9. The recruitment of weeds by 28DAT/DAS in 2001 in the absence of weed control.

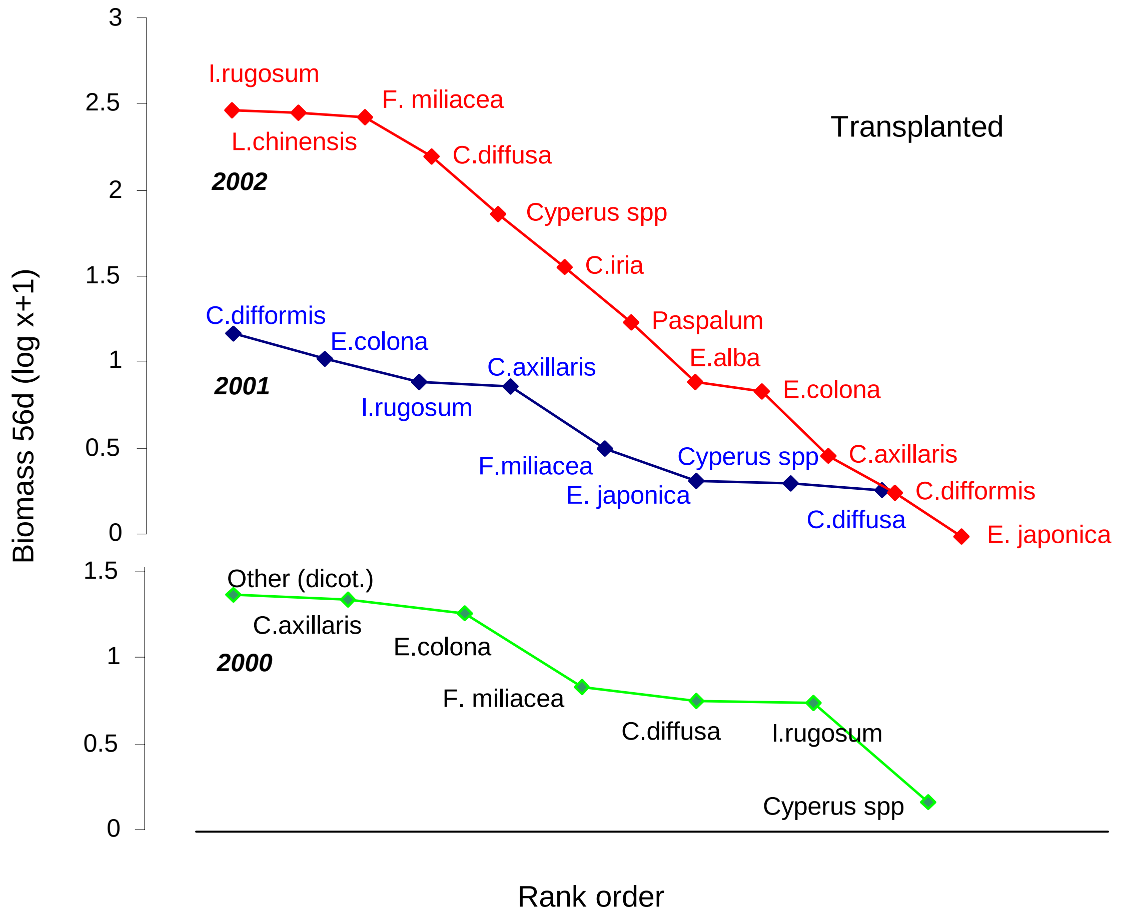


Figure 10. Log rank changes in weed abundance over seasons in transplanted rice. Data are the dry biomass by species per m^2 present at 56 DAT and species are ranked in terms of abundance on a logarithmic (x+1) scale. Not all species were identifiable due to die-back. *Cyperus* spp refers to *C. rotundus* and other *Cyperaceae* and 'others' to unidentified dicotyledenous species.

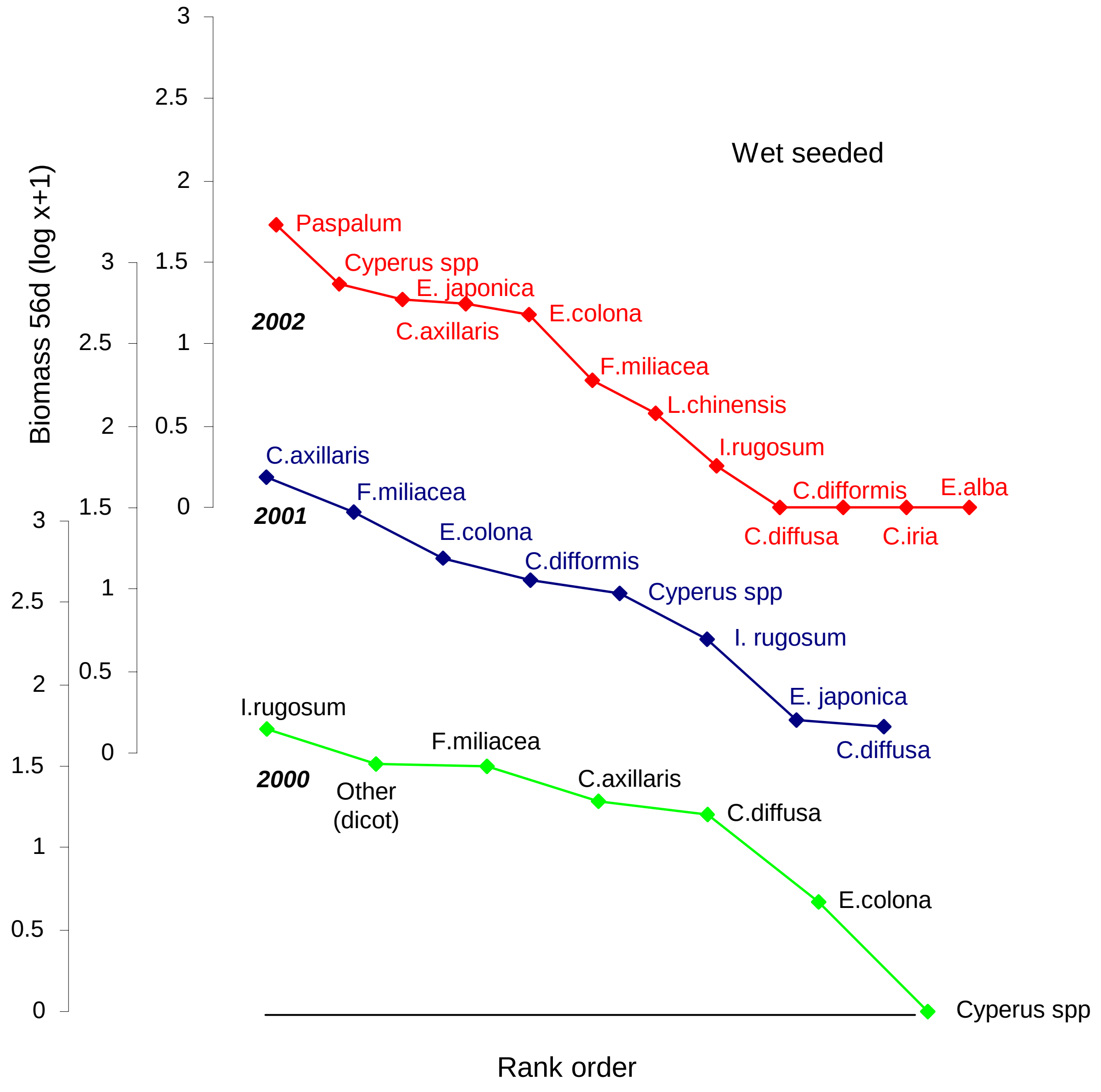


Figure 11. Log rank changes in weed abundance over seasons in wet seeded rice. Data are the dry biomass by species per m^2 present at 56 DAS and species are ranked in terms of abundance on a logarithmic (x+1) scale. Not all species were identifiable due to die-back. *Cyperus* spp refers to *C. rotundus* and other *Cyperaceae* and 'others' to unidentified dicotyledenous species.

