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Effect of Establishment Methods and Weed Management Practices on Weeds and Rice in Rice-Wheat Cropping System

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ABSTRACT

Rice establishment methods had marked effect on weed density and their dry matter production. The highest weed density and dry matter production were recorded in DSR (dry direct seeding unpuddled) and least in WSR (wet seeding in puddled soil) and TPR (transplant) establishment methods at 30 days stage of growth. In weedy plots, the density of *Echinochloa colona* in DSR was higher than in WSR and TPR. Similarly, non-grassy weeds were more in number in DSR than in WSR and TPR. The population of sedges was more in DSR than in WSR, whereas it was not found in TPR. Uncontrolled weeds, on an average, caused 75.8, 70.6 and 62.6% reduction in grain yield of rice when compared with weeded situation in DSR, WSR and TPR, respectively. Thus, the potential yield loss due to weeds was higher in DSR than in TPR. The grain yield of rice was similar under the three establishment systems of rice when weeds were controlled effectively by herbicide application supplemented with weedings.

INTRODUCTION

Transplanting rice seedlings on puddled soil is widespread in the irrigated ecosystems. Puddling reduces water percolation, suppresses weeds and transplanted rice seedlings have a greater competitive advantage over weeds that emerge after transplanting. Transplanting is now facing several constraints i. e. non-availability of labour in time, late rice planting, drudgery to farm workers, high production cost, high water use and restricted root system. The non-availability of labour in time often results in shortages and increasing labour costs (Hobbs *et al.*, 2002). Land preparation for transplanted rice consumes large amounts of water, about 20-40% of the total water required for growing the crop (Bhuiyan *et al.*, 1995). In north-west India, due to excess utilization of ground water, the water table is declining at places with alarming rate of one metre or more per year. Research has shown that submergence of rice field is required for few days only after transplanting so as to discourage weeds, subsequently soil saturation is enough (Gill, 1994).

Rice production systems are undergoing various types of changes and one such change has been the shift from transplanted to direct seeding. Direct seeding for rice establishment is spreading rapidly in Asia particularly Philippines, Malaysia and Thailand (Pandey and Velasco, 2002) as the farmers seek high productivity and profitability to offset increasing costs and scarcity of farm labour (Balasubramanian and Hill, 2002). The main driving forces of this change are the rising wage rate, scarcity of water and labour and at the same time the availability of advanced technologies of integrated weed management (Singh, 2004). In direct seeding, there are two methods (dry and wet seeding) based on the physical conditions of the seed bed and seed (pre-germinated or dry). Dry seeding is practised on rainfed lowland, upland and flood prone areas. India has 12 m ha i. e. 28% of rice area under direct seeding (Palaniappan and Purushothaman, 1991). Most of this area is under unfavourable low productivity systems where mostly short duration varieties are sown under upland conditions. Direct seeding offers certain advantages i. e. saves labour, faster and easier planting helps in timely sowing, less drudgery, early crop maturity by 7-10 days, less water requirements, high tolerance to water deficit, often higher yield, low production cost and more profit, better soil physical conditions for following crops and less

methane emission (Balasubramanian and Hill, 2002). In rice-wheat areas, major cause of low wheat yield in sequence with rice is its late sowing for various reasons like delay in rice transplanting which affects the sowing of succeeding wheat crop.

Considering above conditions, direct seeding of rice and zero tillage of wheat in rice-wheat cropping system can go a long way in rectifying the above situations and making rice-wheat as sustainable system. The weeds are the major constraints in direct seeding of rice. Therefore, a necessity was felt to understand the weed management in different rice establishment methods.

MATERIALS AND METHODS

A field experiment was conducted at Crop Research Centre of Govind Ballabh Pant University of Agriculture & Technology, Pantnagar (Udham Singh Nagar) during **kharif** and **rabi** seasons of 2002-03 and 2003-04 consisting of three rice establishment methods, two levels of weed control practices in rice and two methods of wheat establishment. In all, there were 12 treatment combinations arranged in split plot design with three replications. Main plot consisted of three rice establishment methods (dry direct seeding in unpuddled soil, wet seeding in puddled soil and transplanting in puddled soil), while sub-plots consisted of two levels of weed control practices (herbicide+two hand weedings and weedy). During **rabi** season, wheat was sown as sub-plot treatments as zero tillage and conventional tillage. Each plot where rice was sown in **kharif** season was divided into two parts, half of which was prepared with conventional tillage and rest was sown with zero tillage. Different herbicides were applied in three rice establishment methods. In dry seeded rice pendimethalin at 1 kg ha^{-1} was applied as spray in 600 litres of water two days after sowing followed by hand weeding at 30 and 60 days stages. In wet seeded rice, cyhalofopbutyl at 100 g ha^{-1} was applied as spray in 600 litres of water 15 days after sowing followed by hand weeding after 30 and 60 days stages. While in transplanted rice, butachlor at 1.5 kg ha^{-1} was applied by mixing with urea three days after transplanting followed by hand weeding at 30 and 60 days stages. The herbicides were applied with the help of Maruti foot sprayer fitted with flat fan nozzle.

