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Efficacy of crop establishment techniques and weed control measures on weed dynamics, weed control efficiency and productivity in rice (*Oryza sativa*)

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ABSTRACT

The field experiment was conducted during *kharif* season 2013 and 2014 at C S Azad University of Agriculture and Technology, Kanpur, Uttar Pradesh to assess the performance of four rice establishment techniques and four weed control measures on weed dynamics, weed control efficiency, productivity and profitability of rice. Weed dynamics were higher in direct seeded rice (DSR) as compared to transplanted rice (TPR). The highest total weed density (214-282 plants/m^2) and total weed biomass (40.5-52.2 g/m^2) were recorded in DSR while the lowest in TPR. The efficacy of *Sesbania* brown manuring was significantly higher in both DSR and TPR. Compared with the weedy plots, two hand weeding at 20 DAS/DAT and 45 DAS/DAT followed by Bispyribac sodium 25 g/ha + (Chlorimuron + metsulfuron) 4 g/ha followed by one hand weeding at 45 DAS/DAT provided significant weed control. In both seasons, weed control efficacy was better in DSR and TPR. Across the weed control measures, the mean weed control efficiency ranged from 59.8 -98.6% and 64.2-98.5% at 30 DAS and maturity stage, respectively. TPR produced the maximum rice grain yields. On an average of both years, weed control treatments produced 21 to 43% higher rice grain yield than the weedy plots.

Key words: Crop establishment techniques, Profitability, Rice, Weed dynamics, Weed control

Manual transplanting of seedlings into puddled soil is the major rice production method in India. Puddling, a process of cultivating soil in standing water, consumes a large quantity of water (Bouman and Tuong 2001). Nowadays, water scarcity is a major concern, as competition between agricultural and industrial consumption of water resources intensifies and climatic unpredictability increases (Mahajan *et al*. 2012). To ensure food security, it is imperative to identify rice production methods that require less irrigation water than the conventional transplanted rice to reduce the cost of cultivation and energy consumption, to sustain productivity, and to increase the profit margin of farmers (Singh and Singh 2010). Among the various factors responsible for low rice production, weeds are considered to be as one of the major limiting factors due to manifold harmful effects. The extent of yield reduction due to unchecked weed growth has been estimated on account of 20-25% for transplanted rice and 40-50% for direct-seeded rice (Moody 1980). Herbicides play a multidimensional towards the reducing weed pressure and enhancing the crop yield. However, prolonged use of herbicides with same mode of action can result in development of herbicide resistance in weeds. Brown manuring with sesbania is another technique to reduce weed problems in transplanted rice. It aimed at suppressing the weeds without affecting the soil physico and chemical properties and its associated microbes. It can be achieved through raising green manure crops as intercrop and killing the same by application of post emergence herbicides. In view of the above facts, the present investigation was undertaken to find out the remunerative crop establishment techniques and effective weed control measures to improve the production and weed control efficiency in rice.

MATERIALS AND METHODS

A field experiment was conducted at Chandra Shekhar Azad University of Agriculture and Technology, Kanpur, Uttar Pradesh during two consecutive *kharif* seasons of 2013 and 2014. This location has a typical sub-tropical climate characterized by hot and dry summers and cool winters. The rainfall received during the crop growing period from June to December was 1104.4 mm in 2013 and 505.7 mm in 2014. Maximum temperature during *kharif* season of 2013 and 2014 ranged from 24.5 to 38.6°C and 21.7 to 45.0°C, respectively. The minimum temperature during *kharif* season of 2013 and 2014 varied from 7.1°C to 25.8°C and 9.7°C to 26.8^0 C. The soil was sandy loam