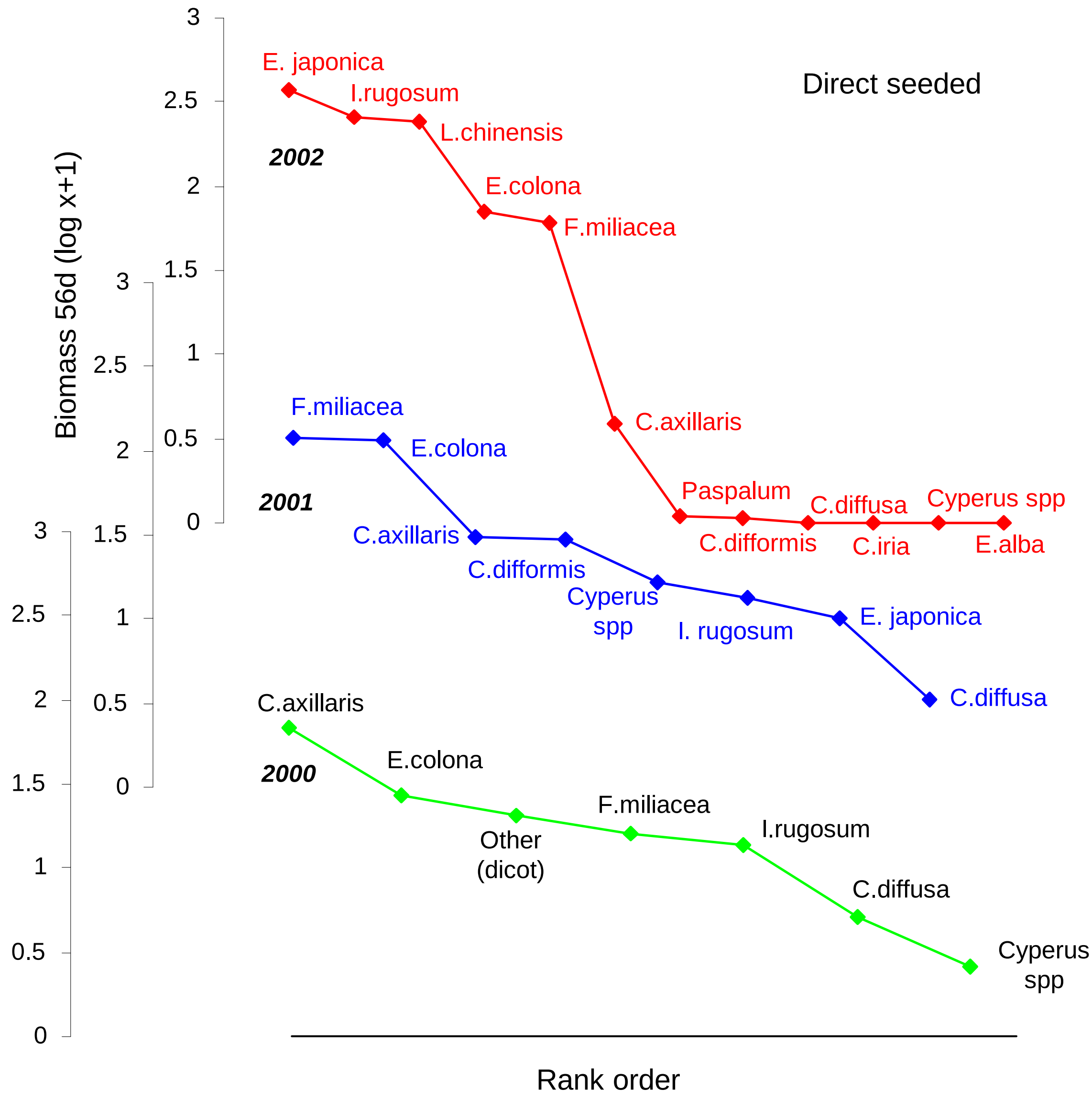


Figure 12. Log rank changes in weed abundance over seasons in direct seeded rice. See Fig 10 for explanation.

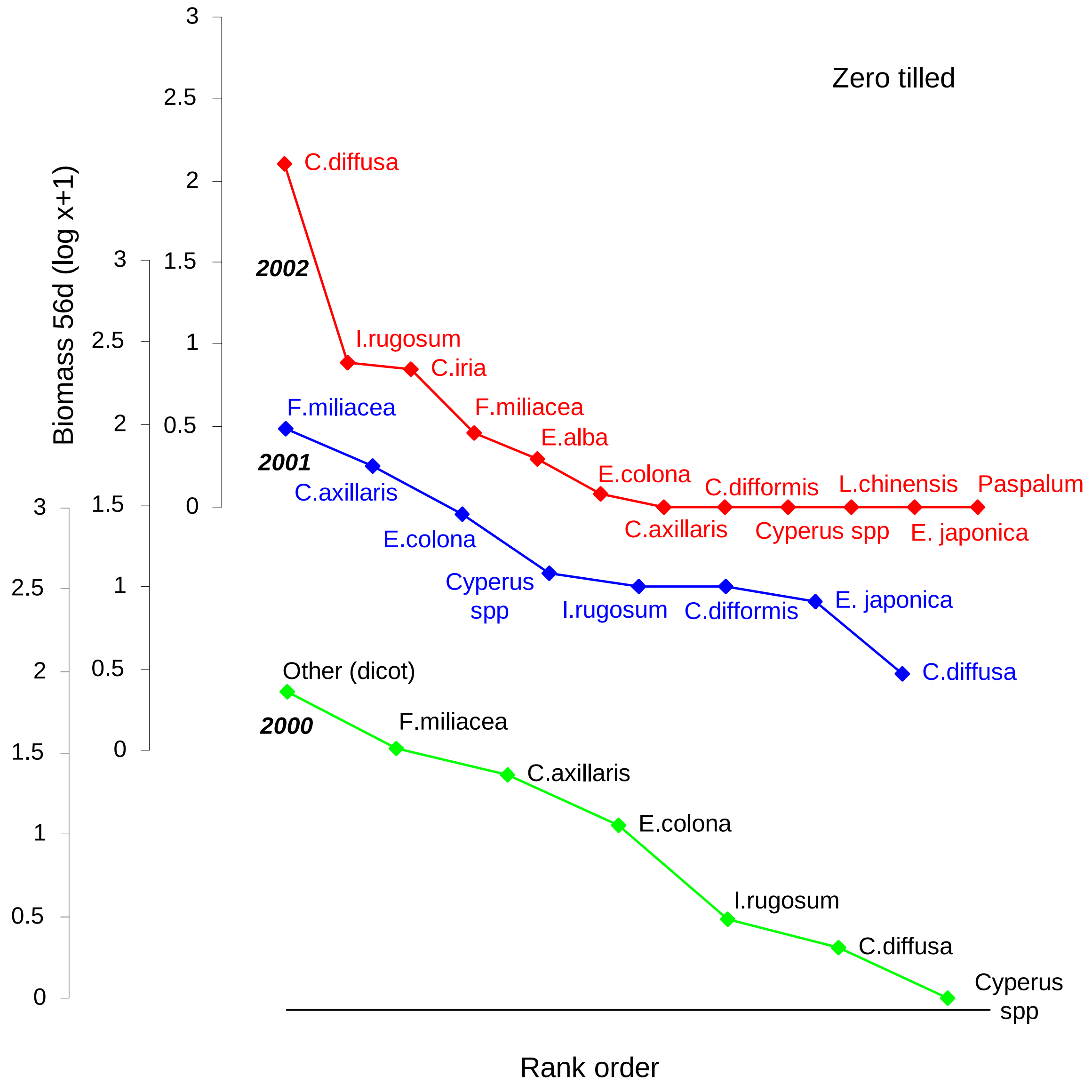


Figure 13. Log rank changes in weed abundance over seasons in direct seeded rice. See Fig 10 for explanation.

