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Effect of weed management practices on crop establishment methods on yield and yield attributes of rice (*Oryza sativa* L.) in Vertisols of Chhattisgarh

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Abstract
A field experiment was conducted at Instructional Farm, DKS College of Agriculture and Research Station, Bhatapara (C.G.) during *Kharif* season of 2021. The experiment was laid out in split plot design with 3 replications. Crop establishment methods and weed management practices were recorded to have significant influence on yield attributes and yield of rice. SRI method was significantly superior over conventional transplanting. Weed free check recorded significantly higher number of tillers plant^{-1}, number of panicle hill^{-1}, panicle length, Number of grains panicle^{-1}, panicle weight and test weight. Weed free check recorded significantly higher grain yield (6400 kg ha^{-1}), straw yield (8826 kg ha^{-1}) and biological yield (15227 kg ha-1) over rest of the treatments. Two hand weeding at 20 and 40 DAT followed by weed control using conoweeder at 10, 20 and 30 DAT were the next best treatment after weed free check. Among the herbicidal weed management practices, post emergence application of bispyribac-sodium 10% SC @ 20 g a.i. ha^{-1} showed supremacy for yield parameters over weedy check. A combination of SRI + weed free-check (C_2W_2) recorded maximum net returns (₹79595) and benefit: cost ratio (1.37).

Keywords: SRI, transplanting, weed management, crop establishment, rice

1. Introduction
Rice (*Oryza sativa* L.) is one of the most important cereal crops, rice grown in India and South East Asia is a plant of Asian origin. It belongs to family Poaceae (Gramineae) sub-family Bamboosoideae, tribe Oryzae.
Globally, rice is cultivated in 154 million ha area with an annual production of around 426 million tonnes with average productivity of 2.76 t ha^{-1} (Jagtap *et al*., 2019) [8].
Rice is considered to be the backbone of Indian food security system. In India rice is grown in 44.86 million ha with production of 109.15 million tones with average productivity of 2390 kg ha^{-1}. Uttar Pradesh has largest area of rice i.e. 5.81 million ha with production of 13.38 million tonnes (Anonymous, 2018) [2].
Chhattisgarh state is popularly known as "Rice bowl of India" because maximum area is covered under rice during *kharif* and contribute major share in national rice production. The state is dependent on monsoon with an annual rainfall 1200-1600mm. In the Chhattisgarh state, rice is mainly grown under rainfed ecosystem. The productivity of rice in Chhattisgarh is 2767 kg ha^{-1} which is considered to be low as compare to Punjab (4366 kg ha^{-1}), Tamil Nadu (3923 kg ha^{-1}), Andhra Pradesh (3792 kg ha^{-1}), Haryana (3181 kg ha^{-1}), Telangana (3176 kg ha^{-1}), and west Bengal (2926 kg ha^{-1}).

2. Materials and Methods
The experiment was carried out at the Instructional Farm Dau Kalyan Singh College of Agriculture and Research Station Bhatapara (C.G.) The field had an even topography and good drainage system. The main plot treatment consisted of two crop establishment methods *viz.* conventional transplanting (C_1) and System of Rice Intensification (C_2). Sub-plot treatments were weedy check (W_1), weed free-check (W_2), interculture by conoweeder 10, 20 and 30 DAT (W_3), two hand weeding at 20 and 40 DAT (W_4), bispyribac-sodium 10% SC @ 20 g a.i. ha^{-1} at 20 DAT (PoE) (W_5) and fenoxaprop-p-ethyl 9.3% EC @ 56.25 g a.i. ha^{-1} and chlorimuron ethyl 10% WP + metsulfuron methyl 10% WP @ 4 g a.i. ha^{-1} at 20 DAT (PoE) (W_6). The experimental soil was medium in organic carbon (0.61%), low in nitrogen (117.56

