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Conservation Agriculture- Based Planting Techniques and Weed Management Practices Influence on Nutrient Content and Their Uptake in Dry Direct-Seeded Rice (*Oryza sativa* L.)

Brijesh Kumar Chaudhary [a≡*], J. P. Singh [aϖ], S. K. Verma [a#], Harsita Nayak [a≡] and Shiv Poojan Yadav [a≡]

[a] Department of Agronomy, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi-221005, India.

Authors' contributions

This work was carried out in collaboration among all authors. Author BKC designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors JPS and SKV managed the analyses of the study. Author HN managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Conventionally established rice leads to major challenges in crop production like soil health degradation, water table declination and labour scarcity which ultimately increases the cost of production. To address these issues of transplanted rice, different conservation agriculture (CA) based crop establishment practices in combination with suitable weed management options were incorporated to sustain rice productivity. The field trial was conducted for two years during *kharif* season of 2018 and 2019 at Research Farm, Banaras Hindu University, Varanasi, Uttar Pradesh (India). The experiment was laid out in split plot design having four planting techniques in main plots v*iz.*, farmer's practice (Conventional Transplanting), zero-till direct seeded rice (ZT-DSR), reduced-till direct seeded rice (RT-DSR) (Rotavator single pass) and conventional-till direct seeded rice (CT-DSR) and five weed management practices v*iz.,* pendimethalin 1 kg ha^{-1} pre-emergence

[≡] *Research Scholar*
[ϖ] *Professor;*
[#] *Assistant Professor;*
**Corresponding author: E-mail: brijeshchaudhary68@gmail.com;*

(PE) *followed by (fb)* chlorimuron + metsulfuron (4g + 4g ha^{-1}) at 20 days after sowing (DAS), pendimethalin 1 kg ha^{-1} PE *fb* pyrazosulfuron (30 g ha^{-1}) at 20 DAS, bispyribac-sodium + chlorimuron + metsulfuron (25g + 4g + 4g ha^{-1}) at 20 DAS, hand weeding at 20 and 40 DAS and Weedy check in sub-plots and replicated thrice. The results showed that Nitrogen (N), Phosphorus (P) and Potassium (K) content in grain and straw were not significantly influenced by planting techniques and weed management practices. However, among various crop establishment methods CT-DSR recorded significantly higher N, P and K uptake by both grain and straw over rest of the treatments except ZT-DSR during both the years. Similarly, two hands weeding (at 20 DAS and 40 DAS) recorded the highest N, P and K uptake by the crop. With respect to herbicidal treatments, higher N, P and K uptake by crop was found with the application of pendimethalin 1 kg ha^{-1} (pre-em) *fb* chlorimuron + metsulfuron (4g + 4g ha^{-1}) at 20 DAS compared to others during both the years of experimentation. Based on the results, it is concluded that application of pendimethalin 1 kg ha^{-1} PE *fb* chlorimuron + metsulfuron (4g + 4g ha^{-1}) at 20 DAS to CT-DSR was registered maximum N, P and K uptake by both grain and straw of rice.

Keywords: Direct-seeded rice (DSR); planting techniques; reduce-tillage; weed management and zero-tillage.

1. INTRODUCTION

Rice (*Oryza sativa* L.) is one of the staple foods of the world. About 90% of the world's rice is produced and consumed in Asia to provide up to three-fourths of the total calories required by 520 million Asians. The term 'rice is life' is most appropriate for India as it plays a vital role in national food security [1]. The most common growing method of rice is manual transplanting of seedlings in puddled soils by creating an impermeable soil layer which causes destruction of the soil structure; ground water depletion and labour crisis leading to high cost of cultivation [2]. Globally, rice consumes only 800-1000 litres of water to produce 1 kg paddy whereas, about 3,000-5,000 litres of water is required in south Asian countries [2] depending on the different rice cultivation methods. Therefore, to overcome water scarcity and labour problem in rice production system, farmers are gradually shifting towards less-water demanding techniques. Among rice growing eco-systems, direct-seeded rice (DSR) has emerged as an alternate and pragmatic approach to tackle the issues of water scarcity, labour shortage and imparting sustainability to the rice cultivation [3,4,5]. Dry-DSR is gaining popularity regarding its high water use, labor use and energy use efficiencies [6].

