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Influence of crop establishment methods and weed management practices on yield and economics of direct-seeded rice (*Oryza sativa*)

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ABSTRACT

A field experiment was conducted during the rainy season of 2006 and 2007 to study the bio-efficacy of various herbicides on weeds, yield and economics of direct seeded rice. The weed flora emerged during experimentation were: grasses like *Echinochloa colonum, Echinochloa crusgalli, Cynodon dactylon*; sedges like *Cyperus rotundus, Cyperus iria, Fimbristylis miliaceae*; and broad-leaved weeds like *Eclipta alba* and *Ceasulia oxilaris*. Rice established by drum seeding method had minimum density of grasses, sedges and broad-leaved weeds and dry weight of grasses (6.18 and 8.77 g/m^2), sedges (3.32 and 4.97 g/m^2), broad-leaved weeds (1.85 and 2.74 g/m^2) at 45 and 60 DAS, N-P-K (4.09-1.53-4.49 kg/ha) uptake by weeds and maximum weed control efficiency (67.02%), grain yield (4.55 t/ha), net return (Rs 24,520) and benefit: cost ratio (1.76). Application of pretilachlor (0.75 kg a.i./ha pre-emergence) followed by 2,4-D (0.50 kg a.i./ha post-emergence) proved to be most effective in minimizing the density of weeds and their dry weight, and in enhancing the weed control efficiency (84.24%), grain yield (4.73 t/ ha), N-P-K uptake by crop, net return (Rs 26,110) and benefit: cost ratio (1.92).

Key words: Direct seeding, Establishment method, Herbicides, Rice, Weeds

Change in the method of crop establishment from traditional manual transplanting of seedlings to direct seeding has occurred in many rice (*Oryza sativa* L.) growing countries in response to increasing production cost, especially for labour and water. Dry seeding with subsequent saturated soil conditions reduced the amount of water required during puddling and thus reduced overall water demand. Direct seeding of rice also aids in quick establishment, early harvest and thus early sowing of wheat (Singh *et al*., 2007). Sowing of pre-germinated rice seeds under puddled condition either manually or drum seeding method reduces the demand of water for puddling and reduced the emergence of weed flora by placing the seed, stems and stolons of weeds into sub-surface.

The direct seeded rice culture is subjected to greater weed competition than transplanted rice because both weed and crop seeds emerge at the same time and compete with each other from the germination resulting in less grain yield. A weed-free period for the first 30-45 days after sowing (DAS) is required to avoid any loss in yield because the dry weight of weeds increases greatly from 30 DAS in dry direct-seeded rice. Uncontrolled weeds reduce the yield by 96% in dry direct-seeded rice, 61% in wet direct-seeded rice (Maity and Mukherjee, 2008). Therefore, the major challenge for farmers is effective weed management, as failure to eliminate weeds may result in low or no yield. Manual removal of weeds is labour intensive, tedious, back breaking and does not ensure weed removal at critical stage of crop-weed competition due to non-availability of labours, and sometimes bad weather condition which does not allow labours to move in the field. Herbicides are more effective in controlling the weeds besides reducing the total energy requirement for rice cultivation. Pre-emergence application of herbicides mainly control weeds in the earlier stages and weeds emerging at later stages of rice growth are not controlled effectively. Hence, the present investigation was undertaken to study the alone and sequential application of herbicides on weed flora, yield, nutrient uptake by weeds and crop, and economics in direct seeded rice under different establishment methods.