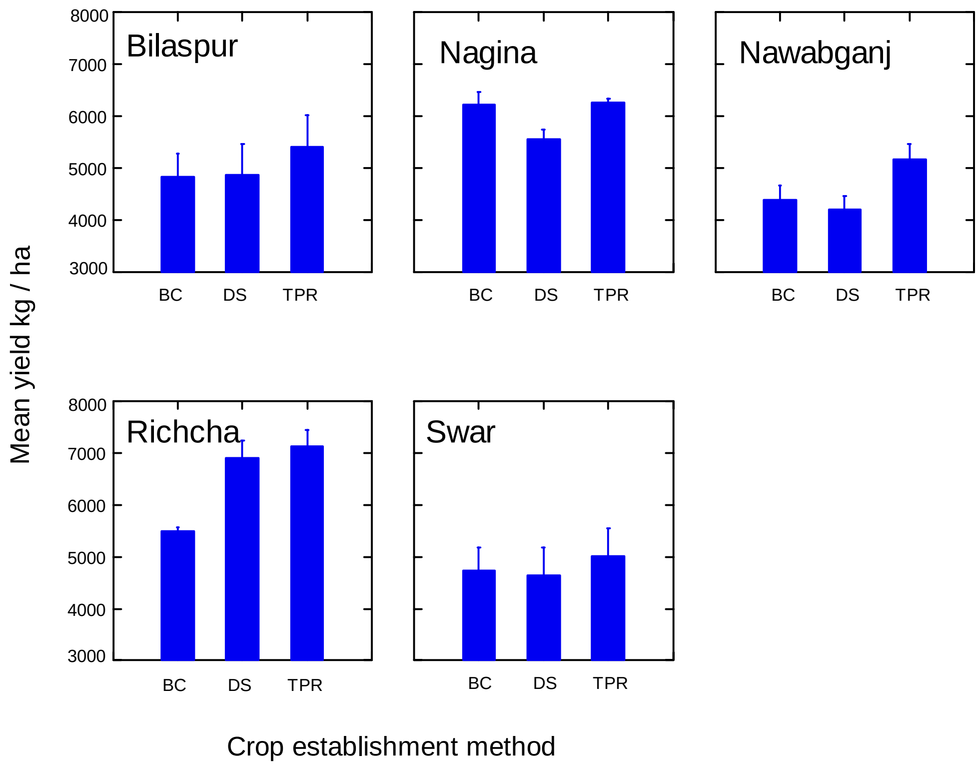
3. Comparative on-farm studies

Trials on sixteen farms in 2000 contrasted three methods of establishment, transplanting, drill seeding and wet seeding and average rice yields were 5.1 (± 0.34), 4.6 (± 0.35) and 4.9 (± 0.16) t / ha respectively. Fig 14 illustrates the variation in yield amongst farms with respect to establishment method; some farmers were successful in achieving equivalent yields under transplanting and direct seeding.

In 2001, in which trials only contrasted drill seeding with transplanting, higher yields were obtained by transplanting, 5.1 (± 0.21) versus 4.2 (± 0.18) t / ha..

Contrastingly in 2002, yields from direct seeded, wet seeded rice and transplanted rice were similar, 6.3 (± 0.81), 6.0 (± 0.93) and 6.0 (± 0.45) t / ha respectively.

Figure 14. Rice yield (kg / ha) in relation to crop establishment method. On-farm trials 2000 in five villages. BC = wet-seeded broadcast rice; DS = drill seeded rice; TPR = transplanted rice .



Weed communities

Unsurprisingly, weed communities (Figure 15) were more diverse (28 DAS/DAT) than those was seen on-station, perennial species such as *Hedyoti*s and *Sorghum halepense* being present. Overall the on-farm weed flora comprised at least 19 species including *Caesulia axillaris, Commelina diffusa, Corchorus acutangulus, Cynodon dactylon, Cyperus difformis, C. iria, C. rotundus, Echinochloa colonum, E. crus-galli, Eclipta alba, Eleusine indica, Fimbristylis miliacea, Hedyotis biflorus, Ipomoea spp., Ischaemum rugosum, Leptochloa chinensis, Eragrostis japonica, Phyllanthus niruri, Solanum nigrum, Sorhum halepense* and *Trianthema monogina*.

Early post emergence herbicides (transplanted- butachlor, wet seeded – anilophos, direct seeded – pendimethalin) reduced weed biomass but grass weeds in particular were abundant

28 DAT/DAS emphasizing the need for subsequent manual weeding. *Echinochloa crus-galli* was recorded in addition to *E. colona* and *L. chinensis. Eragrostis japonica* was not recorded.

4. Comparative studies of herbicide efficacy for direct seeded rice

Eight herbicide treatments were tested on drill seeded rice as shown below.

Treatment	Herbicide	Time of application	Rate of application Kg a.i. ha
1	Pendimethalin	Pre-emergence	1.0
2	Pendimethalin followed by 2,4-D	Pre-emergence	1.0, 0.5
3	Anilofos	Pre-emergence	0.4
4	Anilofos followed by 2,4-D	Pre-emergence; 28 DAS	0.4; 0.5
5	Anilofos	Early post-emergence; 7 DAS	0.4
6	Anilofos early post-emergence followed by 2,4-D	Early post-emergence 7 DAS; 28 DAS	1.0; 0.72
7	Pretilachlor	Pre-emergence	0.75
8	Pretilachlor followed by 2,4-D	Pre-emergence; 28 DAS	0.75, 0.5
9	Weed free	Manual weeding	21, 35, 49 DAS

Highest grain and straw yields were achieved by manual weeding (Fig 16) followed by anilofos applied pre-emergence followed by 2,4-D or pendimethalin followed by 2,4-D. The single application of either anilofos or or pendimethalin was not effective in protecting yield and the sequential application of 2,4-D gained at least 2.5 t / ha. Differences in timing of application of anilofos did not significantly effect yield. Butachlor was not included in these trials as previous work at GBPUAT had shown that is efficacy was equivalent to that of pretilachlor.

Fig 17 illustrates weed species responses to herbicides in direct seeded rice in 2001. For each weed control treatment : the upper, unfilled, plots show the density of weed species 30 DAS after seeding and application of the first herbicide (sequential application of 2,4-D occurred 28 DAS) ; the lower, filled, plots show the change in abundance by 60 DAS. Rates of change are calculated as the logarithm of the ratio of the number of plants at 30DAS to those at 60DAS.

Pendimethalin, anilofos and pretilachlor were effective in providing early control of grass weeds (*E.colona*, *E. japonica and I. rugosum*) in the first 28 DAS, leaving sedge and broadleaved weeds unaffected. Sequential application of 2,4-D resulted in control of sedges with the exception of *F. miliacea* (data not shown). Regrowth of *E. colona* occurred after 28 DAS under most herbicide regimes along with *E. japonica* when treated solely with pendimethalin and anilofos.