Changing cultivation practices from transplanted to DSR not only affects composition of weed species, but also influences dynamics of weed seed bank of surface soil [7,8]. Vigorous preponderance of weeds due to initial agronomic practices in DSR is one of the factors which limits potential yield realization of direct-seeded rice [9,10]. Many researchers have reported that weed infestation during early stage of crop growth resulted in 33-74 % yield reduction or sometimes reduction in productivity up to 75-80% in DSR [11,12] depending upon the weed type and weed density. Hence, appropriate weed management tactics have always been a major focus to overcome the risk of crop failure in DSR. Though manual weeding is considered to be the best, but labours scarcity and increased wages are the emerging constraints in the recent past. Moreover, hand weeding is time consuming and also severely affected by continuous rains and soil condition [13]. Since, both the crop and weeds emerge simultaneously, weed control through herbicides could be a practical as well as economical weed management option in DSR. Hence, the present investigation was conducted to find out most suitable crop establishment method along with appropriate herbicide combinations for greater nutrient content as well as uptake in direct-seeded rice.

2. MATERIALS AND METHODS

2.1 Experimental Site

The experimental site is situated at 25°18' North latitude and 83°03' East longitudes with an elevation of 75.70 meters above the mean sea level having semi-arid to sub-humid subtropical climate being subjected to occasional extreme weather conditions *i.e.* extremely hot in summer and cold in winters. The total rainfall of 777.7 mm and 1113.7 mm was received during the crop season in 2018 and 2019 respectively. During the growing period, the minimum and maximum temperature ranged between 11.7°C-27.9°C and

28.1°C-35.5°C in 2018 and 11.2°C-27.1°C and 27.8°C-39.9°C in 2019, respectively. The mean weekly maximum relative humidity recorded in the range of 77 to 93% and 82 to 95% in the first and second year, respectively. While, the mean weekly minimum humidity recorded between 70 to 88% and 41 to 82% in the first and second year, respectively. The soil of the experimental site was sandy clay loam in texture having low organic carbon and available nitrogen and medium in available phosphorus and potassium. Initial soil properties of the experimental site during both the years of experimentation are presented in Table 1.

2.2 Design and Treatments Details

The experiment was conducted at Research farm of Institute of Agricultural Sciences, Banaras Hindu University, Varanasi during *kharif* (June-September) season of 2018 and 2019. The experiment was laid out in split plot design with three replications assigning four planting techniques *viz*., farmer's practice (Conventional Transplanting), zero-till DSR (ZT-DSR), reduced-till DSR (RT-DSR) (Rotavator single pass) and conventional-till DSR (CT-DSR) in main plots and five weed management practices *viz*., pendimethalin 1 kg ha^{-1} PE *fb* chlorimuron + metsulfuron (4g + 4g ha^{-1}) at 20 DAS, pendimethalin 1 kg ha^{-1} PE *fb* pyrazosulfuron (30g ha^{-1}) at 20 DAS, bispyribac-sodium + chlorimuron + metsulfuron (25g + 4g + 4g ha^{-1}) at 20 DAS, Hand weeding at 20 and 40 DAS and Weedy check were in sub-plots.

2.3 Field Preparation

After harvesting of *rabi* wheat, the field was deep ploughed by mouldboard plough in summer and left open to expose weed seeds and eggs of harmful insects. Pre-sowing light irrigation was applied before field preparation. When the field reached at optimum moisture, experimental field was laid out as per the treatment specifications and sowing was done by using seed rate 30 kg ha^{-1} for nursery raising in transplanted rice and 60 kg ha^{-1} in DSR. Rice variety, HUR-105 (Malviya Sugandh-105) known for its promising performance under irrigated conditions of Varanasi region of the Eastern Uttar Pradesh was used as the test crop for the investigation.

