Indian Journal of Agricultural Sciences **91** (9): 1337–41, September 2021/Article
https://doi.org/10.56093/ijas.v91i9.116082

Effect of sowing and weed control methods on nutrient uptake and soil fertility in direct-seeded rice (*Oryza sativa*)

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Received: 06 January 2021; Accepted: 22 February 2021

ABSTRACT

A 2-year field experiment consisting of 3-planting methods and 5-weed control options was conducted in a three-time replicated split-plot design at Varanasi during *kharif* 2016–17 to assess the nutrient uptake by direct-seeded rice (*Oryza sativa* L.) and available nutrient status of soil under different methods of establishing crop and managing weeds. Zero-till direct-seeded rice (ZT-DSR) + residue + *Sesbania* brown manuring (SBM) recorded lower density and dry-weight of weeds, higher organic carbon (OC), available N, P and K in soil and enhanced N, P and K uptake by 8.9, 6.7, 7.8% and 23.7, 24.5 and 10.2% in grain and straw, respectively, over conventionally-tilled direct-seeded rice (CT-DSR) + SBM. Among weed control options, the use of pendimethalin (1000 g/ha) *fb* chlorimuron + metsulfuron (4 + 4 g/ha, 25 DAS) + 1 HW (45 DAS) resulted in lower density and weeds, higher OC, available N, P and K in soil and improved N, P and K uptake in grain and straw by 23.6, 20.9 and 33.0 and 26.7, 25.5 and 26.6%, respectively over weedy check. However, higher EC and *p*H and lower nutrient (N, P and K) and protein content in grain and straw were found under weed-free condition. Overall, ZT-DSR + residue + SBM and application of pendimethalin (1000 g/ha) *fb* chlorimuron + metsulfuron (4 + 4 g/ha, 25 DAS) + 1 HW (45 DAS) proved better with respect to reduction in weed biomass, OC, available soil nutrients (N, P and K) and their uptake in DSR.

Keywords: Available nutrients, Chlorimuron, DSR, Metsulfuron, Organic carbon, *Sesbania*

Indo-Gangetic plains (IGP) region is the dominant rice (*Oryza sativa* L.) belt of India, where rice is mostly grown by transplanting of 3–6 week-old seedlings into puddled soil with continuous flooding, requiring a huge amount of water from field preparation till crop maturity. Puddled transplanted rice consumes nearly 80% of total water available for agriculture sector in the country (Dass *et al.* 2016), and also deteriorates soil health by dispersion of soil particles and compacting soil apart from causing losses of water through evaporation and deep percolation (Singh *et al.* 2008). Direct-seeded rice (DSR) seems to be a potential alternative and viable rice production system as it saves water and considerably reduces labour requirement by avoiding operations like-puddling and transplanting of young seedlings (Dass *et al*. 2017). ZT-DSR involves retention of at least a part of residues of previous crop on soil surface, thus helps in improving physical and chemical properties of soil by building up of soil organic carbon (SOC), enhancing water infiltration rate (Singh *et al.* 2011), conserving soil moisture and reducing soil erosion (Chauhan *et al.* 2007). Yadav *et al.* (2020) also reported that ZT-wheat with residue (6 t/ha) recorded higher SOC and available N, P and K over conventional tilled wheat without residue. Yet, the adoption of DSR is limited mainly due to severe infestation of weeds, as growing condition of DSR is more conducive for emerging several flushes of weed species (Jabran and Chauhan 2015, Dass *et al*. 2017). Loss of crop yield due to uncontrolled weeds has been found to be up to 85–96% in conventional transplanted rice (Chauhan and Johnson 2011), 98% in ZT-DSR (Singh *et al.* 2011) and further, report is also available which indicates that DSR yield can be enhanced by 15–307% by adopting different weed management strategies (Jabran and Chauhan 2015). In DSR, crop and weeds emerge simultaneously; emerging weed seedlings are more competitive than rice seedlings and lack of water in dry-DSR further aggravate the initial weed infestation (Kashiwar *et al.* 2016). Thus, the current investigation was carried out to determine the effect of different crop establishment and weed management practices on weed density, chemical properties of soil and nutrient accumulation in grain and straw of DSR.