MATERIALS AND METHODS

A field experiment was conducted during rainy season of 2006 and 2007 at the farm of Banaras Hindu University, Varanasi, Uttar Pradesh. The soil of the experimental field was Gangetic alluvial having sandy loam in texture with pH 7.4. It was moderately fertile, being low in organic carbon (0.43%), available nitrogen (197 kg/ha), and medium in available phosphorus (23.4 kg/ha) and potas-

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sium (210 kg/ha). The experiment was laid out in split-plot design with three sowing methods, *viz.* wet seeding (broadcasting of sprouted seeds under puddled condition), dry seeding in rows at 20 cm apart and drum seeding in puddled condition in main plots and 8 weed control treatments, viz. butachlor @1.50 kg/ha (pre-emergence); butachlor fb (followed by) 2,4-D @ 0.50 kg/ha (post-emergence) at 20 DAS; pretilachlor @ 0.75 kg/ha (pre-emergence); pretilachlor fb 2,4-D; pendimethalin @1.0 kg/ha (pre-emergence); pendimethalin fb 2,4-D, hand weeding at 20, 40 and 60 DAS and weedy check in sub-plots during both the years. A uniform fertilizer dose of 120-17.6-50-5 kg N-P-K-Zn/ha was applied. Half dose of N and whole of P, K and Zn were applied as basal before sowing. Remaining N was top-dressed in 2 equal splits at active tillering and panicle-initiation stage. Rice 'NDR 359' of 120-125 days duration was used as test variety. Dry seed of rice @ 60 kg/ha was used for dry seeding and pre-germinated seed @ 40 kg/ha was used for wet and drum seeding of rice. The total rainfall received during crop season was 665.6 and 780.8 mm during 2006 and 2007, respectively. Rainfall was very much erratic during the monsoon period of 2006 leading to occurrence of drought, but it was well distributed in 2007. The crop received 4 and 3 irrigations during 2006 and 2007, respectively. Pre-emergence (just after sowing) and post-emergence (20 DAS) herbicides were applied with the help of a hand-operated knapsack sprayer fitted with flat-fan nozzle and water as a carrier at 600 liters/ha. Observations on weeds were recorded with the help of a quadrate 0.5 m × 0.5 m placed randomly at two spots in each plot at 45 and 60 DAS. The data on weeds were subjected to square-root transformation ($\sqrt{x+0.5}$) to normalize their distribution. Data on dry weight of weeds were recorded by cutting weeds at ground level, washed with tap water, sun-dried first followed oven drying at 65°C for 48 hours and then weighed. The N, P and K uptake by weeds were recorded at 60 DAS and by the crop at harvesting with standard methods. Weed control efficiency was calculated using weed dry weight data at 60 DAS which was maximum during weed growth period irrespective of treatments. Economic analysis was done on the basis of prevailing market price of input used and the output obtained from each treatment. Sale price of output (Rs/tonne) was: rice grain, 7,100; rice straw, 1,000; input price (Rs/kg): rice seed, 20; urea, 5.16; di ammonium phosphate, 9.48; muriate of potash, 5.0; Zinc sulphate, 10.0; herbicides (Rs/litre): butachlor, (180); pretilachlor, (450); pendimethalin, (450); 2,4-D ethyl ether, (200); labour wage, (104/man day). The data were analysed separately for year 2006 and 2007 and individual year's data were subjected for pooled analysis to obtain a trend among results over the years.

RESULTS AND DISCUSSION

Weeds

The dominant weed flora associated with experimental field were *Echinochloa colona* (L.), *E. crusgalli* (L.), in grasses; *Cyperus rotundus, C. iria* and *Fimbristylis miliacea* in sedges and *Eclipta alba* (L.) Hassk and *Ceasulia oxilaris* in broad-leaved weeds. Among the weed flora, averaged over two years, the maximum relative percentage was of *Echinochloa crusgalli* (38.20%, 34.23% and 28.64%) *Cyperus iria* (11.35%, 12.33% and 13.27%) and *Eclipta alba* (8.15%, 9.61% and 8.42%) in dry, wet and drum seeding, respectively. The rice established with drum seeding had minimum density and dry weight of weeds, the maximum density was recorded under dry seeding of rice at 45 and 60 DAS (Table 1). This might be due to effect of puddling which placed the seeds, stems and stolons of weeds into sub-surface, as a result these materials could not get favourable atmosphere for their germination, and thereby there was lower weed population during crop period. Subbalakshmi and Pandian (2002) have also reported similar results.