2.4 Nutrient Application and Plant Protection Measures

Irrespective of the treatment, an equal dose of 120 kg N, 60 kg P_2O_5, 60 kg K_2O and 5 kg $ZnSO_4$ ha^{-1} was applied in all the treatments through urea (46% N), DAP (18% N and 46% P_2O_5), muriate of potash (60% K_2O) and zinc sulphate monohydrate (33%) respectively. Whole dose of P and K and half of N were applied at the time of field preparation. Remaining half dose of nitrogen were split up into two equal parts and applied at the time of maximum tillering and panicle initiation stage. Zinc fertilizer was applied at the time of field preparation as prophylactic measure to avoid khaira disease of rice. Two spray of fungicide propiconazole @ 200 ml ha^{-1} and copper oxychloride @ 500 g ha^{-1} mixed in 500 litres water was done to control the brown spot disease of rice.

2.5 Data Collection

2.5.1 Soil properties

Analysis of initial soil chemical properties was done before the commencement of experiment by following standard procedures (Table. 1). Firstly, a representative soil samples from plough layer were collected, oven dried and processed. The pH and EC of soil was measured with the help of a pH meter and conductivity meter respectively by maintaining the soil-water ratio of 1:2.5 as described by Jackson [14]. The soil organic carbon and available N, P and K in soil sample were analysed by Walkley and Black method [15], Modified macro-Kjeldahl method of Subbiah and Asija [16], ascorbic acid method of Olsen et al. [17] and neutral normal 1N NH4OAc (pH 7.0) of Jackson [14], respectively.

2.5.2 Plant sample analysis

The typical plant samples (grain and straw) from harvested crop were collected separately, oven dried, ground in willey mills and analysed for N, P, and K content. The plant samples for N, P and K content were estimated by modified Kjeldahl, Vanadomolybdate phosphoric yellow colour and Flame photometer method as described by Jackson [14], respectively and subsequently their uptake by grain as well as straw were worked out with the help of following formula-

$$\text{Nutrient Uptake (kg/ha)} = \frac{\text{Nutrient content (\%)} \times \text{Dry matter yield (kg /ha)}}{100}$$

2.5.3 Data analysis

The date recorded from the experimentation was subjected to statistical analysis by using analysis of variance as described by Gomez and Gomez [15] and the comparisons were made at 5 per cent level of significance.

Table 1. The initial soil chemical properties of experimental field (plough layer)

Particulars	Values		Method employed	Reference
	2018-19	2019-20		
Chemical analysis				
pH (1: 2.5 of Soil: Water)	7.22	7.33	Glass electrode digital pH meter	Jackson (1973)
Electrical conductivity (dSm^{-1}) at 25°C	0.26	0.29	Using ELICO conductivity bridge	Jackson (1973)
Organic carbon (%)	0.41	0.43	Walkley and Black rapid titration method	Walkley and Black (1934)
Available nitrogen (kg ha^{-1})	226.12	234.54	Alkaline permanganate method	Subbiah and Asija (1956)
Available phosphorus (kg ha^{-1})	17.24	19.15	0.5 M $NaHCO_3$ (pH 8.5) spectrophotometric method	Olsen *et al*. (1954)
Available potassium (kg ha^{-1})	179.38	186.49	Flame photometric method using neutral normal ammonium acetate extract	Jackson (1973)