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MATERIALS AND METHODS

A field experiment was carried out at Banaras Hindu University, Varanasi, UP (25° 18' N latitude; 83° 03' E longitude; 75.7 m altitude) in the northern Gangetic alluvial plains during *kharif* seasons of 2016 and 2017. Texture of soil at experimental site was sandy-loam with pH 7.9, potassium dichromate oxidizable SOC 0.43%, alkaline KMnO4 oxidizable–N 205.6 kg/ha, 0.5 M $NaHCO_3$ extractable–P 17.9 kg/ha, and 1 N NH_4OAc extractable–K 222.8 kg/ha. The experiment was laid-out in a split-plot design. Main-plot treatments comprised 3-sowing methods, viz. S_1: zero-till-direct seeded rice (ZT-DSR) + SBM, S_2: zero-till-direct seeded rice (ZT-DSR) + residue + SBM and S_3: conventional till-DSR (CT-DSR) + SBM, while sub-plot treatments included 5-weed control options, viz. WCO_1: pendimethalin (1000 g/ha) *fb* bispyribac-sodium (25 g/ha, 25 DAS), WCO_2: pendimethalin (1000 g/ha) *fb* pyrazosulfuron (30 g/h, 25 DAS) + 1 hand weeding (HW, 45 DAS), WCO_3: pendimethalin (1000 g/ha) *fb* chlorimuron + metsulfuron (4 + 4 g/ha, 25 DAS) + 1 HW (45 DAS), WCO_4: weed-free and WCO_5: weedy-check. Rice (var. Rajendra Kasturi) was sown using 40 kg/ha at 20 cm row spacing and *Sesbania* at 25 kg/ha was manually sown between the crop rows. Co-cultured *Sesbania* was knocked-down with the spraying of 2, 4-D at 0.5 kg/ha. Crop residue (4 t/ha) was uniformly applied in between crop rows in the specified treatments. Crop was uniformly fertilized with 120 kg N, 60 kg P_2O_5 and 40 kg K_2O/ha through urea, single super phosphate and muriate of potash. Half of the N and full dose of P_2O_5 and K_2O were applied at the time of sowing and remaining dose of N was top-dressed in two equal splits at active-tillering and panicle initiation stages. Need based irrigation was given to the crop to maintain favorable soil moisture throughout crop growth during both study years. Plant samples of crop (grain and straw) collected at the time of harvest were dried, processed and analyzed for total N, P and K following standard procedures. Samples of individual weed species from each plot were collected by placing a quadrate of 50 cm × 50 cm size randomly at two spots in each plot, washed with distilled water, grouped into grasses, broadleaved and sedges. Soil samples (0–15 cm depth) were collected from each plot with the help of augur after crop harvest and analyzed using standard procedure. The statistical analyses of data were done using analysis of variance technique as described by Rana *et al.* (2014) and comparison was made at 5% level of significance. Protein content in grain and straw was calculated by multiplying their respective N content with 5.95. Nutrient uptake (N, P and K) was calculated as;

$$\text{Nutrient uptake (kg/ha)} = \frac{\text{Nutrient content (\%)}}{100} \times \text{Grain/straw yield (kg/ha)}$$

RESULTS AND DISCUSSION

EC and pH: None of the crop establishment methods influenced EC and pH significantly, however ZT-DSR + residue + SBM recorded marginally lower EC and pH over CT-DSR + SBM (Table 1). Lower value of EC and *p*H with ZT-DSR + residue + SBM might be due to the fact that residue retained on the soil surface after decomposition released different acids and increased the OC which altogether brought down EC and pH of the soil. The results are in line with the findings of Yadav *et al.* (2020). Further, CT-DSR + SBM recorded higher EC and pH than the other treatments, as residue was not retained in this treatment. Amongst herbicidal treatments, pendimethalin (1000 g/ha) *fb* chlorimuron + metsulfuron (4 + 4 g/ha, 25 DAS) + 1 HW (45 DAS) exhibited lower EC, but lower pH