Application of pretilachlor fb 2,4-D showed maximum efficacy in minimizing all kinds of weed flora and proved significantly superior over all the herbicidal treatments. The better performance of pretilachlor could be ascribed to its preferential absorption by *Echinochloa* sp. which was dominant weed flora (Singh *et al*., 2007). The next treatment in this respect was pendimethalin fb 2,4-D (Table 1). Herbicides butachlor, pretilachlor and pendimethalin applied alone were least effective as compared to their sequential application in minimizing the density and dry weight of weeds. This is due to the fact that field was infected with complex weed flora and these being basically grassy herbicides failed to manage broad-leaved weeds. However, all the herbicides were more effective over weedy check in this respect.

The maximum weed control efficiency (WCE) was recorded under drum seeding of rice fb by wet seeding and dry seeding. Among weed control treatments, pretilachlor fb 2,4-D recorded maximum WCE (Table 2). This is due to less number of weeds germinated under this treatment resulting in minimum biomass production. Similar results have been reported by Bahar and Singh (2004). Herbicide applied alone was not as effective as combined application of herbicides in this respect due to their poor control of later emerging weeds.

Interaction effect of sowing methods and weed control treatments were significant for density of grasses (45 and 60 DAS), sedges and broad-leaved weeds at 45 DAS (Table 4) and dry weight of grasses and sedges at 45 DAS (Table 5). Irrespective of sowing methods, minimum density of weeds and their dry weight was recorded under

Table 1. Effect of different sowing methods and weed control treatment on weed density (number./m^2) and weed dry weight (g/m^2)

Treatment	Weed density						Weed dry weight					
	Grasses		Sedges		Broad-leaved weeds		Grasses		Sedges		Broad-leaved weeds	
	45DAS	60DAS	45DAS	60DAS	45 DAS	60 DAS	45 DAS	60 DAS	45 DAS	60 DAS	45 DAS	60 DAS
Sowing method												
Wet seeding	6.34 (39.66)	5.64(31.31)	6.20(37.95)	5.40(28.61)	4.66(21.26)	4.12(16.50)	7.20(51.40)	9.66 (92.82)	3.66(12.87)	5.65(31.43)	2.21(4.39)	2.98 (8.36)
Dry seeding	7.16 (50.72)	7.06(49.38)	6.83(46.10)	6.09(36.64)	5.08(25.26)	4.69(21.47)	8.14(65.76)	12.13(146.75)	4.01(15.61)	6.38(40.26)	2.39(5.21)	3.37(10.86)
Drum seeding	5.44 (29.07)	5.13(25.77)	5.62(31.06)	4.75(22.04)	3.82(14.10)	3.78(13.81)	6.18(37.66)	8.77 (76.35)	3.32(10.55)	4.97(24.20)	1.85(2.93)	2.74 (7.00)
SEm±	0.07	0.06	0.06	0.06	0.05	0.04	0.07	0.10	0.04	0.06	0.02	0.03
CD(P=0.05)	0.21	0.20	0.21	0.18	0.16	0.14	0.24	0.34	0.12	0.19	0.08	0.10
Weed control treatment												
Butachlor(s)	7.00 (48.52)	6.70(44.45)	7.72(59.13)	6.83(46.20)	5.42(28.92)	4.96(24.06)	7.97(63.07)	11.57(133.33)	4.50(19.71)	7.16(50.82)	2.51(5.79)	3.54(12.03)
B fb 2,4-D	6.04 (35.93)	5.83(33.52)	6.44(40.96)	5.42(28.89)	4.53(20.00)	4.26(17.67)	6.87(46.70)	10.05(100.52)	3.76(13.66)	5.68(31.77)	2.12(4.01)	3.06 (8.84)
Pretilachlor (P)	6.49 (41.62)	6.24(38.44)	6.71(44.52)	5.83(33.50)	4.92(23.72)	4.52(19.91)	7.39(54.11)	10.76(115.30)	3.92(14.85)	6.11(36.85)	2.29(4.75)	3.23 (9.96)
P fb 2,4-D	4.41 (18.96)	4.56(20.34)	3.96(15.21)	3.36(10.76)	3.48(11.60)	3.26(10.11)	5.01(24.64)	7.84 (61.00)	2.36 (5.07)	3.51(11.83)	1.68(2.32)	2.36 (5.05)
Pendimethalin (Pm)	6.81 (45.91)	6.59(42.93)	7.47(55.33)	6.57(42.73)	5.34(27.97)	4.93(23.78)	7.76(59.68)	11.37(128.78)	4.35(18.45)	6.89(47.00)	2.47(5.60)	3.52(11.89)
Pm fb 2,4-D	5.77 (32.80)	5.65(31.40)	6.08(36.41)	5.21(26.69)	4.43(19.16)	3.99(15.42)	6.57(42.64)	9.73 (94.17)	3.56(12.14)	5.46(29.36)	2.08(3.84)	2.87 (7.72)
Hand weeding	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71(0.00)	0.71 (0.00)
Weedy check	13.26(175.28)	11.25(126.60)	10.63(112.00)	9.36(87.14)	7.33(53.30)	6.96(48.00)	15.11(227.86)	19.47(378.47)	6.16(37.50)	9.82(95.86)	3.34(10.66)	4.95(24.00)
SEm±	0.09	0.08	0.08	0.07	0.06	0.06	0.11	0.14	0.05	0.08	0.03	0.04
CD (P=0.05)	0.26	0.24	0.23	0.21	0.17	0.16	0.30	0.41	0.14	0.22	0.08	0.11