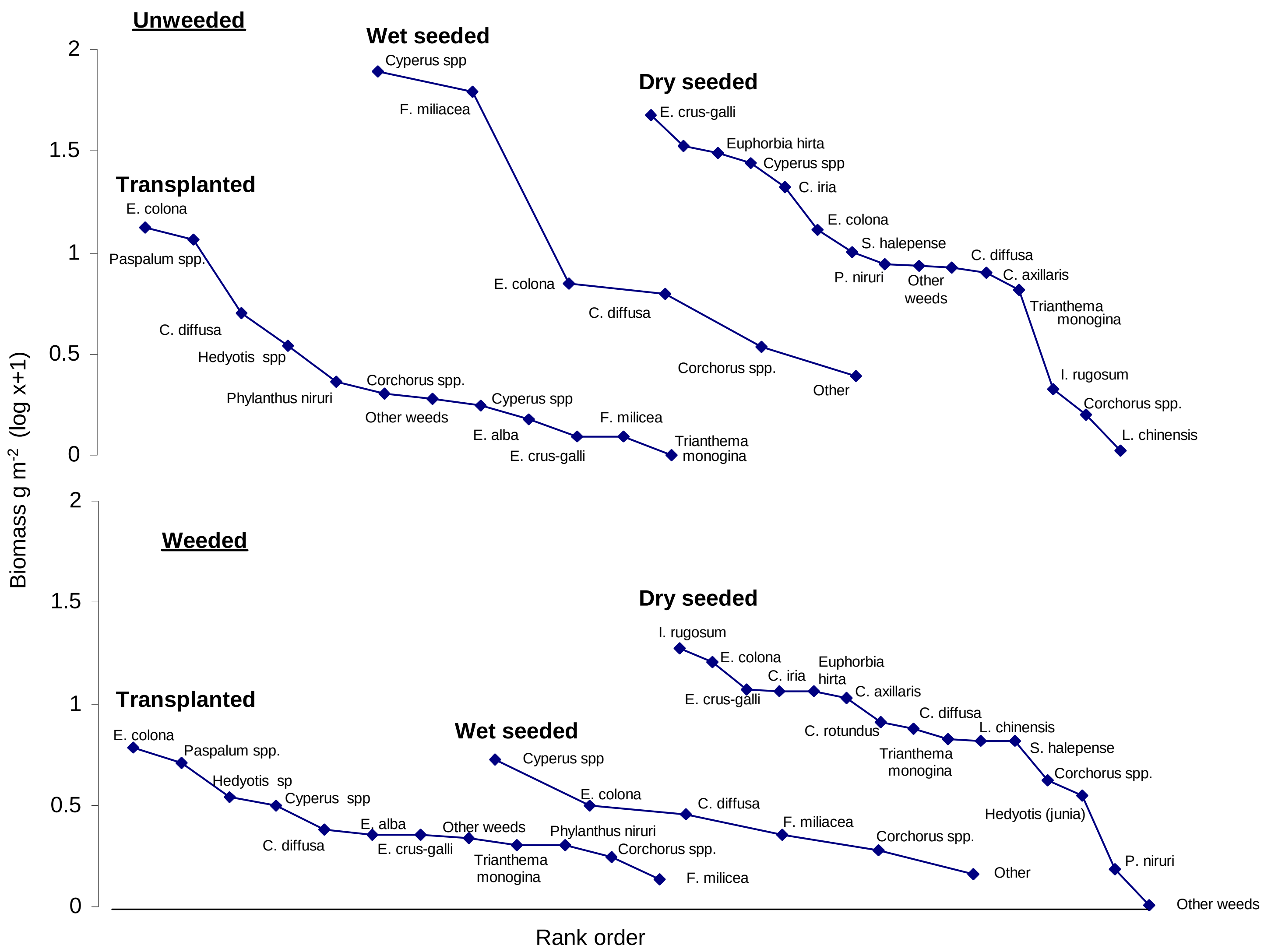


Figure 15. Log rank abundance curves in herbicide treated and unweeded plots from on-farm studies. Data are weed biomass g m –2 28 DAS/DAT, (log x +1).

Figure 16. Rice yield and yield components in relation to selected herbicides. No yield was obtained from unweeded plots.

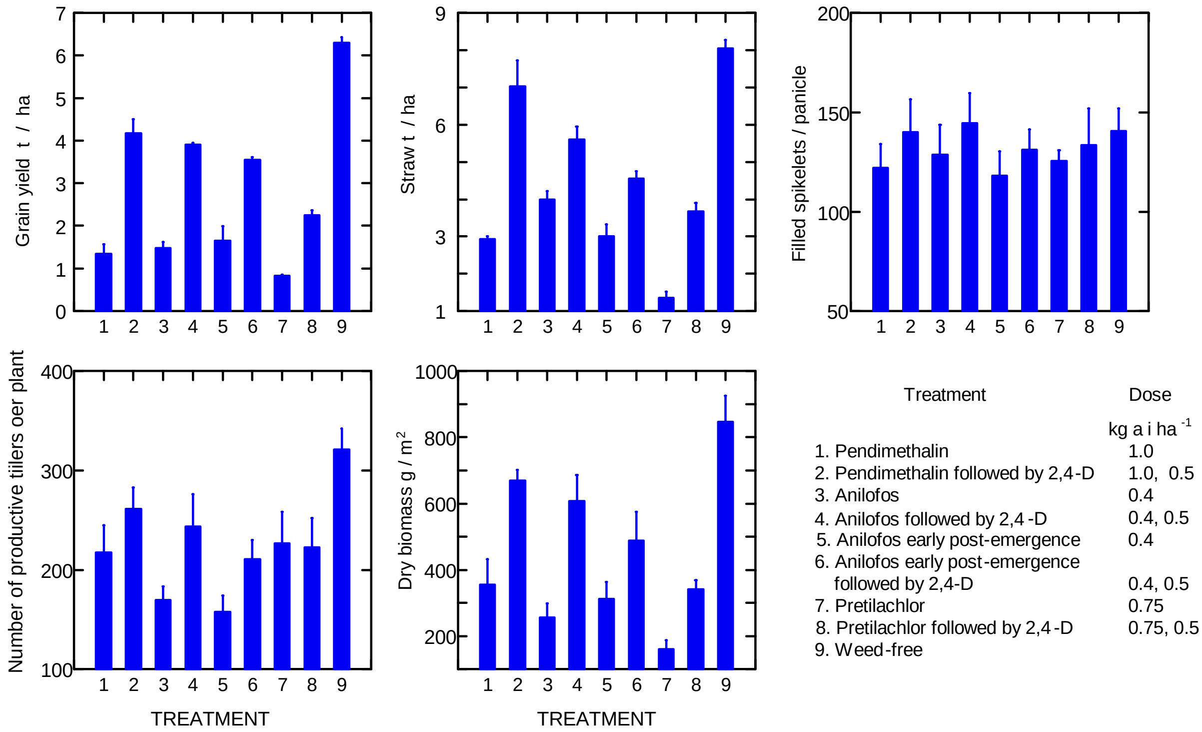
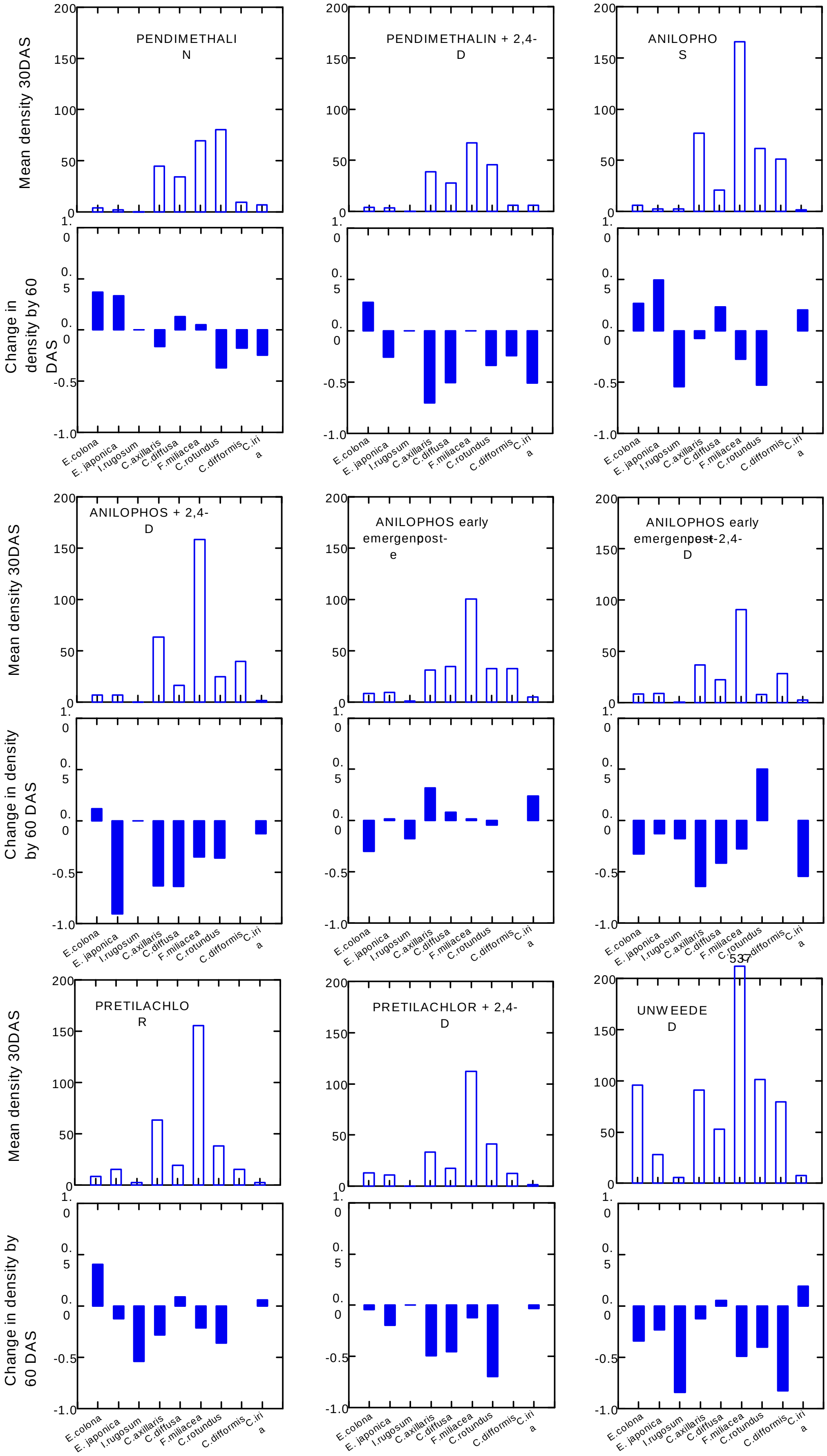