In dry seeded rice, the field was cross harrowed on June 16, 2002 and June 10, 2003 after receiving pre-monsoon showers and was respectively levelled on June 17, 2002 and June 11, 2003, again cross harrowings were done on June 18, 2002 and June 12, 2003 and simultaneously planking was done. Dry seeds of paddy were sown on June 19, 2002 and June 13, 2003 by zero till seed drill at 50 kg seed ha^{-1}. The first irrigation in dry crop was given on June 28, 2002 and June 25, 2003.

In wet seeded rice, the field was cross harrowed on June 16, 2002 and June 10, 2003 after receiving pre-monsoon showers and levelled on June 17, 2002 and June 11, 2003, again cross harrowings were done on June 18, 2002 and June 12, 2003 and simultaneously planking was done. Puddling was done by tractor on June 20, 2002 and June 14, 2003. The rice seeds were soaked on June 19, 2002 and June 13, 2003 (dates on which dry seeding was done) for 24 h and incubated for 12 h for sprouting. The sprouted seeds were seeded in puddled soil on June 21, 2002 and June 15, 2003 using drum seeder. The seed rate used was 70 kg ha^{-1}. The water was drained before seeding so that soil could support the seeder and permit opening of shallow furrows for seeding. The first irrigation was given on June 28, 2002 and July 14, 2003.

The main field for transplanting was cross harrowed on July 15, 2002 and July 12, 2003 and levelled on July 16, 2002 and July 13, 2003 by leveller, again cross harrowings were done on July 17, 2002 and July 14, 2003 and simultaneously planking was done. Puddling was done by tractor on July 17, 2002 and July 14, 2003. The rice seedlings of 28 to 30 days were transplanted on July 18, 2002 and July 15, 2003. The first irrigation to this crop was given after eight days in 2002, while in 2003 early first irrigation was not required due to rains. The seedlings for transplanted rice were raised following wet nursery system as per recommendations. The seed rate used was 40 kg seed ha^{-1}. The paddy seeds were soaked

on June 19, 2002 and June 13, 2003 (the dates on which dry seeding was done).

Rice cv. Sarju-52 was sown in all the three systems having 20 cm inter-row spacing. The experimental crops of rice were fertilized by 120 kg N, 60 kg P_2O_5 and 40 kg K_2O ha^{-1}. Zinc was applied at 30 kg $ZnSO_4$ ha^{-1} only in rice as $ZnSO_4$ (23.5% zinc).

RESULTS AND DISCUSSION

Effect on Weeds

The major species were *Echinochloa colona, Caesulia axillaris* and *Cyperus rotundus*. Species like *Echinochloa crusgalli, Fimbristylis miliacea, Cyperus iria, Digitaria sanguinalis, Ischaemum rugosum, Cyperus difformis, Alternenthera sessiles* and *Commelina benghalensis* were clubbed together as 'other weeds' (Tables 1, 2, 3 and 4).

At 30 days stage, the mean density of *E. colona* was significantly more in DSR (dry direct seeding unpuddled) than in WSR (wet seeding in puddled soil) and TPR (transplant) during first season, while there was non-significant difference in the density of this weed in WSR and TPR, while during second season DSR and WSR had more density of this weed than TPR at this stage. The mean density of *C. axillaris* during first season did not vary significantly under different rice establishment methods at 30 days stage. During second season, population of this weed in DSR and WSR was similar but significantly more than in TPR at this stage. In DSR, the mean density of *C. rotundus* at 30 days stage during first year was significantly higher than in WSR and TPR but in second season at same stage the density of this weed was similar in DSR and WSR. In TPR, there was almost complete control of this weed at all the stages during both the seasons. The mean density of 'other weeds' at 30 days stage during first season in DSR was significantly higher than in WSR and TPR. WSR had significantly higher density than TPR. The density of 'other weeds' at this stage during second season was similar in DSR and WSR (Tables 1 and 2).