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in texture with pH 8.1, organic C 0.61%, available N 217.5 kg/ha, available P 21.0 kg/ha and available K 201.5 kg/ha. The experiment was laid out in split plot design with four crop establishment techniques (1. Transplanted rice, 2. Transplanted Rice + brown manuring (*Sesbania*), 3. Direct seeded rice, 4. Direct seeded rice + brown manuring (*Sesbania*) and in main plots and four treatments of weed management practices [1. weedy check. 2. Bispyribac sodium 25 g/ha + (Chlorimuron + metsulfuron) 4 g/ha. 3. Bispyribac sodium 25 g/ha + (Chlorimuron + metsulfuron) 4 g/ha followed by one hand weeding at 45 DAS/DAT. 4. Two hand weeding at 20 DAS/DAT and 45 DAS/DAT] in sub-plots and replicated thrice. Crops were grown as per recommended package of practices. Transplanted field was prepared by one deep ploughing followed by two cross harrowing and levelling. In DSR, seeds were first kept immersing in water for 24 hr and then in moist gunny bags for 36 hr until radical and plumule protrude. A seed rate of 80 kg/ha was used for sowing direct seeding. In TPR, the 21 day's old seedlings were transplanted at 20 cm apart. The sowing was done in first week of June. *Sesbania rostrata* with the seed rate of 30 kg/ha was grown for brown manuring between the rice row under DSR and TPR. *S. rostrata* was then knock down by the application of 2, 4-D 0.5 kg/ha at 25 DAS followed by its mulching with the help of rotary paddy weeder. Pant 12 cultivar of was used for experimental purpose. Sowing of the crop was done on first week of June and harvesting in October during both the experimental years. The weed control efficiency (WCE) calculated by using following formulae:

$$WCE = (WPC\text{-}WPT/WPC) \times 100$$

where, WPC, weed dry weight in control plot; WPT, weed dry weight in treated plot.

RESULTS AND DISCUSSION

Effect of crop establishment techniques and weed control measures on weed dynamics and weed control efficiency

The common weeds infesting the experimental field including grasses were *Echinochloa crusgalli* and *Echinochloa colonum* (L.). Similarly *Leptochloa chinensis* (L.), *C. benghalensis, Eclipta alba* were dominated among broad leaves; *C. species* among sedges and other weeds in both years of experimentation. Among the crop establishment techniques, the lowest total weed density and weed biomass was observed in transplanted rice with brown manuring (TPR + BM) at 30 DAS and maturity stage as compared to direct seeded rice (DSR), where, highest weed density was recorded in both the years of experimentation (Table 1). On an average, DSR showed maximum weed density (214.30 and 189.72/m^2 in 2013; 282.04 and 160.76/m^2 in

Table 1 Effect of crop establishment techniques and weed control measures on total weed dynamics at 30 DAS and at maturity

Treatment	Total density (No./m^2)				Total weed dry biomass (g m^{-2})			
	2013		2014		2013		2014	
	30 DAS	Maturity stage	30 DAS	Maturity stage	30 DAS	Maturity stage	30 DAS	Maturity stage
TPR	4.80	3.82	6.77	4.58	2.17	1.53	3.13	2.33
	(22.57)	(14.07)	(45.36)	(20.46)	(4.20)	(1.83)	(9.32)	(4.94)
TPR + BM	2.91	2.11	4.48	3.44	1.40	3.13	2.17	1.70
	(7.97)	(3.93)	(19.56)	(11.35)	(1.47)	(9.28)	(4.20)	(2.40)
DSR	14.66	13.79	16.81	12.70	6.41	6.10	7.26	6.21
	(214.30)	(189.72)	(282.04)	(160.76)	(40.56)	(36.76)	(52.19)	(38.08)
DSR+ BM	11.82	11.25	14.14	10.69	5.43	5.12	6.12	5.29
	(139.21)	(126.02)	(199.33)	(113.71)	(28.96)	(25.66)	(36.89)	(27.46)
LSD (P=0.05)	0.47	0.56	0.69	0.42	0.18	1.97	0.26	0.19
W0	16.69	15.46	19.91	15.11	7.61	7.52	8.74	7.29
	(278.19)	(238.45)	(395.99)	(227.84)	(57.38)	(56.02)	(75.96)	(52.70)
W1	9.84	8.88	12.48	9.56	4.29	5.12	5.46	4.48
	(96.25)	(78.41)	(155.33)	(90.82)	(17.89)	(25.73)	(29.29)	(19.53)
W2	5.27	4.39	6.71	4.35	2.26	1.87	2.95	2.30
	(27.30)	(18.79)	(44.56)	(18.44)	(4.60)	(3.00)	(8.19)	(4.79)
W3	2.39	2.23	3.09	2.39	1.25	1.36	1.52	1.47
	(5.20)	(4.46)	(9.04)	(5.19)	(1.07)	(1.36)	(1.82)	(1.65)
LSD (P=0.05)	0.43	0.41	0.54	0.42	0.19	1.69	0.24	0.20

TPR= Transplanted rice, BM= Brown manuring, DSR= Direct seeded rice, W0= Control, W1= Bispyribac sodium 25 g/ha + (Chlorimuron + metsulfuron) 4 g/ha, W2= Bispyribac sodium 25 g/ha + (Chlorimuron + metsulfuron) 4 g/ha followed by one hand weeding at 45 DAS/DAT, W3= Two hand weeding at 20 DAS/DAT and 45 DAS/DAT. Data were subjected to $\sqrt{x+0.5}$ transformations before statistical analysis. Figures in parentheses are the original values.