3. RESULTS AND DISCUSSION

3.1 Nutrients (N, P AND K) Content and Uptake by Grain and Straw

Perusal of data presented in Table 2 revealed that nitrogen (N), phosphorus (P) and potassium (K) content in grain and straw were not reached up to the level of significant due to the execution of different planting techniques and weed management practices during both the years of study. These results are in close conformity with the findings of Nazir et al. [19], and Sanjay et al. [20]. Contrastingly, the uptake of N, P and K by grain and straw was significantly influenced by different planting techniques and weed management practices during both the years of experimentation (Table 3). Among the planting techniques, CT-DSR recorded distinctly superior N, P and K uptake by grain and straw over RT-DSR (Rotavator single pass) and farmer's practice (Conventional Transplanting.) being statistically at par with ZT-DSR during both the years of investigation. This could be attributed to better establishment of rice crop as maximum plant dry matter accumulation, minimum weed density as well as dry matter and reduced nutrient depletion by weeds were advocated by the establishment method leading to more availability of these nutrients to the crop which ultimately increased N, P and K uptake efficiently. These findings are in consonance to results reported by Chongtham et al. [21].

All the weed management practices recorded significantly more N, P and K uptake by grain and straw over weedy check during both the years of observation. Two hands weeding (at 20 and 40 DAS) registered significantly higher N, P and K uptake by grain and straw due to minimum competition for growth factors between crop and weed resulting more availability of these resources to the crop over any other herbicidal treatments. Kumar et al. [22] also had similar opinion. However, among the herbicidal treatments, the highest value of N, P and K were uptake by grain and straw were recorded where pendimethalin 1 kg ha^{-1} (pre-em) *fb* chlorimuron + metsulfuron (4g + 4g ha^{-1}) at 20 DAS were applied in comparison to other treatments. Nevertheless, it remained statistically at par with the application of bispyribac-sodium + chlorimuron + metsulfuron (25g + 4g + 4g ha^{-1}) at 20 DAS. The highest uptake of N, P and K in this treatment might be due to the marked improvement in dry matter production, yield attributes and minimum crop weed competition. These observations are close agreement with the research findings of Kumar et al. [22] and Verma et al. [23].

Table 2. Effect of planting techniques and weed management practices on nitrogen, phosphorus and potassium content in grain and straw in DSR at harvest

Treatments	N content in grain (%)		N content in straw (%)		P content in grain (%)		P content in straw (%)		K content in grain (%)		K content in straw (%)	
	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019
Planting techniques												
Farmer's practice (Conventional Transplanting)	1.17	1.16	0.73	0.72	0.32	0.31	0.127	0.126	0.34	0.33	1.49	1.48
ZT-DSR	1.14	1.13	0.70	0.69	0.29	0.28	0.123	0.122	0.31	0.30	1.46	1.45
RT-DSR (Rotavator single pass)	1.15	1.14	0.71	0.70	0.30	0.29	0.124	0.123	0.33	0.31	1.47	1.46
CT-DSR	1.10	1.09	0.69	0.68	0.28	0.27	0.119	0.118	0.30	0.29	1.42	1.41
SEm ±	0.02	0.02	0.02	0.02	0.02	0.02	0.016	0.016	0.02	0.02	0.02	0.02
CD (*P*=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Weed management practices												
Pendimethalin 1 kg ha^{-1} PE *fb* Chlorimuron + Metsulfuron (4g + 4g ha^{-1}) at 20 DAS	1.11	1.10	0.70	0.69	0.29	0.28	0.121	0.120	0.31	0.30	1.43	1.42
Pendimethalin 1 kg ha^{-1} PE *fb* Pyrozosulfuron (30 ha^{-1}) at 20 DAS	1.15	1.14	0.72	0.71	0.31	0.30	0.126	0.125	0.33	0.32	1.47	1.46
Bispyribac-sodium + Chlorimuron + Metsulfuron (25g + 4g + 4g ha^{-1}) at 20 DAS	1.14	1.13	0.71	0.70	0.30	0.29	0.122	0.121	0.33	0.31	1.46	1.45
Hand weeding at 20 and 40 DAS	1.10	1.09	0.68	0.67	0.27	0.26	0.120	0.119	0.29	0.28	1.42	1.41
Weedy check	1.20	1.19	0.73	0.72	0.32	0.31	0.127	0.126	0.35	0.32	1.52	1.51
SEm ±	0.01	0.01	0.02	0.02	0.02	0.02	0.013	0.013	0.02	0.02	0.01	0.01
CD (*P*=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 3. Effect of planting techniques and weed management practices on nitrogen, phosphorus and potassium uptake by grain and straw in DSR at harvest