kg ha^{-1}), medium in phosphorus (20.50 kg ha^{-1}) and high in potassium (382 kg ha^{-1}). Rice variety 'IGKVR-1' (Rajeshwari) was transplanting as a test crop on July 30^{th}, 2021. The crop was harvested on November 11^{th}, 2021. For the nursery raising under SRI method the rice seeds were soaked in water for 24 hours. Then the seeds were put in a sac and covered with paddy straw for 24 hours. Prior to sowing a thin layer of FYM and soil was spread on the seed bed. The raised nursery bed was prepared with soil and FYM (2:1) and @ 6 kg ha^{-1} seeds were uniformly spread on the bed and covered with a thin layer of FYM and soil mix for 2-3 days. It was watered by rose cans. At the time of transplanting seedlings were taken along with soil without disturbing root system. Application of fertilizers the required quantity of fertilizer and manure was applied before transplanting in experimental field. Experimental crop was fertilized @ 120, 80 and 40 kg N, P_2O_5 and K_2O ha^{-1} respectively half dose of nitrogen and full dose of phosphorus and potash was applied through Urea, DAP and MOP. The rest half dose of nitrogen top dressed in two splits at tillering and panicle initiation stage. FYM as per treatment was applied and mixed 20 days before transplanting of crop. Transplanting of seedling: In conventional method of transplanting twenty five days old seedling of rice was transplanted at 20cm × 10cm hill spacing by using 2-3 seedlings $hill^{-1}$. In SRI method twelve days old seedling of rice was transplanted at 25cm × 25cm hill spacing by using only one seedling $hill^{-1}$. herbicides were applied as per scheduled time and quantity. A stock solution of chemical containing the required quantity was prepared in a bucket by dissolving in a known volume of water. For spraying each plot the stock solution was further diluted. The quantity of water used was 800 liters ha^{-1} inclusive of stock solution. The spraying was done with flat fan nozzle. Care was taken to avoid herbicide drifting into the crop area as far as possible. Methodology for increasing the productivity of rice by changing the management of plants, water and nutrients.

3. Results and Discussion

Data pertaining to yield attributes and yield as influenced by the different treatments is presented in Table 1, 2 and 3.

3.1 Number of tillers $plant^{-1}$

The data pertaining to effect of crop establishment methods and weed management practices on number of tillers $plant^{-1}$ have been presented in Table 1. System of Rice Intensification (C_2) recorded significantly higher number of tillers $plant^{-1}$ as compared to conventional transplanting (C_1). Variations in number of tillers $plant^{-1}$ due to crop establishment methods were found to be significant at 30, 60, 90 DAT and at harvest. Variations in number of tillers $plant^{-1}$ due to weed management practices were significantly over weedy check treatment and statistically at par found Interculture by conoweeder at 10, 20 and 30 DAT (W_3) at crop growth stage *i.e.* at 30, 60 DAT and at harvest. Weed free-check (W_2) and weedy check (W_1) recorded the maximum and the minimum number of tillers $plant^{-1}$ respectively. It might be due to less crop-weed competition and better resources utilization at the time of tillering as the weeds were properly controlled under these practices. The interaction effect of crop establishment methods and weed management practices found significant at 30, 60 and 90 DAT Table 1. Similar results have been reported by Arunbabu and Satya (2014) [3], Reuben *et al.* (2016) [15], Kumar *et al.* (2018) [10], Zhimomi *et al.* (2021) [19] and Kumar *et al.* (2021) [9].

3.2 Number of panicles $hill^{-1}$

The data pertaining to effect of crop establishment methods and weed management practices on number of panicles $hill^{-1}$ have been presented in Table 2. Variations in number of panicles $hill^{-1}$ due to crop establishment methods were significant. Two-hand weeding at 20 and 40 DAT was statistically at par with weed free-check and recorded higher number of panicles $hill^{-1}$ than that among all the weed management practices. Amongst the herbicidal treatments to bispyribac-sodium 10% SC @ 20 g a.i. ha^{-1} at 20 DAT (PoE) (W_5) had statistically more number of panicles $hill^{-1}$ as compared to fenoxaprop-p-ethyl 9.3% EC @ 56.25 g a.i. ha^{-1} + chlorimuron ethyl 10% WP + metsulfuron methyl 10% WP @ 4 g a.i. ha^{-1} at 20 DAT (PoE) (W_6). Weed free-check (W_2) and weedy check (W_1) recorded the maximum and the minimum number of panicles $hill^{-1}$ respectively. The number of panicles $hill^{-1}$ is a crucial yield contributing factor that has a significant impact on the crop production potential. The higher number of panicle $hill^{-1}$ in these treatments could be due to more space available to express their potential, lower weed-crop competition in terms of weed dry matter production and a good source sink relationship that allows the crop to absorb the necessary amount of nutrient, water and sunlight for growth and tillering behaviour. Similar findings were also reported by Hasanuzzaman *et al.* (2008) [6], Bhurer *et al.* (2013) [4] and Rajput *et al.* (2020) [14].

3.3 Panicle length (cm)

The data pertaining to effect of crop establishment methods and weed management practices on panicle length have been presented in Table 2. Variations in panicle length were significant due to crop establishment methods. However, variations in the panicle length due to different herbicidal treatments were significant over weedy check treatment. Weed free-check and weedy check recorded the longest and the shortest panicle length respectively among all the weed management practices. Greater panicle length of the above treatments could be responsible for greater panicle weight. This could be owing to improved photosynthate transport to the sink, which adds to panicle weight gain. Kumar *et al.* (2014) [11] and Zhimomi *et al.* (2021) [19] also reported similar results from their study.