Figure 17. Responses to herbicides and mixtures by nine species, see text for details.



3. ***Output 3: Screening protocols for identifying competitiveness in rice adapted for use in India and the role of competitive rice cultivars in direct seeding systems evaluated.***

The development of screening protocols for competitive ability under lowland conditions is on-going in WARDA in West Africa, with trials being conducted in the 2000 and 2001 seasons under lowland and hydromorphic conditions. Some of the materials that have been developed from crosses between *O. glaberrima* and *O. sativa* indica lines are promising for use under lowland conditions.

A selection of rice cultivars gathered from material grown in India, elsewhere in S.E. Asia and West Africa was grown under lowland conditions at Pantnagar in the Kharif 2002. This material was drawn from breeding programmes in W. Africa, India and elsewhere in Asia and comprised improved and traditional *O. sativa*, and *O. glaberrima*. The trial provided initial characterisation of the cultivars to enable the selection of diverse plant types for further screening. Previous work in West Africa and elsewhere has suggested that plant height and tiller number are associated with greater competitiveness with weeds. Among the cultivar selection grown at Pantnagar there were significant differences in tiller numbers, plant height and grain yield (Table 14). Plant height at harvest was significantly correlated with yield (-0.237, n = 118) while height and tiller number at the vegetative stages of rice growth were not correlated to yield. Within this selection of cultivars therefore, that at the vegetative stages taller plants and those with high tiller number were not associated with lower yields. This indicates that early, rapid vegetative growth could be selected for within populations without necessarily selecting those with lower yields. A number of the introduced lines such as V 1 and V39 gave similar or greater yields than the improved yields to the local improved checks, V2-V5.

Table 14 Growth and yield of a selection of rice cultivars at Pantnagaar, Kharif, 2002. Tiller number (m row) at 21 and 28 DAS (T21, T28), plant height (cm) at 14, 28, 56 DAS and harvest (H14, H28, H56 and H harv.) and grain yield t ha.

Cultivar	T 21	T 28	H 14	H 28	H 56	Ht harv.	Grain yield
V1 Jaya	5.6	8.5	10.0	36.8	71.6	92.3	7.2
V2 Pant Dhan 4	7.9	10.5	11.6	39.7	76.2	96.6	5.1
V3 Sarju 52	12.6	14.4	8.7	38.5	72.9	86.1	4.1
V4 Indrasan	8.7	10.7	13.8	41.6	73.9	80.5	4.7
V5 Pusa 44	10.8	14.1	12.6	38.4	82.9	78.3	6.7
V6Narendra 359	6.6	10.4	13.7	43.9	81.7	99.3	7.1
V7 Pant Dhan 10	8.4	11.8	15.8	42.0	59.1	87.0	4.2
V8 UPR 1561-6-3	7.5	10.3	14.6	43.6	84.3	89.4	6.7
V9 UPRI 570-5-7-1	8.1	10.9	15.8	44.8	83.5	103.2	6.1
V10UPRI 92-79	10.5	15.0	15.1	41.3	82.3	104.2	5.5
V11 UPRI 1230-9-2	6.1	9.0	14.4	40.9	76.2	84.1	6.2
V12 Manhar	5.1	9.5	13.1	36.5	80.3	75.6	5.6
V13 Pant Dhan 12	6.4	9.4	17.3	41.1	76.2	93.6	5.3
V14 Govind	9.2	13.2	12.8	37.6	71.0	68.4	5.5
V15 Narendra 80	10.2	14.1	15.3	38.8	64.2	104.2	5.7
V16 Imp. Sarwati	10.1	12.7	15.9	44.0	83.9	92.0	6.2
V17 Pant Dhan 6	7.7	10.4	13.4	37.3	69.8	96.3	4.2
V-18 Pant Dhan 11	12.4	15.7	14.1	42.6	48.2	64.3	4.1
V19 Pusa Basmati 1	6.5	10.5	18.3	43.3	68.9	93.3	5.3

