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EVALUATION OF CROP ESTABLISHMENT METHODS AND WEED MANAGEMENT PRACTICES UNDER DRY-DIRECT SEEDED RICE (*ORYZA SATIVA* L.)

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ABSTRACT

A field experiment was conducted at Agricultural Research Station, Ummedganj, Kota, Rajasthan during kharif 2021 to evaluate different crop establishment methods and weed management practices under dry direct seeded rice. Results showed that mechanical line sowing using seed drill was found as the most effective crop establishment method, yielding significantly highest grain yield (5.17 t/ha) and net returns (Rs. 1,20,874/ha) with a B:C ratio 3.57. Among weed management practices, manual weeding three times (at 20, 40 and 60 DAS) provided the best weed control and highest grain yield (4.95 t/ha), however, net return (Rs. 109932 /ha) fetched by it, was not found significantly higher over herbicidal treatments due to higher labour cost. Application of Pendimethalin (pre-emergence) 1 kg a.i./ha fb two manual weeding at 20 & 40 DAS (4.85 t/ha) or Pendimethalin (pre-emergence) 1 kg a.i./ha fb Bispyribac sodium 35 g a.i./ha as post emergence at 20 DAS (4.67 t/ha) were found to be more practical alternative. The highest B:C ratio (3.38) was recorded under application of Pendimethalin (pre-emergence) 1 kg a.i./ha fb Bispyribac sodium 35 g a.i./ha at 20 DAS. The study concluded that mechanical line sowing combined with an integrated weed management approach enhances yield and economic returns in dry DSR system.

***Ke ywords*:** crop establishment, direct seeded, integrated weed management, rice

Introduction

India is the second largest rice producing country in the world after China, with production of 137.8 million tonnes grown under 47.8 m ha area with a hovering productivity of 4.32 t/ha (Anonymous, 2025). In Rajasthan, paddy is cultivated in an area of 0.234 million hectare with an annual production of 0.57million tonnes and average productivity of 2.46 t/ha (Anonymous, 2023). Rice is commonly cultivated by transplanting seedlings in puddled conditions. Presently, manual transplanting is very expensive due to higher labour cost required for nursery raising and transplanting. Manual transplanting has several constraints, which include a huge water demand (1000-2000 mm) for puddling and maintaining continuous flooding condition, a huge energy requirement ranging between 5630-8448 MJ per ha and almost 15-20% higher labour inputs than direct-seeded rice (Shekhawat *et al.*, 2020). Puddling has deteriorating effects on the soil structure, which adversely affect the subsequent crop. Direct-seeded rice (DSR) systems are gaining importance for efficient utilization of resources and timely sowing of the subsequent crops, mitigate greenhouse gas emission and improve environmental sustainability. Dry DSR is one of the methods of direct seeding which avoids the transplanting and puddling operations. Although, the yield obtained in transplanted method of rice is more than that of DSR, but the net returns as well as the BC ratio is higher in case of DSR as reported by Kumar and Batra (2017).

In dry DSR, seeds are directly sown on well-prepared seed bed under un-puddled and unsaturated soil conditions either by broadcasting or drilling in lines. Poor crop establishment and weed infestation are the major challenges confronting the development of dry DSR in India. There is need to work out the strategies which may help in mitigating the constraints to dry DSR. Aerobic

soil conditions with intermittent wetting and drying creates favourable conditions for weed germination and growth under dry DSR. Therefore, weeds poses the main biological constraint to the success of DSR (Chauhan, 2012), and failure to control weed infestation result in yield losses ranging from 50 to 90% (Chauhan and Johnson, 2011, Chauhan and Opeña, 2012). Several approaches such as mechanical weed removal, cultural practices, and judicious use of herbicides can be employed to effectively manage weeds and minimize yield losses in DSR cultivation (Rao *et al.*, 2007). However, chemical weed management is replacing manual weeding due to non-availability of timely labour, higher labour costs and drudgery involved. Pre-emergence herbicides initially control germinating weeds and late-emerging weeds are managed by selective post-emergence herbicides. Due to diverse weed growth during crop season under dry DSR, a single strategy of weed management may not be effective. The continuous application of high-dose pre-emergence herbicides can lead to a shift in weed populations from grasses to non-grassy species (Singh *et al*., 2009) and contribute to the development of herbicide resistance due to their prolonged persistence in the soil. To address these challenges, post-emergence herbicides are essential for weed control in direct-seeded rice (DSR), as they offer broad-spectrum effectiveness and help mitigate the issue of herbicide resistance. To accomplish the effective weed management under dry DSR, the integrated approach of weed management seems a better alternative. Also, there is need to evaluate different crop establishment methods under dry DSR for yield and economic feasibility in the South-eastern Rajasthan. In view of the above facts, an experiment was undertaken at Agricultural Research Station, Ummedganj Farm, Kota during *kharif*, 2021 to assess yield levels and economic returns under different crop establishment and weed management practices in South-eastern Rajasthan conditions.