DAS, Days after sowing

Data were subjected to square root transformation. Data are given in parenthesis are original values.

drum seeding of rice with all the weed control treatments. The minimum weed density and dry weight was associated with the crop treated with pretilachlor fb 2,4-D in all the sowing methods. Application of pretilachlor fb 2,4-D under drum seeding of rice being at par with pretilachlor fb 2,4-D under wet seeding of rice was effective in reducing the density and dry weight of weeds and was found significantly superior over rest of the treatments. The better efficacy of herbicides under drum seeding might be due to emergence of weeds in short span in which most of the weeds were affected by herbicides. The poor efficacy of herbicides under dry seeding was owing to extended period of weed emergence as it provided better environment for emergence of weeds in different flushes and smaller period of herbicide persistence.

Different crop establishment methods and weed control treatments significantly influenced the N, P and K uptake (kg/ha) by weeds (Table 3). Rice established by drum seeding significantly reduced the N-P-K uptake by weeds than wet and dry seeding of rice**.** All the herbicidal treatments significantly reduced the N-P-K uptake by weeds than weedy check. Pretilachlor fb 2,4-D was found most effective in reducing the nutrient uptake by weeds. The next best treatment in these respects was pendimethalin fb 2,4-D.

Crop

The highest yield attributes, *viz.* number of panicles/m^2, 1,000-grain weight and grains/panicle were recorded in drum seeding of rice, mainly due to the lowest weed dry weight and highest weed control efficiency. Among the weed control treatments, the highest yield attributes were recorded with pretilachlor fb 2,4-D due to lowest weed-crop competition during the crop growth (Table 2).

Yield data (Table 2) revealed that among sowing methods, rice established by drum seeding produced significantly higher grain yield than other 2 methods of establishment. Drum seed rice has 6.6 and 16.4% higher grain yield than wet and dry seeding, respectively. The higher grain yield in drum seeding was the result of better weed control efficiency and higher yield attributes. The findings are in agreement with the findings of Bohra *et al*. (2006), Budhar and Tamilselvan (2002).

Weed control treatments showed marked improvement in grain yield and the maximum grain yield (4.73 t/ha) was recorded under pretilachlor fb 2,4-D which was on par with hand weeding treatments (4.87 t/ha) and pendimethalin fb 2,4-D which had grain yield of 4.59 t/ha. This result can be attributed to marked im-

Table 2. Effect of sowing method and weed control treatment on yield attributes, yield and weed control efficiency (pooled data).