3.4 Number of grains $panicle^{-1}$

The data pertaining to effect of crop establishment methods and weed management practices on number of grains $panicle^{-1}$ have been presented in Table 2. Effects of crop establishment methods on number of grains $panicle^{-1}$ were significant. Two-hand weeding at 20 and 40 DAT was statistically at par with weed free-check and recorded higher number of grains $panicle^{-1}$ than that among all the weed management practices. Amongst the herbicidal treatments, bispyribac-sodium 10% SC @ 20 g a.i. ha^{-1} at 20 DAT (PoE) had statistically more number of grains $panicle^{-1}$ as compared to fenoxaprop-p-ethyl 9.3% EC @ 56.25 g a.i. ha^{-1} + chlorimuron ethyl 10% WP + metsulfuron methyl 10% WP @ 4 g a.i. ha^{-1} at 20 DAT (PoE). Weed free-check and weedy check recorded the maximum and the minimum number of grains $panicle^{-1}$, respectively amongst all the weed management practices. It might be due to the lower weed competition in terms of dry matter of weeds that might have created overall agreeable environment for growth and development of rice and resulted in more availability of light, moisture, nutrients and space for rice plants which helped in producing sound grains panicle^{-1}. These results are in conformity with those reported by Hasanuzzaman *et al.* (2008) [6], Bhurer *et al.* (2013) [4], Rajput *et al.* (2020) [14] and Zhimomi *et al.* (2021) [19].

3.5 Panicle weight (g)
The data pertaining to effect of crop establishment methods and weed management practices on panicle weight have been presented in Table 2. Effects of crop establishment methods on panicle weight were significant. However, variations in the panicle weight due to herbicidal treatments were significant over weedy check treatment and two-hand weeding at 20 and 40 DAT were statistically at par with weed free-check. Weed free-check and weedy check recorded the highest and the lowest panicle weight (g), respectively. These results are in conformity with those reported by Hasanuzzaman *et al.* (2008) [6], Bhurer *et al.* (2013) [4] and Rajput *et al.* (2020) [14].

3.6 Weight of 1000-grains (g)
The data pertaining to effect of crop establishment methods and weed management practices on weight of 1000-grains (g) have been presented in Table 2. Effects of crop establishment methods on weight of 1000-grains (g) were significant. However, variations due to herbicidal treatments on weight of 1000-grain (g) were significant over weedy check treatment. Amongst the herbicidal treatments bispyribac-sodium 10% SC @ 20 g a.i. ha^{-1} at 20 DAT (PoE) had statistically more weight of 1000-grains as compared to fenoxaprop-p-ethyl 9.3% EC @ 56.25 g a.i. ha^{-1} and chlorimuron ethyl 10% WP + metsulfuron methyl 10% WP @ 4 g a.i. ha^{-1} at 20 DAT (PoE). Weed free-check and weedy check recorded the highest and the lowest weight of 1000-grains (g), respectively among all the weed management practices. This might be due to increased production and translocation of photosynthates to grains because of adequate availability of resources due to better and timely control of weeds from early growth period by hand weeding and sequential application of herbicides. This has eventually resulted in better yield components and grain yield. Similar findings have been reported by Duttarangvi *et al.* (2016) [5], Murali *et al.* (2017) [11] and Zhimomi *et al.* (2021) [19].

3.7 Grain yield (kg ha^{-1})
The data pertaining to effect of crop establishment methods and weed management practices on grain yield (kg ha^{-1}) have been presented in Table 3. Crop establishment methods were found significant variations in grain yield. However, the interculture by conoweeder and herbicidal treatments gave significantly higher grain yield over the weedy check treatment. Weed free-check and weedy check recorded the highest and the lowest grain yield respectively among all the weed management practices.

The highest grain yield observed in SRI is described due to the enhanced expression of yield attributes. Under SRI, transplanting young seedlings promotes better tillering, resulting in greater improved tillers, more filled spikelets, and maximum grain weight. In addition, wider spacing 25cm × 25cm encourages canopy and root growth, enhancing grain filling. Herbicide application inhibited weed growth and permitted the rice crop to receive adequate nutrient supply. Production of more photosynthates *via* more effective number of tillers plant^{-1} and proper dry matter partitioning (source to sink) resulted in higher grain yield. This might be due to weed free environment created from early stage to till harvest which led to less competition by weeds and minimum nutrient removal by weeds which might have increased the capacity of nutrient uptake and enhanced the source and sink size which in turn increased the yield attributes. The interaction effect of crop establishment methods and weed management practices found significant Table 3. Similar findings have been reported by Ahmed *et al.* (2015) [1], Sudhakar *et al.* (2017) [18], Naik *et al.* (2018) [12], Hemlatha *et al.* (2020) [17], Kumar *et al.* (2021) [9] and Singh *et al.* (2021) [16].