Table 1 Effect of sowing methods and weed control options on OC, pH and EC and available N, P and K in soil (mean of two years data)

Treatment	Organic carbon (%)	*p*H	EC (dS/m)	Available nutrients (kg/ha)		
				Nitrogen	Phosphorus	Potassium
Sowing methods						
S_1	0.432	7.82	0.19	207.0	17.9	222.8
S_2	0.434	7.80	0.18	208.1	18.8	225.0
S_3	0.430	7.84	0.21	204.6	16.9	222.1
SEm±	0.031	0.04	0.02	1.27	0.58	1.57
CD (P=0.05)	NS	NS	NS	NS	NS	NS
Weed control options						
WCO_1	0.430	7.84	0.20	206.7	17.2	220.7
WCO_2	0.432	7.81	0.19	207.5	17.4	222.6
WCO_3	0.435	7.83	0.18	209.7	17.9	223.8
WCO_4	0.436	7.86	0.23	210.8	18.4	224.9
WCO_5	0.431	7.79	0.22	206.6	16.5	221.8
SEm±	0.020	0.03	0.02	1.075	0.56	2.08
CD (P=0.05)	NS	NS	NS	NS	NS	NS

was found in pendimethalin (1000 g/ha) *fb* pyrazosulfuron (30 g/ha, 25 DAS) + 1 HW, 45 DAS) than the remaining treatments. However, weed-free plots recorded higher pH and EC because this treatment was devoid of any residue hence, possessed less production of organic acids.

Organic carbon (OC): Highest OC was found under ZT-DSR + residue + SBM, which could be attributed to the minimum soil disturbances, residue and root system of the previous crop left in the soil, which leads to accumulation of organic matter. Under zero-tillage or lower intensity of tillage the rate of macro-aggregate formation and degradation leads to formation of stable micro-aggregation in which C is stabilized and sequestrated in the long-run (Vyas *et al.* 2013). In contrary, CT-DSR + SBM recorded lower OC owing to more oxidation of organic matter present in soil as favored by frequent tilling of the soil. Using pendimethalin (1000 g/ha) *fb* chlorimuron + metsulfuron (4 + 4 g/ha, 25 DAS) + 1 HW (45 DAS) recorded higher OC content than the other treatments except weed-free which recorded maximum OC over rest of the treatments (Table 1).

Available N, P and K: Zero-till-DSR + residue + SBM recorded higher available N, P and K than the other treatments (Table 1). This could be ascribed to the fact that residue retained on the soil surface helps in reducing loss of nutrients by covering the soil surface and reducing weed population besides maintaining thermal heat and favorable soil moisture throughout the crop season resulting in increased N, P and K availability in soil. All the herbicidal treatments recorded significantly higher N, P and K over weedy check. However, pendimethalin (1000 g/ha) *fb* chlorimuron + metsulfuron (4 + 4 g/ha, 25 DAS) + 1 HW (45 DAS) recorded higher available N, P and K and followed by pendimethalin (1000 g/ha) *fb* pyrazosulfuron (30 g/ha 20 DAS) + 1 HW, 45 DAS than the other herbicidal treatments. This could be possible through reducing nutrient removal by weeds because of greater control.