Treatment	Yield attributes			Yield		Weed control efficiency (%)
	Panicles/m^2	Grains/panicle	Test weight (g)	Grain	Biological	
Sowing method						
Wet seeding	299.4	128.9	24.37	4.27	10.04	65.78
Dry seeding	263.9	116.3	23.82	3.91	9.36	62.50
Drum seeding	325.2	148.5	26.34	4.55	10.58	67.02
SEm±	3.6	1.7	0.30	0.05	0.12	
CD(P=0.05)	11.8	5.4	0.97	0.17	0.40	
Weed control treatment						
Butachlor (1.5 kg/ha)	281.5	115.0	24.26	4.16	9.95	60.78
Butachlor fb 2,4-D(1.5 fb 0.5 kg/ha)	303.5	138.0	25.08	4.52	10.46	71.90
Pretilachlor (0.75 kg/ha)	297.5	124.8	24.60	4.18	9.99	67.65
Pretilachlor fb 2,4-D(0.75 fb 0.5 kg/ha)	319.9	162.7	26.43	4.73	10.77	84.24
Pendimethalin(1.0 fb 0.5 kg/ha)	292.8	118.0	24.26	4.17	9.97	62.37
Pendimethalin fb 2,4-D(1.0 fb 0.5 kg/ha)	307.4	139.5	25.18	4.59	10.65	73.85
Hand weeding (20, 40 and 60 DAS)	323.0	165.3	26.49	4.87	10.92	100.00
Weedy check	243.8	86.3	22.44	2.72	7.22	0.00
SEm±	3.0	1.3	0.26	0.04	0.10	
CD (P=0.05)	8.6	3.8	0.72	0.12	0.28	

Table 3. Effect of sowing method and weed control treatment on nutrient uptake (kg/ha) by weeds and crop and economics (pooled data)

Treatment	Nutrient uptake by weeds			Nutrient uptake by crop			Cost of cultivation (× 10^3Rs/ha)	Net return (× 10^3 Rs/ha)	B:C ratio
	N	P	K	N	P	K			
Sowing method									
Wet seeding	4.52 (19.95)	1.63 (2.17)	4.94 (23.91)	71.62	17.54	99.0	13.71	22.40	1.63
Dry seeding	4.86 (23.15)	1.89 (3.08)	5.26 (27.21)	63.71	15.28	92.1	14.28	18.91	1.32
Drum seeding	4.09 (16.22)	1.53 (1.83)	4.49 (19.64)	82.04	20.02	112.2	13.91	24.52	1.76
SEm±	0.05	0.02	0.05	0.93	0.22	1.3			
CD(P=0.05)	0.16	0.06	0.17	3.02	0.73	4.1			
Weed control treatment									
Butachlor	5.16 (26.12)	1.87 (2.99)	5.62 (31.10)	64.89	15.74	92.5	13.38	21.98	1.65
Butachlor fb 2,4-D	4.50 (19.79)	1.63 (2.16)	4.85 (22.99)	74.45	19.20	108.1	13.61	24.50	1.80
Pretilachlor	4.93 (23.77)	1.72 (2.47)	5.37 (28.30)	69.68	16.94	95.1	13.46	22.05	1.65
Pretilachlor fb 2,4-D	4.23 (17.43)	1.49 (1.72)	4.54 (20.11)	88.68	21.40	117.5	13.66	26.11	1.92
Pendimethalin	4.93 (23.76)	1.81 (2.79)	5.38 (28.47)	67.49	15.78	92.7	14.27	21.16	1.49
Pendimethalin fb 2,4-D	4.42 (19.08)	1.58 (2.00)	4.76 (22.11)	80.49	19.89	109.9	14.47	24.23	1.68
Hand weeding	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	91.88	21.99	121.4	16.27	24.55	1.51
Weedy check	7.05 (49.20)	2.66 (6.56)	7.96 (62.82)	42.09	9.99	72.0	12.62	10.99	0.88
SEm±	0.06	0.02	0.06	0.74	0.18	1.0			
CD (P=0.05)	0.16	0.06	0.18	2.08	0.50	2.9			

Data were subjected to square root transformation. Figures parenthesis are original values.

provement in dry matter accumulation, yield attributes and better weed control efficiency. The minimum grain yield was recorded under weedy check which was attributed to more weed growth and poor yield attributes formation. The results are in agreement with the findings of Mohan *et al*. (2005).