V20- UPRBS 92-4	10.5	12.8	17.3	40.3	75.3	120.7	4.8
V21 Basmati 386	7.7	10.2	14.3	47.7	93.2	132.7	4.6
V22 Tarai Basmati	5.7	8.8	13.1	44.3	62.4	120.3	3.2
V23 Type 3	6.3	9.7	13.4	40.7	83.7	151.6	3.3
V24 UPR 1840-31-1-1	5.8	8.7	12.9	42.1	70.3	105.2	4.8
V25 UPRI 93-63-2	9.8	12.1	18.2	45.6	73.5	92.2	4.8
V26 UPRI 95-49	5.4	9.4	18.9	38.3	65.6	88.5	5.5
V27 Ratna	9.3	13.6	14.7	34.8	75.8	86.1	4.6
V28 WAB450-11-1P31-HB	7.0	10.2	12.7	32.7	76.3	149.5	3.0
V29 WAB450-11-1-2-P41-HB	2.3	4.7	10.7	31.0	53.0	101.2	2.7
V30 WAB 450-B-1A1-1	1.9	4.0	13.8	32.9	82.2	109.8	4.0
V31 WAB450-B9A2-1	3.5	5.8	12.6	36.5	67.8	85.1	3.3
V32 WAB450-1-B-P-38-HB	3.3	*	13.2	35.5	75.8	117.3	4.3
V33 WAB 450-1-B-P-51-2-1	6.6	9.0	14.8	45.8	80.2	107.9	3.6
V34 WAB 450-1-B-65-4-1	10.3	13.2	15.2	39.0	74.6	94.2	3.0
V35 WAB 450-1-B-P-103-HB	2.3	4.4	13.6	32.5	94.3	128.3	3.3
V36 WAB 450-1-B-P-121-4-1	3.1	5.1	13.8	36.4	74.0	89.9	3.7
V-37 WAB 450-1-B-P-159-3-3	3.2	6.3	13.9	38.0	73.8	98.3	5.1
V38 WITA3	8.7	10.4	17.8	42.4	80.7	91.4	4.7
V39 WITA4	4.9	9.5	17.9	41.0	75.0	109.1	7.4
V40 WITA6	6.3	6.9	16.9	40.5	84.1	102.9	5.1
V41 WITA7	7.4	9.6	16.4	43.0	84.1	69.4	4.3
V42 WITA8	7.6	10.1	17.3	41.2	54.1	102.6	4.8
V43 WITA12	8.2	12.1	15.6	39.3	69.8	121.7	3.9
V44 WAB638-1	4.3	6.4	13.6	41.8	86.0	107.1	4.0
V45 FARO 8	7.8	10.0	17.3	49.0	71.2	138.7	4.8
V47- IET 16611	9.2	14.8	15.4	37.9	76.1	94.4	5.2
V48 IET 16613	7.0	8.2	15.1	42.3	81.9	108.7	6.2
V49 IET 16615	10.5	15.3	12.8	40.2	75.3	96.2	5.8
V50 IET 16838	4.5	6.5	14.7	42.0	77.2	85.0	4.0
V51 IET 16839	9.8	12.8	14.0	36.8	78.1	96.2	5.6
V52 IET 16840	7.5	9.6	15.2	39.2	75.1	111.4	4.9
V53 IET 16841	14.2	18.4	13.6	42.7	80.0	102.9	4.6
V54 IET 16842	14.7	18.8	17.8	44.9	82.0	104.3	3.6
V55 IET 16843	11.6	13.7	14.8	40.0	75.1	91.7	5.8
V-56 Triguna	4.4	7.1	23.9	68.0	110.1	153.7	5.4
V57 Prasanna	6.5	9.8	14.6	38.3	46.1	85.0	5.3
V58 Krishnahansa	9.5	12.5	16.1	38.2	86.4	104.8	5.0
V59 Aditya	7.9	11.8	18.4	41.0	81.3	104.0	6.2
V60 Nidhi	10.1	14.4	15.7	48.5	84.2	117.6	6.2
V61 Tulsi	8.8	12.3	15.0	43.0	78.3	102.3	4.6
V62- Vikas	8.0	12.2	14.4	42.3	68.0	87.1	6.0
V63 IR-64	8.9	12.9	15.3	45.9	86.0	77.0	5.9
V64 VL-206	10.6	18.7	16.2	36.9	59.1	85.1	4.8
V65 Pant Dhan Majhera 7	6.6	10.1	23.8	64.2	88.1	128.7	4.2
Mean	7.79	10.95	15.1	41.3	75.8	100.7	4.93
S.E	1.11	1.61	0.97	1.68	1.46	2.65	0.52
Significance (P≤)	0.001	0.001	0.001	0.001	0.001	0.001	0.001

4. *Output 4: Integrated weed management options developed in on-station and on-farm trials in India.*

Activities conducted for Output 2 provide baseline information on the range of target species, the effectiveness of available herbicides and the responsiveness of weed species to different crop establishment methods. This area of the planned activities has been particularly successful. A wide range of crop establishment and weed management methods has being tested in on-station experiments and an extensive set of data has been established.

Results emerging from this work clearly indicate that direct seeding in rice and wheat can be shown to give yields that are broadly compatible with those using conventional practices. On-farm trials also indicate that rice yields under direct seeding can be similar to those from transplanting and under intensive weeding, wet seeded rice gave the best yield with dry drill seeded rice being about 20% lower. Yields of dry drill seeded rice however were greatly reduced where weed management was limited to one hand weeding, underlining the critical nature of weed management in direct seeded systems and the importance of chemical weed control. Under drill seeding, two weed species may prove problematic, *I rugosum* and *F. miliacea*, and in both instances integrating flush irrigation as a cultural practice with anilophos and 2,4-D may prove an effective option.

The on-station trial have provided data from three cropping seasons that begin to expose longer-term shifts in weed populations. This primary data set, when combined with information derived from the household studies, will then allow a decision making framework to be constructed matching anticipated changes in the weed flora to crop establishment and weed control options. Comparative on-farm trials will support validation of this framework and feed back for improvements. In this respect GBPUAT has expressed keen interest in continuation of these experiments.

5. *Output 5: Potential for evolution of herbicide resistant weeds in direct seeded rice determined and procedures for its avoidance designed and promoted.*

Where direct seeding is being adopted in India (Pantnagar area) farmers use pre-emergence application of pendimethalin and post-emergence 2,4-D. The resistance risk for pendimethalin (a microtubule assembly inhibitor) is considered to be low and the only case of resistance to this mode of action has been and isolated report for *Echinochloa crus-galli* in an orchard in Bulgaria. Indeed in Costa Rica there is evidence that resistance to propanil has developed more slowly in fields where farmers have applied the herbicide in a tank mix with pendimethalin. There have also been few reports on resistance to the auxin herbicide 2,4-D. The occurrence of resistance in *Fimbristylis miliacea* in Malaysia could however be particularly significant. The annual sedge *F. miliaceae* produces copious seeds and there would be every opportunity for resistance to build-up quickly if 2,4-D selected for a few resistant individuals and was then used continuously.

There has to date been no report of resistance to the herbicides used in experiments in India to anilofos or oxyfluorofen and oxadiargyl, although the latter has only recently come onto the market. There is clearly a greater risk for many important species from intensive use of butachlor and the ALS inhibitors chlorimoron-ethyl and ethoxysulfuron. Species and relatives of those that are resistant to bensulfuron and other sulfonylureas elsewhere would be at risk from the introduction of chlorimoron-ethyl and ethoxysulfuron in India. For butachlor evolution of resistance in *Echinochloa crus-galli* would seem most likely. Recommendations for herbicide use in India will take account of studies conducted elsewhere to reduce the risk elsewhere (e.g. Valverde *et al.,* 2000).

The initial desk study has been completed and the required information is available for the development of a strategy to reduce the risks of herbicide resistance developing.

6. *Output 6. Decision tools for integrated weed management in direct seeded rice developed and promoted.*

The decision tools are being developed as a result of the on-farm and station experiments that have been conducted in 2000 to 2002, combined with information from the household surveys. The socio-economic survey data will result in a calculation of the potential savings of shifting to direct seeding of rice for small, medium and large farmers. The technologies that have been promoted through the on-farm trials appear to be relatively robust and effective in controlling the weeds after direct seeding. These methods will be promoted together with information on management factors to be taken into consideration such as the flexibility of irrigation facilities, skills related to pesticide use and soil type. The development and promotion of the decision tools were main items on the agenda at the “end of project workshop” at Pantnagar. Recommendations for the management of weeds under dry and wet direct seeding and these are to be made available by GBPUAT in mid-2003. With regard to the cultural practices associated with direct seeding, however, wider testing of the technologies in a range of agro-ecologies is planned.

A collection of photographs of the important weeds of rice and wheat has been made and it is intended that this is made up into a pamphlet/poster to aid the identification and facilitate the means of control. It is planned that this will be co-ordinated by IRRI and will be extended for work in Nepal and Bangladesh.

6.1 Economic evaluation of direct-seeded and transplanted rice, and the social costs of herbicide use and direct seeding. [by Dr A W Orr, NRI Agricultural Economist]

These results are provisional and are based on the 2002 Kharif season data. Partial budgets allow the comparison of the two direct seeding systems with those of transplanting, by measuring those costs that vary between treatments and not the costs of all inputs. This analysis shows that the returns from direct dry and wet seeding are similar and that wet seeding gives a return some 40% higher than transplanting (Table 15).

Table 15 Partial budget for direct-seeded and transplanted Kharif rice, GBPUAT.