2014) as compared to TPR with BM (7.97 and 3.93 in 2013; 19.56 and 11.35/m^2 in 2014) at 30 DAS and maturity stage, respectively. The weed density and weed biomass reduced at maturity stage. Similarly, the DSR showed higher weed biomass (40.56 and 36.76 g/m^2) than TPR (1.47 and 9.28 g/m^2) at 30 DAS and maturity stage, respectively. Brown manuring with sesbania either in transplanted rice or direct seeded rice significantly reduced the weed density and dry weight. These results are corroborated with the findings of Maity and Mukherjee (2007).

All the weed control treatments resulted in significant reduction in the population density of *Echinochloa* species, *Leptochloa chinensis, C. benghalensis*, *Eclipta alba*, *C.* species and other weeds as compared to weedy check at 30 DAS and at maturity stage of crop growth. Two hand weedings at 20 DAS/DAT and 45 DAS/DAT caused significantly higher reduction in the weed density of *Echinochloa* species, *Leptochloa chinensis, C. benghalensis*, *Eclipta alba*, *C.* species and other weeds recorded at 30 DAS, which, however followed with application of Bispyribac sodium 25 g/ha + (Chlorimuron + metsulfuron) 4 g/ha followed by one hand weeding at 45 DAS/DAT amongst the weed control measures (Table 1). With the advancement of crop growth, the weed density of *Echinochloa* species, *Leptochloa chinensis, C. benghalensis, Eclipta alba, C*. species and other weeds were also increased at 30 days onwards in all the treatments except two hand weedings at 20 DAS/DAT and 45 DAS/DAT and application of Bispyribac sodium 25 g/ha + (Chlorimuron + metsulfuron) 4 g/ha followed by one hand weeding at 45 DAS/DAT. However there was decline trend in the weed population at harvest as compared to the population recorded at previous stages in all the treatments in both the years of experimentation. Population and dry weight was significantly reduced due to herbicidal treatment at all stages of observation. This may be attributed to the inhibition of germination of weeds owing to paralysis of vital metabolic process, viz. cell division, protein synthesis etc and subsequently drying of susceptible weed species (Kumar and Ladha 2011). Increasing trend in the weed population and weed dry weight across various crop stages was observed in all herbicidal treatments and hand weeding, which resulted in reduced weed growth. Across the weed control measures, the mean weed control efficiency ranged from 59.8 -98.6% and 64.2-98.5% at 30 DAS and maturity stage, respectively. Amongst weed management treatments the highest weed control efficiency (98.6% and 98.5) were achieved at 30 DAS and at maturity stage, respectively under two hand weedings at 20 DAS/DAT and 45 DAS/DAT. The second best treatment in increasing weed control efficiency (64.04%) was with the application of Bispyribac sodium 25 g/ha + (Chlorimuron + metsulfuron) 4 g/ha followed by one hand weeding at 45 DAS/DAT (71.32 and 74.40% in 2013 as well as 66.73 and 67.23% in 2014).

Effect of crop establishment techniques and weed control measures on growth and yield attributes of rice

The significantly higher values of crop growth parameters like plant height and dry matter accumulation and yield attributing characteristics, i.e. grains/panicle of rice was recorded under transplanted rice with brown manuring (TPR + BM) treatment at maturity stage. However, the lowest plant heights were recorded under direct seeded rice (Table 2). The growth and yield attributes was diminished under weedy check due to heavy competition with weed flora. Our results were similar with Mishra and Singh (2012) who stated that yield attributes and yield was observed higher due to brown manuring. Transplanted rice with brown manuring provide congenial environment for growth and development due to less weeded plot during the critical period, which increase rice grain yield significantly (Cabangon *et al*. 2000).