Drum seeding of rice recorded more number of panicles followed by wet and dry seeding of rice under all the herbicidal treatments (Table 5). The treatment combination of pretilachlor fb 2,4-D and drum seeding of rice was on par with pendimethalin fb 2,4-D under same seeding and produced significantly more number of panicles

Table 4. Interaction between sowing methods and weed control treatments on density of grasses, sedges and broad-leaved weeds (pooled data).

Treatment	Weed density											
	Grasses						Sedges			Broad-leaved weeds		
	At 45 DAS			At 60 DAS			At 45 DAS			At 45 DAS		
	Wet seeding	Dry seeding	Drum seeding	Wet seeding	Dry seeding	Drum seeding	Wet seeding	Dry seeding	Drum seeding	Wet seeding	Dry seeding	Drum seeding
Sowing method												
Butachlor	7.06(49.32)	7.97(63.06)	5.97(35.19)	6.33(39.61)	8.04(64.07)	5.74(32.49)	7.79(60.13)	8.42(70.45)	6.96(47.90)	5.69(31.82)	6.15(37.34)	4.44(19.18)
Butachlor fb 2,4-D	6.03(35.84)	7.02(48.79)	5.06(25.08)	5.42(28.85)	7.23(51.84)	4.85(22.98)	6.48(41.50)	7.26 (2.24)	5.57(30.57)	4.72(21.79)	5.28(27.36)	3.58(12.35)
Pretilachlor	6.29(39.08)	7.53(56.13)	5.65(31.47)	5.71(32.09)	7.65(58.07)	5.36(28.22)	6.85(46.41)	7.73(59.28)	5.55(30.28)	5.12(25.76)	5.65(31.37)	3.99(15.46)
Pretilachlor fb 2,4-D	4.35(18.42)	4.71(21.72)	4.17(16.88)	4.36(18.48)	5.15(26.05)	4.18(17.01)	3.95(15.13)	4.38(18.69)	3.55(12.14)	3.61(12.52)	3.79(13.88)	3.03 (8.70)
Pendimethalin	6.82(46.06)	7.74(59.47)	5.87(33.97)	6.13(37.11)	7.84(61.02)	5.79(33.08)	7.38(53.97)	8.11(65.27)	6.93(47.47)	5.52(29.97)	6.03(35.89)	4.46(19.35)
Pendimethalin fb 2,4-D	5.69(31.93)	6.80(45.75)	4.82(22.71)	5.22(26.71)	7.02(48.77)	4.71(21.67)	5.89(34.19)	6.68(44.07)	5.66(31.55)	4.51(19.84)	5.27(27.26)	3.52(11.90)
Hand weeding	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)
Weedy check	13.75(188.48)	14.77(217.72)	11.26(126.18)	11.25(125.96)	12.86(164.79)	9.66(92.84)	10.56(111.02)	11.32(127.60)	10.01(99.74)	7.44(54.90)	7.73(59.26)	6.83(46.17)
SEm± for W at same M			0.13			0.12			0.12			0.8
CD (P=0.05)			0.37			0.33			0.33			0.24
SEm± for M at same/different W			0.18			0.17			0.18			0.13
CD (P=0.05)			0.59			0.55			0.57			0.43

DAS, Days after sowing
Data were subjected to square root transformation. Figures in parenthesis are original values.