Costs that vary	**Units**	**Wet seeding**	**Dry seeding**	**Transplanting**
Labour				
Nursery	Mandays/ha [a]			20.98
Hand-sowing	“	16.68		
Transplanting	“			27.80
Applying fertiliser and herbicide	“	3.12	12.16	6.00
Irrigation	“	1.19	0.63	1.58

Total labour requirements that vary	"	20.99	12.79	56.36
Labour costs that vary [b]	Rs/ha	1259	767	3382
Material inputs				
Seed drill hire [c]	Rs/ha		636	
Nursery fertiliser	"			1091
Nursery irrigation	"			80
Herbicides [d]	"	1560	1336	480
Irrigation water [e]	"	2129	1112	2843
Roller hire [f]	"		636	
Total material costs that vary	"	3689	3084	4494
Grand total of costs that vary	"	4948	3851	7876
Average yield	Kg/ha	6.76	6.69	6.14
Adjusted yield [g]	Kg/ha	5.41	5.35	4.91
Price	Rs/kg	4.75	4.75	4.75
Gross returns	Rs/ha	25,698	25,413	23,323
Net returns	Rs/ha	**20,750**	**21,562**	**15,447**

Notes

[a] Assumed mandays of 8 hours/day.
[b] Labour wage 60 Rs/day.
[c] Hire 200 Rs/hour.
[d] Wet seeded, Cyhalofop- butyl, 1 l/ha @ 1560 Rs/l; dry-seeded, Pendimethalin, 3.34 l/ha @ 400 Rs/l; transplanted, Butachlor, 3 l/ha @ 160 Rs/l.
[e] Hire rate, 40 Rs/hr.
[f] Hire rate, 200 Rs/hr
[g] Adjusted downwards by 20% to reflect difference between experimental yield and yield farmers might expect from same treatment.

The social costs of herbicides/direct seeding

Herbicides and direct seeding are financially profitable to the farmer, but these profits do not necessarily reflect their true economic costs. An economic or social cost-benefit analysis (SCBA) of herbicides/direct seeding technology would have to include the costs of:

- *Externalities*, such as possible damage to the environment through pollution, potential revenue losses from damage to fish stocks, and damage to human health caused by inappropriate methods of application or contamination through the food chain.

- *User costs*, or the discounted value of foregone future revenues due to environmental damage caused by herbicides.

- *Labour displacement*, particularly in economies where market wage rates do not reflect the real opportunity cost of labour and alternative employment opportunities for displaced workers may not be available.

The absence of information on these costs makes it impossible to measure the net economic costs of herbicides/direct seeding accurately. Following Naylor (1994), however, it *is* possible to provide some answers by asking three questions:

- How much would variable costs have to rise (reflecting externalities) for the benefit-cost ratio of herbicides/direct-seeding to equal that of transplanting?

- How much would yields have to fall (reflecting user costs) for the benefit-cost ratio of herbicides/direct-seeding to equal that of transplanting?

- How much would labour wages have to fall (reflecting the economic cost of labour) for the benefit-cost ratio of herbicides/direct seeding to equal that of transplanting?

Table 16 shows a sensitivity analysis for transplanted rice in eastern Uttar Pradesh. Case A represents the base-scenario, based on costs and returns data from on-station trials. Case B, C, and D represent the scenarios for potential externalities, user costs, and labour displacement effects, respectively, of herbicides/direct seeding. The results show that:

- Benefit-cost ratios for herbicides/direct seeding and transplanting would be equal if the environment and health-related costs of herbicides/direct seeding were twice as large as private costs (8682 Rs/ha vs. 4948 Rs/ha for wet-seeding and 8585 Rs/ha vs. 3851 Rs/ha for dry-seeding). (Case B).

- Benefit-cost ratios for herbicides/direct seeding would be equal to transplanting if rice yields fell by 40-50 % (from 5.41 t/ha to 3.4 t/ha for wet-seeding and 2.64 t/ha for dry seeding). (Case C).

- Benefit-cost ratios for herbicides/direct-seeding would be equal to transplanting if the true opportunity cost of labour were zero or negative (Case D).

Overall, the evidence suggests that the use of herbicides/direct-seeding in Uttar Pradesh is socially profitable. In particular, the economic costs of labour displacement are relatively low. Direct-seeding is only as socially profitable as transplanting if the opportunity cost of agricultural labour is assumed to be zero. Studies of the rural labour market in Uttar Pradesh suggest, however, that the real wage-rate for peak-season operations like transplanting are near the market rate. Transplanting relies heavily on male labour which is highly mobile and whose wage-rates have risen in real terms through a combination of labour militancy and opportunities for off-farm employment. Peak-season periods have seen successful labour strikes for wage-increases in the 1990s (Lerche, 2002; Srivastava, 2002).

Table 16 Sensitivity analysis of social profitability of direct-seeding, eastern Uttar Pradesh, India.

Case	Control method	Rice yield (t/ha) [a]	Total variable cost (Rs/ha) [b]		Gross benefits (Rs/ha) [c]	Net benefits (Rs/ha) [d]	Benefit:cost ratio [e]
A	*Transplanted* kharif *rice, base case*		Labour	Materials			
	Transplanting	5.41	3382	4494	23,323	15,447	1.96
	Wet seeding	5.35	1259	3689	25,698	20,750	4.19
	Dry seeding	4.91	767	3084	25,413	21,562	5.60
B	*Allow material costs to change and hold yields constant*						
	Transplanting	5.41	3382	4494	23,323	15,447	1.96
	Wet seeding	5.35	1259	7423	25,698	17,016	1.96
	Dry seeding	4.91	767	8585	25,413	16,828	1.96
C	*Allow yields to change and hold material costs constant*						
	Transplanting	5.41	3382	4494	23,323	15,447	1.96
	Wet seeding	3.40	1259	3689	14,646	9698	1.96
	Dry seeding	2.64	767	3084	11,399	7548	1.96
D	*Allow cost of labour to change and hold yields constant*						
	Transplanting	5.41	0	4449	23,323	18,829	4.19
	Transplanting	5.41	-915	4449	23,323	19,789	5.60
	Wet seeding	5.35	1259	3689	25,698	20,750	4.19
	Dry seeding	4.91	767	3084	25,413	21,562	5.60

[a] Yields from on-station trials, GBPUAT, mean of 2001 and 2002 *Kharif* seasons, adjusted downwards by 20 % to allow for experimental conditions.
[b] Variable costs of crop establishment and weed control only. Herbicides account for 58 % of material costs for wet-seeding and 43 % for dry-seeding, with rest comprising payments for irrigation water and equipment hire.
[c] Farmgate price of 4.75 Rs/kg.
[d] Gross benefits minus total variable costs of crop establishment and weed control.
[e] Net benefits divided by total variable costs of crop establishment and weed control

7. Publications and dissemination :

Published Conference papers subject to editorial review (each accompanied by a poster)

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. *(Editorial Review)*

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. *(Editorial Review)*

In press:

Johnson, D.E, Wopereis, M.C.S., Mbodj, D, Diallo, S. and Haefele, S.M. (200x) Application of the Intercom simulation model to improve weed management in irrigated rice in the Sahel. ii. Effect of timing of weed management. *Field Crops Research* (submitted) *(Editorial Review)*

In preparation:

Haefele, S., Johnson, D.E., M'Bodj, D., Miezan, K., Wopereis, M.C.S. Selection of rice cultivars for improved weed competitiveness in the irrigated lowlands ecologies. *Field Crops Research.*

White, J.L., Meadows, K. and Attwater, H. Household studies in Narainpur, Mirzapur, Cakarpur, Dhaniya Kote and Banskhera villages, Uttaranchal.

Planned:

Identification guide for rice weeds in the Indo-Gangetic Plains.

Changes in weed population resulting from different rice establishment methods and weed management in the Indo-Gangetic Plain. (*Journal article*)

Contribution of rice production to livelihoods in Uttaranchal State: results of a household survey

Conference proceedings

Hobbs, P.R., Singh, Y., Giri, G.S., Lauren, J.G., and Duxbury, J.M. (2002) Direct-seeding and reduced-tillage options in the rice-wheat systems of the Indo-Gangetic Plains of South Asia. In : Pandey, S., Mortimer; M., Wade, L., Tuong, TP and Hardy, B (2002). "Direct seeding in Asian rice systems: strategic research issues and opportunities". International Rice Research Institute (In press 383 pp)

Singh, Y., Singh, G., Singh, V.P., Singh, R.K., Singh, P., Srivastava, R.S.L., Saxena A., Mortimer, M. Johnson D.E and White, J.L. (2002) Effect of different establishment methods on rice-wheat and the implications of weed management in Indo-Gangetic Plains. In 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.