With regard to the weed control measures, during both the years of study the highest plant height, dry matter

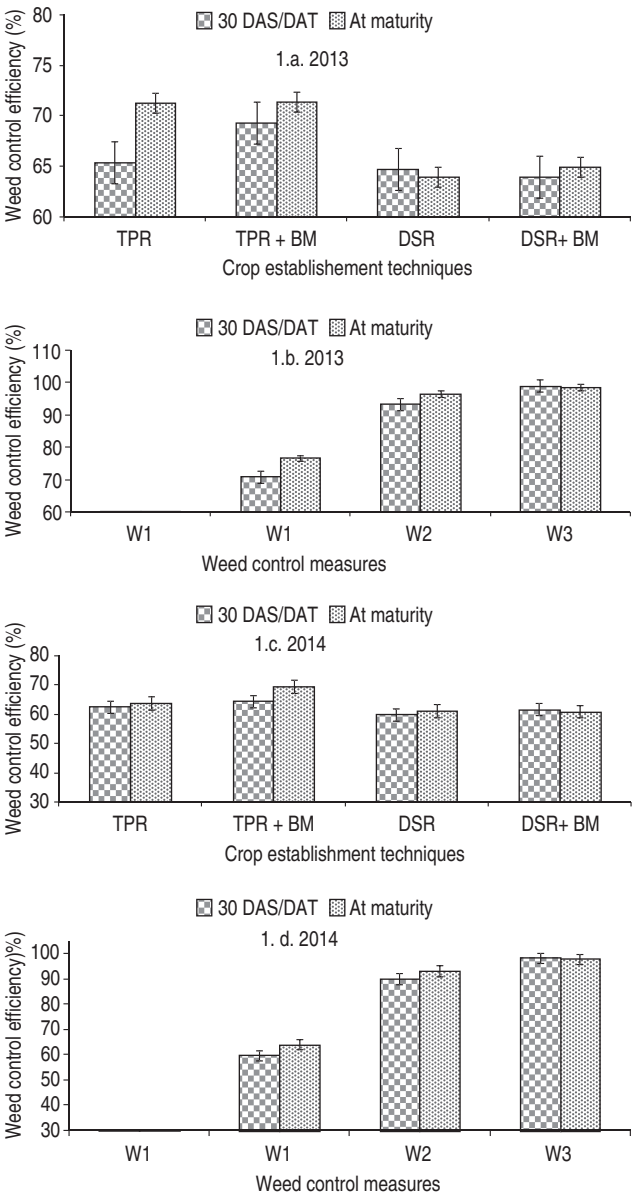

Fig 1 Effect of crop establishment techniques and weed control measures on weed control efficiency.

Table 2 Effect of crop establishment techniques and weed control practices on growth and yield attributes of rice

Treatment	Plant height at maturity (cm)		Dry matter production at maturity (g/m^2)		No. of grains/ panicle	
	2013	2014	2013	2014	2013	2014
Crop establishment techniques						
TPR	82.9	77.1	767.9	732.0	95.8	99.9
TPR + BM	89.4	81.4	787.1	750.5	104.6	109.4
DSR	73.4	70.5	718.5	684.3	87.0	90.1
DSR + BM	76.9	72.4	738.2	703.7	88.4	91.9
LSD (P=0.05)	4.2	3.3	46.0	43.7	9.6	10.9
Weed control						
W0	73.2	69.7	693	667.7	93.83	96.31
W1	79.7	74	752.3	714.7	92.67	96.88
W2	84.3	78.4	779	740.1	93.67	98
W3	85.4	79.4	787.5	748.1	95.67	100.1
LSD (P=0.05)	4.8	5.2	26.4	24.8	NS	NS

accumulation and grains/panicle were recorded with two hand weedings at 20 DAS/DAT and 45 DAS/DAT followed by Bispyribac sodium 25 g/ha + (Chlorimuron + metsulfuron) 4 g/ha followed by one hand weeding at 45 DAS/DAT and lowest with control treatment (Table 2). The resultant of crop growth, they were significantly higher in weed free plot due to no weed competition. This may be assigned to elimination of weed competition at critical stage of growth and concomitant favourable conditions for proper development of plant and increased photosynthetic activity. Significant improvement in all yield attributes except test weight was obtained with the application of all herbicide probably because of lower weed population and dry weight and higher weed control efficiency. Our results are in confirmation with Jaiswal and Singh (2001).

Effect of crop establishment techniques and weed control measures on yield and profitability of rice

The significantly higher grain yield of rice was recorded when rice was planted under transplanted condition with brown manuring of sesbania (5.14 and 5.01 tonnes/ha in 2013 and 2014, respectively) as compared to direct seeded rice (3.65 and 3.54 tonnes/ha in 2013 and 2014, respectively) during both the years of experimentation. Similarly, higher net returns and net return per rupee invested under transplanted rice with brown manuring of sesbania (₹ 53.92 × 10^3 and 3.29, respectively) in 2013 and (₹ 51.92 × 10^3 and 3.21, respectively) in 2014 as compared to other planting methods during both the years of experimentation (Table 3).