Treatments	N uptake by grain (kg ha^{-1})		N uptake by straw (kg ha^{-1})		P uptake by grain (kg ha^{-1})		P uptake by straw (kg ha^{-1})		K uptake by grain (kg ha^{-1})		K uptake by straw (kg ha^{-1})	
	2018	**2019**	**2018**	**2019**	**2018**	**2019**	**2018**	**2019**	**2018**	**2019**	**2018**	**2019**
Planting techniques												
Farmer's practice (Conventional Transplanting)	34.09	36.30	21.53	23.85	5.63	6.33	3.43	4.19	9.16	10.07	73.82	78.57
ZT-DSR	44.92	48.67	32.62	36.65	9.65	11.06	8.30	10.74	13.43	15.05	94.46	102.68
RT-DSR (Rotavator single pass)	41.26	43.46	24.34	27.17	7.88	8.52	5.71	6.53	11.57	12.12	88.86	92.50
CT-DSR	46.60	50.61	34.43	38.26	10.57	12.03	9.65	11.56	14.47	16.25	97.01	105.89
SEm ±	1.15	1.28	2.27	3.15	0.88	1.06	1.19	1.42	1.05	1.06	4.67	5.41
CD (*P*=0.05)	3.99	4.44	7.86	10.91	3.05	3.67	4.13	4.91	3.63	3.65	16.17	18.71
Weed management practices												
Pendimethalin 1 kg ha^{-1} PE *fb* Chlorimuron + Metsulfuron (4g + 4g ha^{-1}) at 20 DAS	46.80	51.08	32.54	36.99	9.94	11.24	8.86	10.56	14.03	15.57	100.02	107.90
Pendimethalin 1 kg ha^{-1} PE *fb* Pyrozosulfuron (30 ha^{-1}) at 20 DAS	42.86	43.64	27.61	28.48	8.01	8.70	6.15	7.29	12.11	12.82	89.49	91.19
Bispyribac-sodium + Chlorimuron + Metsulfuron (25g + 4g + 4g ha^{-1}) at 20 DAS	44.68	48.80	31.38	35.00	9.18	10.42	6.99	8.72	13.22	14.68	94.71	102.71
Hand weeding at 20 and 40 DAS	54.51	58.37	38.94	45.33	11.66	13.14	10.52	12.79	16.25	17.99	114.44	126.24
Weedy check	19.73	21.90	10.67	11.61	3.38	3.92	1.32	1.92	5.18	5.81	44.03	46.50
SEm ±	1.10	1.15	2.24	2.89	0.77	0.80	1.11	1.23	0.86	1.05	3.96	4.10
CD (*P*=0.05)	3.18	3.31	6.44	8.33	2.22	2.30	3.20	3.53	2.48	3.04	11.41	11.80

4. CONCLUSION

It may be inferred from the above investigation that rice crop harvested maximum N, P and K by both grain and straw in conventional-till DSR followed by ZT-DSR. Similarly, among several weed management practices, two hand weeding at 20 DAS and 40 DAS found superior with respect to uptake of N, P and K by rice crop. However, as per the economics, application of pendimethalin 1 kg ha^{-1} (pre-em) *fb* chlorimuron + metsulfuron (4g + 4g ha^{-1}) at 20 DAS was effective in acquisition of N, P and K in both grain and straw of rice over other herbicidal treatments.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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