At 30 days stage during both the seasons, the mean dry matter production of *E. colona* was significantly more in DSR and WSR as compared to TPR. DSR and WSR were at par with respect to dry matter of this weed during first season but in next season WSR had less dry matter than DSR. The mean dry matter of *C. axillaris* during both the seasons did not vary significantly under different rice establishment methods. In DSR, the dry matter of *C. rotundus* at 30 days stage during both the seasons was significantly higher than in TPR. During first season, WSR had less dry matter of this weed than DSR but in second season the difference in this regard was non-significant. The mean dry matter of 'other weeds' at 30 days stage during first season was similar in WSR and TPR but was significantly lower than in DSR. In next season, TPR had significantly less dry matter of 'other weeds' than DSR and WSR. DSR and WSR were similar in dry matter production of these weeds (Tables 3 and 4).

At 30-day stage, the interaction effects of rice establishment methods and weed control practices on density of *E. colona, C. rotundus* and 'other weeds' in first season and 'other weeds' during second season were significant. The interaction effects clearly showed that weed number and dry matter production in herbicide followed by two hand weeded plots were always higher in DSR plots than in WSR and TPR plots, while between WSR and TPR weed number and dry matter production were similar or less in TPR. Some weed species in TPR or WSR were completely controlled in initial stages. This clearly showed that because of puddling effect weeds were killed in WSR and TPR establishment methods. In TPR by transplanting of one month old seedlings gave age advantage over weeds which suppressed them by reducing its number and dry weight. In case of WSR, crop and weed came together so there was crop-weed competition in initial stages of the establishment. Plots treated with herbicide followed by two hand weedings had lower weed density and dry weight than the weedy plots. Herbicides reduced the weed density and dry weight due to their selective nature and both killing and suppressing effects. Similar observations were reported by Chandar and Pandey (1997).

Table 1. Weeds (No. m^{-2}) at 30 days stage as influenced by crop establishment methods and weed management practices during 2002

Treatment	*E. colona*			*C. axillaris*			*C. rotundus*			Other weeds		
	H+2 HW	WO.	Mean	H+2 HW	WO	Mean	H+2 HW	WO	Mean	H+2 HW	WO	Mean
Establishment methods												
DSR	5 (1.74)	63 (4.16)	34 (2.95)	9 (2.17)	19 (2.96)	14 (2.57)	7 (1.98)	17 (2.59)	12 (2.29)	8 (2.18)	66 (4.17)	37 (3.17)
WSR	2 (1.09)	26 (3.25)	14 (2.17)	5 (1.63)	11 (2.31)	8 (1.97)	0 (0.00)	7 (2.03)	3 (1.01)	0 (0.00)	35 (3.59)	18 (1.79)
TPR	3 (1.44)	7 (2.09)	5 (1.77)	2 (1.09)	4 (1.38)	3 (1.24)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	2 (0.69)	1 (0.35)
Mean	3 (1.43)	32 (3.17)		5 (1.64)	11 (2.22)		2 (0.66)	8 (1.54)		3 (0.73)	34 (0.28)	
				LSD (P=0.05)		LSD (P=0.05)		LSD (P=0.05)		LSD (P=0.05)		
Establishment methods of rice				0.73		NS		0.64		0.91		
Weed management practice				0.31		0.29		0.58		0.58		
For comparing establishment methods at same or different weed management practices				0.53		NS		1.00		1.00		
For comparing weed management practices under same establishment methods				0.82		NS		0.95		1.16		

Values in parentheses were transformed to log (x+1) for analyses.
DSR–Direct dry seeding unpuddled, WSR–Wet seeding in puddled soil, TPR–Transplanted rice, H+2 HW–Herbicide followed by two hand weedings, WO–Weedy. NS–Not Significant.