Among the weed control treatments, the maximum grain yield (5.25 and 4.98 tonnes/ha in 2013 and 2014, respectively) was obtained with two hand weeding at 20 DAS/DAT and 45 DAS/DAT followed by Bispyribac sodium 25 g/ha + (Chlorimuron + metsulfuron) 4 g/ha followed by one hand weeding at 45 DAS/DAT (4.78 and 4.58 tonnes/ha in 2013 and 2014, respectively) and lowest was observed in control treatment (3.48 and 3.68 tonnes/ha in 2013 and 2014, respectively). Similarly, two hand weedings at 20 DAS/DAT and 45 DAS/DAT followed by Bispyribac sodium 25 g/ha + (Chlorimuron + metsulfuron) 4 g/ha followed by one hand weeding at 45 DAS/DAT and lowest was observed in control treatment to the crops fetched the highest net returns (₹ 56.94 × 10^3 and 52.84 × 10^3 in 2013 and 2014, respectively) and rupee per rupee invested (3.59 and 3.40 in 2013 and 2014, respectively) over other treatments (Table 3). The better performance of these treatments in term of grain yield could be attributed to better expression of their yield attributes due to reduction in crop weed competition as evidenced by higher weed control efficiency and lower weed index. This could be attributed to their selectivity to crop and significant reduction in the weed growth. Dry matter accumulation in straw followed almost similar trend

Table 3 Effect of crop establishment techniques and weed control measures on yield and profitability of rice

Treatment	Grain yield (tonnes/ha)		Straw yield (tonnes/ha)		Net returns (₹/ha)		B: C ratio	
	2013	2014	2013	2014	2013	2014	2013	2014
Crop establishment techniques								
TPR	4.76	4.64	6.84	6.57	49 882	48 007	3.29	3.21
TPR + BM	5.14	5.01	7.44	7.20	53 926	51 922	3.29	3.21
DSR	3.65	3.54	5.10	4.93	37 798	36 122	3.20	3.12
DSR + BM	4.41	4.29	6.32	6.14	47 544	45 744	3.52	3.43
LSD (P=0.05)	0.30	0.39	0.27	0.29	4 261	5 496	0.20	0.22
Weed control								
W0	3.49	3.68	5.08	5.10	34 038	36 687	2.84	2.98
W1	4.43	4.24	6.29	6.03	47 305	44 465	3.46	3.31
W2	4.79	4.59	6.80	6.51	50 866	47 799	3.42	3.27
W3	5.26	4.98	7.53	7.21	56 942	52 844	3.59	3.40
LSD (P=0.05)	0.26	0.25	0.28	0.28	3 549	3 423	0.16	0.16

Table 4 Relationship between total weed dry biomass and grain yield at various growth stages

Weed dry biomass (g/m^2)	2013		2014	
	R^2	Regression equation	R^2	Regression equation
30 DAS	0.9193	y = -0.8923x + 51.975	0.9454	y = -1.0155x + 56.367
60 DAS	0.9235	y = -0.5757x + 51.989	0.9458	y = -0.8727x + 56.352
90 DAS	0.924	y = -0.4895x + 52.335	0.9459	y = -0.6172x + 56.378
Maturity	0.9102	y = -0.9471x + 51.126	0.9469	y = -1.2192x + 56.311

to those obtained in grain yield under different weed control treatments and therefore followed the same result and same justification may hold true.

Relationships between weed biomass and rice grain yield

In both years, a negative linear correlation was found between weed biomass and grain yield (Table 4). Weed biomass had a stronger relationship with grain yield than weed density. The significant negative correlation at 30, 60, 90 DAS and at harvest of weed dry biomass with grain yield further justified that the remarkable effect of TPR + BM and weed management practices (two hand weedings at 20 and 45 DAS/DAT) for yield improvement.

Transplanted rice with brown manuring of sesbania significantly reduces the weed dynamics (density), weed dry weight and found highest weed control efficiency as compared to direct seeded rice. Among weed management practices, two hand weedings at 20 and 45 DAS/DAT significantly reduces the weed dynamics (density), weed dry weight and found highest weed control efficiency as compared to direct seeded rice. Consequently, better performance of these treatments in term of grain yield could be attributed to better expression of their yield attributes due to reduction in crop weed competition as evidenced by higher weed control efficiency and profitability.

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