3.8 Straw yield (kg ha^{-1})
The data pertaining to effect of crop establishment methods and weed management practices on straw yield (kg ha^{-1}) have been presented in Table 3. Crop establishment methods were produce significant variations in straw yield. However, the interculture by conoweeder at 10, 20 and 30 DAT and herbicidal treatments resulted in significantly higher straw yield over the weedy check treatment. Weed free-check and weedy check recorded the highest and the lowest straw yield, respectively among all the weed management practices. This increase in straw yield could be due to effective suppression of weeds. This is due to increase of number of shoots per unit area and height of the plant along with dry matter accumulation. Similar findings were also reported by Singh and Guru (2011) [17], Nivetha *et al.* (2017), Zhimomi *et al.* (2021) [19] and Kumar *et al.* (2021) [9].

3.9 Biological yield (kg ha^{-1})
The data pertaining to effect of crop establishment methods and weed management practices on biological yield (kg ha^{-1}) have been presented in Table 3. Variations in biological yield due to crop establishment methods were significant. However, the interculture by conoweeder and herbicidal treatments gave significantly higher biological yield over the weedy check treatment. Weed free-check and weedy check recorded the highest and the lowest biological yield, respectively among all the weed management practices. The highest yield (grain + straw) observed in SRI is described due to the enhanced expression of yield attributes. Under SRI, transplanting young seedlings promotes better tillering, resulting in greater improved tillers, more filled spikelets, and maximum grain weight. In addition, wider spacing 25cm × 25cm encourages canopy and root growth, enhancing grain filling. The interaction effect of crop establishment methods and weed management practices found significant (Table 3). Similar results have been reported by Singh *et al.* (2021) [16] and Kumar *et al.* (2021) [9].

3.10 Harvest index (%)
The data pertaining to effect of crop establishment methods and weed management practices on harvest index have been presented in Table 3. The effect of crop establishment methods were not found significant and weed management practices on harvest index was found to be significant. However, weed free-check, interculture by conoweeder at 10, 20 and 30 DAT and bispyribac-sodium 10% SC @ 20 g a.i. ha^{-1} at 20 DAT (PoE) and fenoxaprop-p-ethyl 9.3% EC @ 56.25 g a.i. ha^{-1} + chlorimuron ethyl 10% WP + metsulfuron methyl 10% WP @ 4 g a.i. ha^{-1} at 20 DAT (PoE) resulted in statistically at par with weed free-check over the weedy check

treatment. Among the crop establishment methods the highest harvest index was obtained when crop raised through SRI method (42.20%). The lowest harvest index was observed when crop raised through conventional transplanting (42.04%). Among weed management practices the highest harvest index was obtained under two hand- weeding at 20 and 40 DAT (42.92%). The lowest harvest index was obtained under weedy check (40.42%) implying that weed control is required to produce higher economical and biological yield. Similar results have been reported by Naik *et al.* (2018) [12], Zhimomi *et al.* (2021) [19] and Kumar *et al.* (2021) [9].

Table 1: Number of tillers of rice as influenced by crop establishment methods and weed management practices

Treatments	**Number of tillers plant^{-1}**			
	30 DAT	**60 DAT**	**90 DAT**	**At harvest**
Crop establishment methods				
C_1 (Conventional transplanting)	11.77	15.51	19.41	18.52
C_2 (System of Rice Intensification)	14.08	20.56	23.94	23.61
SE(m)±	0.21	0.16	0.15	0.78
CD (*P*=0.05)	1.27	1.00	0.91	4.74
Weed management practices				
W_1 (Weedy check)	9.17	11.90	14.38	14.22
W_2 (Weed-free check)	15.75	21.58	27.02	26.02
W_3 (Interculture by conoweeder at 10, 20 and 30 DAT)	13.13	19.43	23.02	22.02
W_4 (Two hand- weeding at 20 and 40 DAT)	15.58	21.55	24.10	23.77
W_5 (Bispyribac - sodium 10% SC @ 20 g a.i. ha^{-1} at 20 DAT (PoE))	12.75	17.82	21.58	20.58
W_6 (Fenoxaprop -P- Ethyl 9.3% EC @ 56.25 g a.i. ha^{-1} + Chlorimuron Ethyl 10% WP + Metsulfuron Methyl 10% WP @ 4 g a.i. ha^{-1} at 20 DAT (PoE)	11.19	15.90	19.95	19.78
SE(m)±	0.40	0.52	0.40	0.95
CD (*P*=0.05)	1.17	1.54	1.18	2.80