Table 2. Weeds (No. m^{-2}) at 30 days stage as influenced by crop establishment methods and weed management practices during 2003

Treatment	*E. colona*			*C. axillaris*			*C. rotundus*			Other weeds		
	H+2 HW	WO	Mean	H+2 HW	WO	Mean	H+2 HW	WO	Mean	H+2 HW	WO	Mean
Establishment methods												
DSR	4 (1.61)	5 (1.70)	5 (1.65)	8 (2.13)	15 (2.78)	11 (2.44)	6 (1.58)	14 (2.59)	10 (2.09)	4 (1.55)	6 (1.94)	5 (1.75)
WSR	2 (1.09)	5 (1.72)	3 (1.41)	7 (1.89)	11 (2.43)	9 (2.17)	5 (1.89)	5 (1.84)	5 (1.87)	3 (1.27)	5 (1.83)	4 (1.55)
TPR	0 (0.00)	1 (0.36)	0.3 (0.18)	0 (0.00)	0.6 (0.36)	0.3 (0.18)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)
Mean	2 (0.90)	3 (1.26)		5 (1.33)	9 (1.86)		3 (1.16)	6 (1.48)		2 (0.94)	4 (1.26)	
				LSD (P=0.05)		LSD (P=0.05)		LSD (P=0.05)		LSD (P=0.05)		
Establishment methods of rice				0.59		0.94		0.37		0.28		
Weed management practice				NS		0.45		NS		0.23		
For comparing establishment methods at same or different weed management practices				NS		NS		NS		NS		
For comparing weed management practices under same establishment methods				NS		NS		NS		NS		

Values in parentheses were transformed to log (x+1) for analyses.
DSR–Direct dry seeding unpuddled, WSR–Wet seeding in puddled soil, TPR–Transplanted rice, H+2 HW–Herbicide followed by two hand weedings, WO–Weedy. NS–Not Significant.

Table 3. Weeds dry weight (g m^{-2}) at 30 days stage as influenced by crop establishment methods and weed management practices during 2002

Treatment	*E. colona*			*C. axillaris*			*C. rotundus*			Other weeds		
	H+2 HW	WO	Mean	H+2 HW	WO	Mean	H+2 HW	WO	Mean	H+2 HW	WO	Mean
Establishment methods												
DSR	27.3 (3.20)	158.3 (5.02)	92.8 (4.11)	0.7 (0.40)	2.8 (1.25)	1.7 (0.83)	3.2 (1.25)	8.6 (2.11)	5.9 (1.68)	2.2 (1.10)	5.2 (1.79)	3.7 (1.45)
WSR	12.2 (2.57)	113.8 (4.73)	62.9 (3.65)	0.3 (0.26)	2.8 (1.32)	1.5 (0.79)	0 (0.00)	3.6 (1.52)	1.8 (0.76)	0 (0.00)	2.4 (1.23)	1.2 (0.61)
TPR	7.8 (2.14)	45.9 (3.82)	26.8 (2.98)	0.08 (0.07)	0.7 (0.50)	0.4 (0.29)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1.2 (0.67)	0.6 (0.33)
Mean	15.7 (2.64)	106.0 (4.53)		0.4 (0.25)	2.1 (1.02)		1.1 (0.42)	4.1 (1.21)		0.7 (0.37)	2.9 (1.23)	
				LSD (P=0.05)		LSD (P=0.05)		LSD (P=0.05)			LSD (P=0.05)	
Establishment methods of rice				0.47		NS		0.75			0.61	
Weed management practice				0.54		1.99		0.45			0.33	
For comparing establishment methods at same or different weed management practices				NS		0.34		0.79			NS	
For comparing weed management practices under same establishment methods				NS		0.83		0.93			NS	

Values in parentheses were transformed to log (x+1) for analyses.

DSR–Direct dry seeding unpuddled, WSR–Wet seeding in puddled soil, TPR–Transplanted rice, H+2 HW–Herbicide followed by two hand weedings, WO–Weedy. NS–Not Significant.

Table 4. Weeds dry weight (g m^{-2}) at 30 days stage as influenced by crop establishment methods and weed management practices during 2003