Journal articles

Haefele, S., Johnson, D.E., Diallo, S., Wopereis, M.C.S. and Janin, I. (2000) Improved soil fertility and weed management pays off for irrigated rice farmers of the Sahel, West Africa. *Field Crops Research* **66:** 101-113. *(Editorial Review)*

Internal reports:

Riches, C. R. (2002) An evaluation of the risks of herbicide resistance developing in weeds of rice in Bangladesh and India (draft). 6 pp.

Srivastava, R.S.L. (2002) Studies of farm households in Narainpur, Mirzapur, Cakarpur, Dhaniya Kote and Banskhera villages, Uttaranchal. 33 pp.

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Other dissemination of results, training etc:

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Farmers' field days - in 2001, at the on-farm field sites 50-75 farmers participated in the presentations of direct seeding and weed management treatments. Farmers' were also brought from Ghaziabad (Uttar Pradesh) to visit the fields in the Pantnagar area (Uttaranchal).

Farmers' fair Pantnagar, October 2001. Field demonstrations of direct seeding and weed management

GBPUAT pamphlets on zero and conventional tillage in the rice wheat systems. 1000 copies printed and distributed.

University Chancellor's tour of farmers' fields, with lead farmers and local government staff, and local radio interview with Drs Mortimer and Johnson, on the direct seeding, February 2001.

Prof. Y. Singh as representative of India at the Weed Ecology Working Group meeting in Bangkok, 1999 and 2002.

Workshop GBPUAT "End of Project ", 100 participants September 2

8. Contribution of outputs to developmental impact:

The Gangetic Plains (IGP) contributes 40% of India’s grains and rice wheat cultivation, which is probably the world's most important cropping system, is crucial to the food security of some 350 million people. Emerging issues of sustainability with intensification include ground-water depletion, soil structure and labour scarcity for agriculture. Direct seeding rather than transplanting addresses these concerns but problems of weed management in the system has been a key constraint to its development. Project R7377, through collaborative links with GBPUAT and IRRI, has developed weed management systems for direct seeding and these have been successfully tested on-farm. Farmers believe that such a system is required to allow earlier establishment of the rice and wheat crops and to address the high costs of irrigation and labour associated with transplanting. The project has developed and tested methods of integrated weed management and shown that the direct seeding of rice is feasible in the Pantnagar area and that it can give similar yields to those of transplanting. While yields may not be greater under direct seeding, the cost-effective weed control measures that have been developed are likely to lead to improved returns for farmers.

9. Promotion pathways whereby present and anticipated future outputs will impact on sustainable livelihoods:

GBPUAT is closely linked with the extension services and government development agencies and has well-established links with the farming community that allows for testing and wide dissemination. Farmers have been exposed to the project's activities and the weed management practices being promoted through Farmer fairs, field days and farm demonstrations. A series of leaflets promoting the weed management practices for direct seeding will become available to farmers in 2003. If successfully promoted amongst wider farming communities, the new technologies could provide farmers with the means to reduce the costs of rice production for subsistence and enhance profitability for the sale of rice, thereby contributing to poverty alleviation and sustainable livelihoods.

Through the collaborative links with IRRI the project is linked to the Weed Ecology Working Group (WEWG). This is a small thematic group of collaborating NARES with the common strategic goal of developing integrated weed management practices for rice in south and south-east Asia. This project has supported the attendance of Prof. Y. Singh at three work group meetings (Bangkok, 1999, IPM-net, Chang Mai, March 2000; IRRC, Bangkok 2002) and in addition to attendance at the Brighton Crop Protection Conference 2001, with Dr G. Singh. The WEWG is in the process of extending its research agenda. (http://www.irri.org/irrc/weeds.htm). Prof. Y. Singh is the representative member for India and his participation will ensure that members from NARES in the region will continue to be made aware of research outputs from India. IRRI and GBPUAT have an on-going commitment to the development of direct seeding systems for rice. Collaborative links with IRRI and GBPUAT have been very successful and the existing project has permitted the development of a programme that has served the objectives of the stakeholders well.

The Executive of the Rice Wheat Consortium, in February 2002, recommended that there should be greater emphasis on the scaling-up of technologies within the region and more inclusion of socio-economic aspects in the research process. Also recently, at the International workshop entitled "Herbicide resistance management & zero tillage in rice-wheat cropping system", March 4-6, 2002 in Hisar, several speakers called for more emphasis to be placed on developing and promoting improved weed management methods for direct seeding in rice.

10. Follow-up action / research

A workshop was held in September 2002, at which the project findings were presented to researchers, farmers' groups and other stakeholders. A significant portion of the discussions at the workshop concerned "scaling-up" the application of the weed management and direct seeding technologies. To date the testing and development of the direct seeding technologies have only taken place on a limited compared to the very extensive areas on which the rice wheat system is practised. It is therefore necessary that there is wider testing and refinement of technologies before these are widely promoted.

A subsequent phase to this project has been agreed with DFID's CPP and this will focus on "scaling-up" and promotion of these technologies. The project "Promotion of integrated weed management for direct seeded rice in the Gangetic Plains of India" (R8233) is scheduled from 1 January 2003 to 31 March 2005. The activities will allow scaling-up and promotion of direct seeding to farmers through Indian universities and the extension service. The project will cover a wider geographic and through G.B.PUAT will link with the agricultural universities at Patna, Faizabad. These activities will cover a wide geographic area and different agro-ecological conditions. At the time of writing, an initial planning meeting of this project, with all the partners, has been held in India. It is been agreed that on-farm demonstration and farmers' trials will be established in 2003 in four areas, and leaflets and publications will be made available to farmers, extension workers and relevant institutions.

11. Final version of logframe:

Narrative Summary	Objectively Verifiable Indicators	Means of Verification	Important Assumptions
Goal			
Yields improved and sustainability enhanced in high potential cropping systems by cost-effective reductions in losses due to pests.	To be completed by Programme Manager	To be completed by Programme Manager	To be completed by Programme Manager
Purpose			
Improved methods for the management of weeds in irrigated rice (and rice-fish) systems developed and promoted.	To be completed by Programme Manager	To be completed by Programme Manager	To be completed by Programme Manager
Outputs			
1. Farmer weed control practices, perceptions of constraints & criteria for choice of weed methods determined.	Surveys and PRA completed by August 2001; farmer focus group meetings held during period of on-farm trials.	Project Q reports; Conference & journal papers.	Outputs 1-6. - rice scientists in IRRI Weed Ecology Working Group & WARDA Task force collaborate in studies
2. Weed shifts in response to planting method & herbicide use determined.	Sites selected by May 2000, data collected by Dec 2001 and analysed by May 2002. Weed Ecology Working Group reviews progress in 12/00 & 10/02.	Project Q reports, conference and journal papers, presentation at Weed Ecology working Group & WARDA Task Force meeting. Data used for planning future trials.	- NGOs and extension agencies in project target areas have resources to link in with project to promote findings.
3. Role of competitive rice	Trials in India	Project Q reports,	- Adverse weather

cultivars in direct seeding (DS) systems determined.	established by 6/01, completed by 10/02	conference and journal papers. Competitive lines used in on-farm trials.	conditions do not prevent timely achievement of outputs.
4. Integrated weed management options for DS rice developed	On-station and on-farm trials begin 05/00 and completed by 9/02.	Project Q reports, conference and journal papers, presentations at Weed Ecology Working Group; information used in output 6.	
5. Potential for evolution of herbicide resistant weeds in DS evaluated & methods for it's prevention designed & promoted.	Data collected via networks following meeting of Weed Ecology working Group in 10/00 and study conducted by 12/01.	Project report, discussed at WARDA Task Force & Weed Ecology Working Group, meeting reports circulated to extension agencies.	
6. Decision tools for improved weed management strategies developed & promoted.	Drafts of dissemination materials available by 9/02.	Leaflets and reports suitable for extension agencies.	

Name and signature of author of this report and date signed:

D E Johnson (with inclusion of sections from M Mortimer, J.L. White)

6 March 2003

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