Materials and Methods

The experiment was undertaken at Agricultural Research Station, Ummedganj, Kota (25°13' N and 75° 25' E, 258 m above mean sea level) during *kharif* 2021 to evaluate different crop establishment methods and weed management practices under dry DSR. Soil of the experimental field was clay in texture with pH 7.40 and organic carbon 0.60%. The soil was low in available nitrogen (169 kg/ha), medium in phosphorus (34 kg/ha) and high in potassium (413 kg/ha). The experiment was laid out in split plot design with three replications, comprising three crop establishment methods in main plots (M_1- Broadcasting of seeds, M_2-Manual line sowing of seeds at 20 cm row spacing, M_3 -Mechanized line sowing of seeds at 22.5 cm row spacing using seed drill) and four weed management practices in sub-plots (W_1-Manual weeding three times at 20, 40 and 60 DAS, W_2-Pre-emergence (PE) application of Pendimethalin @ 1.0 kg *a.i.*/ha *fb* Post-emergence (POE) application of Bispyribac sodium @ 35 g *a.i.*/ha at 20 DAS, W_3-Pendimethalin @ 1.0 kg a.i./ha (PE) *fb* manual weeding two times at 20 & 40 DAS and W_4- Mechanical weeding using conoweeder three times 15, 40 & 60 DAS).

The field was well prepared by ploughing with a disc plough followed by harrowing with a rotavator to get a fine tilth. Further, after installation of plots as per experimental design, individual plots were also levelled manually. In broadcasting method, dry seeds were broadcasted and mixed thoroughly in the soil properly. Manual line sowing was done by manually opening furrows at 20 cm apart and dropping 2 dry seeds at 15 cm seed to seed spacing and then the seeds were covered with soil. Mechanized line sowing of seeds was done at 22.5 cm row spacing and at shallow depth of 2-3 cm using seed drill. Irrigation was applied just after sowing to ensure proper germination and the field was kept in the saturation condition up to vegetative phase.

Rice variety 'Pusa Sugandha-5 (P-2511)' was sown using the seed rates of 50 kg/ha for broadcasting and 30 kg/ha for line sowing methods. Herbicides were applied as per the treatments using knap-sack sprayer fitted with flat-fan nozzle. The spray volume of herbicides was 500 litres/ha. The crop was raised under irrigated condition with the recommended package of practices. Recommended doses of fertilizers NPK @ 120-60-40 kg/ha were applied through urea, DAP, and MOP; respectively. Full quantity of phosphorous and potassium were applied as a basal dose while nitrogen was applied in three splits with half as a basal dose and the one-fourth doses each at tillering and panicle initiation stages. The total rainfall received during crop season was 1229 mm.

Total weed density and their dry weight were taken at active tillering and panicle initiation stages by placing a one square meter quadrate randomly in each plot. These data were subjected to square root transformation before analysis. The number of tillers and panicles were counted in a one-meter row length from two randomly selected rows in each plot, which were then expressed as number per m^2. Random sampling of ten panicles from each plot were carried out at physiological maturity and length of each panicle was measured to work out average length (cm) and panicle weight were taken after drying to get average panicle weight. The above ground portion of plants of net plot area were sun dried after harvest and

Table 1: Effect of crop establishment methods and weed management on weed density and weed dry weight in dry direct seeded rice.

Treatment	Weed density /m²		Weed Dry weight (g/m²)	
	At Active tillering	At Panicle Initiation	At Active tillering	At Panicle Initiation
Establishment method				
M_1-Broadcasting	4.63 (22.8)	4.09 (18.3)	4.61 (22.6)	5.39 (31.9)
M_2-Manual line sowing	4.27 (19.1)	3.48 (13.5)	4.40(20.4)	5.09 (29.0)
M_3-Mechanical line sowing	4.14 (17.9)	3.47 (13.2)	4.28 (19.4)	4.88 (27.2)
SEm± 0.087	0.102	0.065	0.091	
CD (P=0.05) 0.34	0.40	NS	0.36	
Weed management				
W_1-Manual weeding 3 times	2.74 (7.1)	2.74 (5.8)	2.72 (7.0)	3.16 (9.6)
W2-PE+ POE herbicide	4.30 (18.0)	3.81 (14.1)	4.45 (19.4)	5.76 (32.7)
W3-PE+ manual weeding 2 time	4.21 (17.3)	2.65 (6.7)	4.31 (18.1)	3.66 (13.0)
W_4-Mechanical weeding 3 times	6.13 (37.3)	5.80 (33.4)	6.25 (38.7)	7.91 (62.1)
SEm± 0.081	0.097	0.102	0.84	
CD (P=0.05)0.24	0.29	0.30	2.51	

Note : Data under parenthesis are the original values subjected to square root transformation of $\sqrt{X+0.5}$

then weighed to work out biological yield. Grain yield of net plots was recorded after manual threshing of harvested produce. Straw yield was worked out by subtracting the grain yield from the biological yield. The data were analysed statistically and the treatment means were compared using least significant difference at 5% level of significance (Panse and Sukatme,1985). Economic returns were worked out based on the prevailing market price of input used and the output obtained from each treatment. Net returns for each treatment were calculated by deducting the cost of cultivation from gross returns. Benefit-cost ratio (B:C ratio) was calculated as the ratio between gross returns to total cost of cultivation.