Treatment	*E. colona*			*C. axillaris*			*C. rotundus*			Other weeds		
	H+2 HW	WO	Mean	H+2 HW	WO	Mean	H+2 HW	WO	Mean	H+2 HW	WO	Mean
Establishment methods												
DSR	25.2 (3.26)	29.2 (3.39)	27.2 (3.32)	0.6 (0.39)	3.6 (1.53)	2.1 (1.00)	1.9 (1.06)	9.6 (2.13)	5.8 (1.59)	0.8 (0.58)	4.1 (1.61)	2.4 (1.09)
WSR	1.72 (0.98)	8.9 (2.13)	5.3 (1.56)	0.5 (0.38)	2.7 (1.31)	1.6 (0.85)	2.4 (1.21)	3.0 (1.38)	2.7 (1.30)	0.6 (0.47)	3.8 (1.57)	2.2 (1.02)
TPR	0 (0.00)	2.8 (0.75)	1.4 (0.37)	0.3 (0.00)	1.3 (0.52)	0.6 (0.26)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)
Mean	8.9 (1.41)	13.6 (2.09)		0.3 (0.26)	2.5 (1.12)		1.4 (0.76)	4.2 (1.17)		0.46 (0.35)	2.6 (1.06)	
				LSD (P=0.05)		LSD (P=0.05)		LSD (P=0.05)			LSD (P=0.05)	
Establishment methods of rice				0.87		NS		0.62			0.10	
Weed management practice				0.75		0.47		NS			0.07	
For comparing establishment methods at same or different weed management practices				NS		NS		NS			0.11	
For comparing weed management practices under same establishment methods				NS		NS		NS			0.13	

Values in parentheses were transformed to log (x+1) for analyses.

DSR–Direct dry seeding unpuddled, WSR–Wet seeding in puddled soil, TPR–Transplanted rice, H+2 HW–Herbicide followed by two hand weedings, WO–Weedy. NS–Not Significant.

Table 5. Effect of crop establishment methods and weed control practices on grain yield and yield attributing characters

Treatment	Grain yield (kg ha^{-1})						Number of panicles m^{-2}						Number of grains panicle^{-1}				
	2002			2003			2002			2003			2002			2003	
	H+2 HW	WO	Mean	H+2 HW	WO	Mean	H+2 HW	WO	Mean	H+2 HW	WO	Mean	H+2 HW	WO	Mean	H+2 HW	WO
Mean																	
Establishment methods																	
DSR	5580	1132	3356	5807	1587	3697	302	88	195	303	233	268	117	61	89	151	93
122																	
WSR	5249	1332	3290	6130	2040	4035	420	197	308	438	295	367	112	93	102	142	89
115																	
TPR	5387	1883	3635	5982	2380	4181	237	132	184	260	225	242	151	140	145	173	158
165																	
Mean	5405	1449		5973	2002		320	139		334	251		126	98		155	113
					LSD (P=0.05)		LSD (P=0.05)			LSD (P=0.05)			LSD (P=0.05)			LSD (P=0.05)	
Establishment methods of rice					217		252			23			16		9		18
Weed management practices					193		203			20			16		7		8
For comparing establishment methods at same or different weed management practices					334		352			35			28		12		14
For comparing weed management practices unders same establishment methods					320		353			34			25		12		20

DSR–Direct dry seeding unpuddled, WSR–Wet seeding in puddled soil, TPR–Transplanted rice, H+2 HW–Herbicide followed by two hand weedings, WO–Weedy.

Effect on Crop

The grain yield of rice did not differ significantly due to various establishment methods during both the seasons when plots were treated with herbicide and supplemented with two hand weedings (Table 5). In unweeded plots significantly higher yield was obtained in TPR than in DSR during both the seasons. The difference in grain yields of rice between DSR and WSR was non-significant in first season but during second season WSR and TPR did not differ significantly. The reduction in grain yield due to weeds was highest in DSR followed by WSR and TPR during both the seasons. The grain yields in unweeded plots under all the establishment methods were significantly less than in plots treated with herbicide supplemented with two hand weedings. The grain yield when averaged over weed management practices did not differ significantly in DSR and WSR in first season and between WSR and TPR in second season but yield was significantly higher in TPR than in WSR and DSR during first season, while in next season TPR and WSR had more yield than DSR. There was significant variation in the number of rice panicles per unit area under different establishment methods (Table 5). The number of panicles per unit area was significantly higher in WSR (429 m^{-2}) than in DSR (302 m^{-2}) and TPR (248 m^{-2}). But the number of grains per panicle was significantly higher in TPR (162 $panicle^{-1}$) than in DSR (134 $panicle^{-1}$) and WSR (127 $panicle^{-1}$). Inspite of less number of panicles per unit area in TPR the grain yield was similar to DSR and WSR. This was mainly because of the reason that less number of panicles per unit area was compensated by producing longer panicles and more number of grains per panicle in TPR. On the other hand, reduced panicle length and reduced number of grains per panicle in DSR and WSR did not reduce the yields of rice because the total number of panicles per unit area was much higher in these two systems as compared to TPR (Table 5). Similar observations were reported by Singh *et al.* (2002) and Hobbs *et al.* (2002).

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