Density of weeds: ZT-DSR + residue + SBM resulted in lower density of weeds than CT-DSR + SBM. Lower density of weeds in ZT-DSR + residue + SBM could be ascribed to greater control of weeds by the combined effect of residue as weeds are not able to protrude as residue retained on soil surface and *Sesbania* brown manure exert smothering effect on emerged weeds. However, in CT-DSR + SBM density of weeds was more because repeated tillage operation results in deep buried weed seeds come up on the soil surface and grow more vigorously, accumulation more dry-weight. As obvious, all the herbicidal treatments resulted in a lower density (Fig 1) of weeds than the weedy-check. However, pendimethalin (1000 g/ha) *fb* chlorimuron + metsulfuron (4 + 4 g/ha, 20 DAS) + 1 HW (45 DAS) recorded lower density of weeds due to greater control of weeds over rest of the treatments.

N, P and K content in grain and straw: Neither crop establishment methods nor weed management practices influenced the nutrient content in grain and straw significantly. However, ZT-DSR + residue + SBM recorded lower N, P and K content both in grain and straw than the rest of the treatments (Table 2), might be due to the fact that higher grain and straw yield were recorded under this treatment, and thus, there was a dilution effect in accordance with the Wilcox inverse yield relationship. In contrast to this, CT-DSR + SBM exhibited higher N, P and K in grain and straw owing to significantly lower grain and straw yield than the other treatments. For the same reason, weedy-check recorded higher nutrient (N, P and K) content in grain and straw over herbicidal treatment. Using pendimethalin (1000 g/ha) *fb* chlorimuron + metsulfuron (4 + 4 g/ha, 20 DAS) + 1 HW (45 DAS) recorded lower nutrient (N, P and K) content than the other treatments, could be attributed to the fact that significantly higher grain and straw yield were recorded under this treatment envisaging dilution effect.

N, P and K uptake by the crop: ZT-DSR + residue + SBM showed significantly higher N, P and K uptake by grain and straw over ZT-DSR + SBM and CT-DSR + SBM, which could be attributed to higher grain and straw yield as a result of better growing condition during crop growth period which aids in greater absorption and translocation of nutrients in different plant parts as a result of greater weed control. However, minimum N, P and K uptake was found under CT-DSR + SBM because of lower grain and straw yield owing to more density and dry-weight of weeds results in depletion that is more nutrient by the weeds.

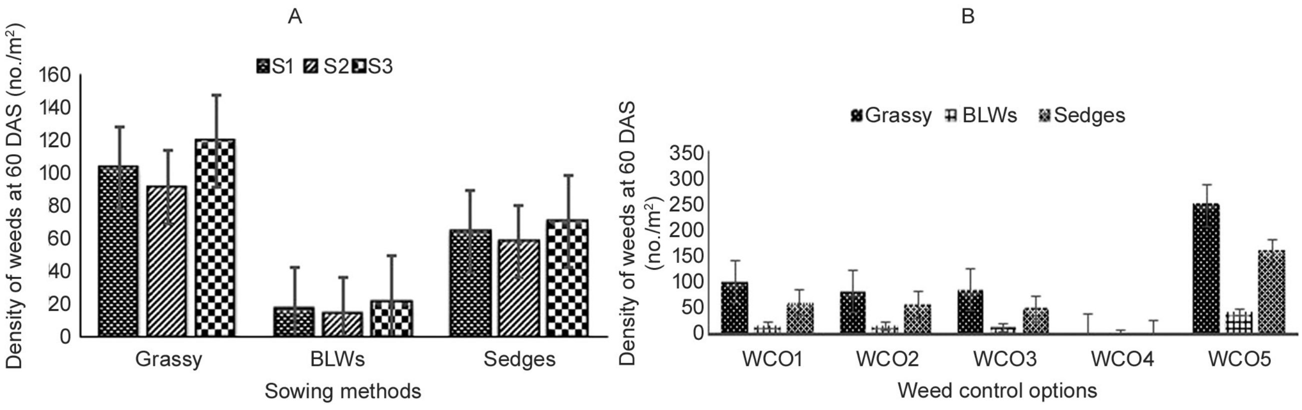

Fig 1 Effect of sowing methods (A) and weed control options (B) on weed density at 60 DAS.