Table 5. Interaction between sowing methods and weed control treatments on weed dry weight (g/m^2), number of panicles and grain yield (pooled data)

Weed control treatment (w)	Weed dry weight						Panicles/m^2			Grain yield (t/ha)		
	Grasses At 45 DAS			Sedges 45 DAS								
	Sowing method (M)											
	Wet seeding	Dry seeding	Drum seeding	Wet seeding	Dry seeding	Drum seeding	Wet seeding	Dry seeding	Drum seeding	Wet seeding	Dry seeding	Drum seeding
Butachlor	8.04(64.12)	9.08(81.97)	6.80(45.74)	4.53(20.04)	4.90(23.48)	4.06(15.97)	297.6	227.7	319.0	4.12	3.91	4.47
Butachlor fb 2,4-D	6.86(46.59)	8.00(63.43)	5.75(32.60)	3.79(13.83)	4.23(17.41)	3.27(10.19)	303.0	285.3	322.3	4.48	4.17	4.90
Pretilachlor	7.16(50.80)	8.57(72.97)	6.44(40.92)	4.00(15.47)	4.50(19.76)	3.25(10.09)	298.5	273.5	320.8	4.17	3.97	4.41
Pretilachlor fb 2,4-D	4.94(23.94)	5.36(28.24)	4.74(21.95)	2.36 (5.05)	2.60 (6.24)	2.13 (4.05)	317.8	287.6	354.2	4.80	4.41	4.99
Pendimethalin (Pm)	7.77(59.87)	8.82(77.31)	6.68(44.16)	4.30(17.99)	4.72(21.76)	4.04(15.82)	305.3	254.2	318.8	4.11	3.97	4.44
Pm fb 2,4-D	6.48(41.51)	7.74(59.47)	5.48(29.52)	3.45(11.90)	3.90(14.70)	3.32(10.52)	306.9	273.6	341.9	4.67	4.21	4.88
Hand weeding	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	317.8	288.5	362.8	4.93	4.49	5.19
Weedy check	15.67(245.02)	16.84(283.03)	12.83(164.03)	6.12(37.01)	6.56(42.53)	5.81(33.25)	248.6	221.1	261.7	2.86	2.14	3.15
SEm± for W at same M			0.15			0.07			4.3			0.60
CD (P=0.05)			0.43			0.19			12.1			1.69
SEm± for M at same/different W			0.21			0.10			9.8			0.14
CD (P=0.05)			0.67			0.34			31.8			0.47

DAS, Days after sowing
Data were subjected to square root transformation. Figures in parenthesis are original values.

over all the other treatment combinations. Pretilachlor fb 2,4-D under drum seeding of rice recorded maximum grain yield than all the other treatment combinations but was found at par to pendimethalin fb 2,4-D and butachlor fb 2,4-D under drum seeding and pretilachlor fb 2,4-D and pendimethalin fb 2,4-D in wet seeding and pretilachlor fb 2,4-D under dry seeding of rice. This was owing to the fact that all the herbicidal treatments under drum seeding produced maximum crop growth, and thereby increased accumulation of photosynthates in reproductive parts, which ultimately brought about marked improvement in yield. Gnanasambandan and Murthy (2000) have also reported that treatments which had better growth and yield attributes had resulted in higher grains yields, accordingly.

The N, P and K uptake by crop was significantly influenced by crop establishment methods and weed management practices (Table 3). The nutrient uptake was highest in drum seeding of rice. Application of pretilachlor fb 2,4-D recorded significantly higher total uptake of N, P and K and was found significantly superior to other weed control treatments.

Economics

Economic analysis of data (Table 3) showed that drum seeding of rice was more effective than wet and dry seeding of rice in realizing higher net returns and benefit: cost ratio.

Net returns and B:C ratio, were maximum with pretilachlor fb 2,4-D. The higher net return and benefit: cost ratio under these treatments was owing to more grain yield and comparatively low cost of pretilachlor as compared to other pre-mergence herbicides.

It can be concluded from the study that drum seeding of rice with the application of pretilachlor @ 0.75 kg/ha (pre-emergence) followed by 2,4-D @0.50 kg/ha (post-emergence at 20 DAS) was found to be most effective for minimizing weed growth and maximizing yield and profits of direct seeded rice.

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