Table 2: Yield attributes of rice as influenced by crop establishment methods and weed management practices

Treatments					
	Number of panicle hill^{-1}	**Panicle length (cm)**	**Number of grains panicle^{-1}**	**Panicle weight (g)**	**Weight of 1000-grains (g)**
Crop establishment methods					
C_1 (Conventional transplanting)	18.37	20.35	115.6	3.12	19.63
C_2 (System of Rice Intensification)	22.22	22.96	155.3	4.19	21.13
SE(m)±	0.17	0.42	4.33	0.12	0.18
CD (*P*=0.05)	1.05	2.58	26.35	0.73	1.11
Weed management practices					
W_1 (Weedy check)	14.95	15.83	88.20	2.38	16.08
W_2 (Weed-free check)	25.16	26.21	161.0	4.35	23.53
W_3 (Interculture by conoweeder at 10, 20 and 30 DAT)	20.36	22.38	141.1	3.81	21.18
W_4 (Two hand- weeding at 20 and 40 DAT)	22.65	24.37	155.7	4.19	22.26
W_5 (Bispyribac-sodium 10% SC @ 20 g a.i. ha^{-1} at 20 DAT (PoE))	19.46	21.04	138.8	3.75	19.91
W_6 (Fenoxaprop -P- Ethyl 9.3% EC @ 56.25 g a.i. ha^{-1} + Chlorimuron Ethyl 10% WP + Metsulfuron Methyl 10% WP @ 4 g a.i. ha^{-1} at 20 DAT (PoE))	19.20	20.11	127.6	3.45	19.35
SE(m)±	0.48	0.43	4.24	0.12	0.39
CD (*P*=0.05)	1.43	1.27	12.51	0.35	1.16

Table 3: Yield and harvest index of rice as influenced by crop establishment methods and weed management practices

Treatments				
Grain yield (kg ha^{-1})		**Straw yield (kg ha^{-1})**	**Biological yield (kg ha^{-1})**	**Harvest index (%)**
Crop establishment methods				
C_1 (Conventional transplanting)	4529	6215	10745	42.04
C_2 (System of Rice Intensification)	5084	6930	12015	42.20
SE(m)±	17.06	82.39	68.46	0.48
CD (*P*=0.05)	103.79	501.32	416.59	NS
Weed management practices				
W_1 (Weedy check)	2805	4141	6947	40.42
W_2 (Weedfree-check)	6400	8826	15227	42.02
W_3 (Interculture by conoweeder at 10, 20 and 30 DAT)	5148	6933	12082	42.65
W_4 (Two hand-weeding at 20 and 40 DAT)	5726	7617	13344	42.92
W_5 (Bispyribac-sodium 10% SC @ 20 g a.i. ha^{-1} at 20 DAT (PoE))	4638	6319	10957	42.31
W_6 (Fenoxaprop-P-Ethyl 9.3% EC @ 56.25 g a.i. ha^{-1} + Chlorimuron Ethyl 10% WP + Metsulfuron Methyl 10% WP @ 4 g a.i. ha^{-1} at 20 DAT (PoE)	4122	5599	9722	42.40
SE(m)±	35.63	92.95	100.1	0.48
CD (*P*=0.05)	105.1	274.2	295.3	1.42

4. Conclusion

In the present study, an attempt was made to study the on yield and yield attributes of rice. SRI methods in combination with bispyribac-sodium 10% SC @ 20 g a.i. ha^{-1} at 20 DAT (PoE) followed by fenoxaprop -p- ethyl 9.3% EC @ 56.25 g a.i. ha^{-1} + chlorimuron ethyl 10% WP + metsulfuron methyl 10% WP @ 4 g a.i. ha^{-1} at 20 DAT (PoE) can be recommended for weed management in rice under solutions of labour scarity. SRI demonstrated the higher yield (grain + straw) of rice under weed management practices, weed free-check showed the highest yield of rice. Which indicate that the above-mentioned treatment combination can be employed in the east-central region of India for optimum resource utilization to boost rice productivity. The SRI method is superior regarding grain yield over the conventional transplanting (12.25% higher) but following all principles of SRI is a herculean task for farmers in some regions because of the unavailability of resources.

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