Table 2 Effect of sowing methods and weed control options on protein content, N, P and K content and their uptake by grain and straw (mean of two years data)

Treatment	N content (%)		P content (%)		K content (%)		Protein content (%)		N uptake (kg/ha)		P uptake (kg/ha)		K uptake (kg/ha)	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
Sowing methods														
S_1	1.135	0.705	0.30	0.1125	0.34	1.50	6.75	4.19	27.21	45.58	7.19	7.31	8.15	97.18
S_2	1.095	0.685	0.29	0.1115	0.35	1.49	6.52	4.08	27.68	54.70	7.34	8.94	8.85	119.21
S_3	1.145	0.715	0.31	0.1155	0.37	1.74	6.81	4.25	25.41	44.22	6.88	7.18	8.21	108.15
SEm±	0.05	0.065	0.035	0.003	0.05	0.26	0.30	0.39	0.50	1.62	0.12	0.52	0.22	3.07
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	1.53	4.89	0.38	1.56	0.66	9.19
Weed control options														
WCO_1	1.135	0.705	0.31	0.1135	0.35	1.59	6.75	4.19	26.46	46.73	7.29	7.52	8.31	105.26
WCO_2	1.125	0.695	0.29	0.1135	0.34	1.55	6.69	4.14	27.05	46.74	7.04	7.62	8.33	104.08
WCO_3	1.105	0.695	0.29	0.1125	0.35	1.56	6.57	4.14	28.36	50.81	7.51	8.21	9.14	113.92
WCO_4	1.075	0.685	0.28	0.1115	0.34	1.55	6.40	4.08	29.05	56.17	7.64	9.18	9.34	127.64
WCO_5	1.195	0.725	0.32	0.1185	0.35	1.63	7.11	4.31	22.94	40.10	6.21	6.54	6.87	90.02
SEm±	0.03	0.045	0.02	0.002	0.03	0.24	0.18	0.27	0.25	1.34	0.07	0.24	0.14	2.81
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	0.76	4.02	0.22	0.73	0.43	8.42

Application of pendimethalin (1000 g/ha) *fb* chlorimuron + metsulfuron (4 + 4 g/ha, 20 DAS) + 1 HW (45 DAS) resulted in higher N, P and K uptake by grain and straw over rest of the herbicidal treatments (Table 2). This could possibly be due to lesser depletion of soil nutrient by the weeds under this treatment leaving aside larger quantities of nutrients for absorption by and translocation in different parts of rice plant. Similar were the findings of Rao *et al.* (2016).

Protein content: CT-DSR + SBM recorded higher protein content in grain and straw over ZT-DSR + SBM and ZT-DSR + residue + SBM (Table 2). As protein content is directly related with N content in grain and straw, the higher protein content in CT-DSR + SBM could be due to higher N content in both grain and straw than the other treatments. Lower protein content in grain and straw was recorded in ZT-DSR + residue + SBM than the other treatments because of higher grain yield exerting a N dilution effect. Amongst herbicidal treatments, pendimethalin (1000 g/ha) *fb* chlorimuron + metsulfuron (4 + 4 g/ha, 20 DAS) + 1 HW (45 DAS) recorded lower protein content in grain and straw owing to lower N content in grain and straw than the other treatments.

Based on results of the 2-year field experimentation, it could be concluded that ZT-DSR + residue + SBM proved superior to CT-DSR + SBM for reducing overall density of weeds and improving OC, and available N, P, K in soil as well as total N, P and K uptake by the direct-seeded rice crop. Among weed management practices application of pendimethalin (1000 g/ha) *fb* chlorimuron + metsulfuron (4 + 4 g/ha, 20 DAS) + 1 HW (45 DAS) found better with respect to EC, *p*H and available SOC, N, P, K in soil and nutrient uptake by rice crop.

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