Results and Discussion

Weeds dynamics

The dominant weed species observed in the experimental plots included grassy weeds like *Echinochloa colonum* (L.), *Echinochloa crusgalli* (L.) and *Ishchaemum rugosum;* broad leaf weeds like, *Ammannia baccifera, Commelina benghalensis, Eclipta alba* (L.), and *Ludwigia octovalvis* (L.) and sedges like *Cyperus iria* (L). and *Cyperus difformis* (L). These weed species under direct seeded rice were also reported by Chongtham *et al.,* (2016) and Verma *et al.,* (2022).

Crop establishment methods exhibited a significant impact on weed density and weed dry weight at active tillering as well as panicle initiation stages. Data in Table 1 shows that broadcasting method resulted in maximum weed density (22.8 and 18.3/m²) and weed dry weight (22.6 and 31.9 g/m²) at active tillering as well as panicle initiation stages; respectively and found to be significant over both mechanical and manual line sowing methods. Mechanical line sowing recorded lowest weed density (17.9 and 13.2/m²) and weed dry weight (19.4 and 22.2 g/m²) at active tillering and panicle initiation stages; respectively. While manual line sowing was found at par with mechanical line sowing at both the stages. However, weed dry weight at active tillering stage did not prove to be statistically significant among establishment methods. Higher weed incidence in broadcast method compared to line sown methods might be due to uneven crop stand in broadcast which resulted in higher crop-weed competition. These results are in conformity to Saha *et al.,* (2021).

Among weed management treatments, lowest weed density (7.1 and 5.8/m²) and weed dry weight (7.0 and 9.6 g/m²) at both stages were recorded under three times manual weeding and found significantly lower as compared to other weed management treatments. Similar findings are observed by Nadeem Akbar *et al.,* (2011). On the other hand, highest weed density (37.3 and 33.4/ m²) and weed dry weight (38.7 and 62.1 g/m²) at both the stages were observed under mechanical weeding using conoweeder, which might be ascribed to the aerobic condition of soils under dry DSR where conoweeder was not found feasible. Weed density and weed dry weight at active tillering stage under application of Pendamethalin (PE) *fb* Bispyribac sodium (POE) did not differ significantly with Pendamethalin (PE) *fb* manual weeding two times, however, at panicle initiation stage Pendamethalin (PE) *fb* Bispyribac sodium (POE) recorded significantly higher weed density & weed dry weight over Pendamethalin (PE) *fb* manual weeding two time. The results are in agreement with the findings of Arunbabu and Jena (2018).

Table 2: Effect of establishment method and weed management practices on yield attributes of rice.

Treatment	Tiller/m²	Panicle/m²	Panicle weight (g)	Panicle length	Test weight (g)
Establishment methods					
M_1- Broadcasting	317	275	3.12	25.9	22.57
M_2- Manual line sowing	328	294	3.39	27.8	23.24
M_3- Mechanical line sowing	343	306	3.59	28.3	23.44
SEm±	4.35	3.78	0.04	0.43	0.08
CD (P=0.05)	17.07	14.82	0.16	1.70	0.31
Weed management					
W_1-Manual weeding 3 times	343	303	3.64	27.7	23.43
W_2-PE+ POE herbicide	328	293	3.36	27.6	23.00
W_3-PE+ manual weeding 2 time	337	298	3.44	27.3	23.23
W_4-Mechanical weeding 3 times	310	272	3.04	26.7	22.68
SEm±	5.26	4.27	0.10	0.27	0.19
CD (P=0.05)	15.64	12.69	0.30	NS	NS

Yield attributes

The data presented in the Table 2 highlights the influence of different crop establishment methods and weed management practices on yield attributes such as tiller production, panicle formation, panicle weight, panicle length, and test weight. These parameters are critical in determining the overall productivity of rice crop. Mechanical line sowing recorded significantly highest number of tillers/m² (343) and panicles/m² (306), followed by manual line sowing (328 tillers/m², 294 panicles/m²) and broadcasting (317 tillers/m², 275 panicles/m²). The significantly higher tiller and panicle count in mechanical line sowing can be attributed to uniform plant spacing, better root establishment, and reduced intra-plant competition. Broadcasting, on the other hand, leads to uneven seed distribution and higher plant competition, which may reduce tillering and panicle formation. Similarly, mechanical line sowing resulted in the highest panicle weight (3.59 g) and panicle length (28.3 cm), followed by manual line sowing (3.39 g, 27.8 cm) and broadcasting (3.12 g, 25.9 cm). The increased panicle weight and length in line-sown methods may be due to improved resource utilization, which enhances plant growth and grain-filling capacity. Test weight, which indicates grain density and quality, was also highest in mechanical line sowing (23.44 g), followed closely by manual line sowing (23.24 g). Broadcasting recorded the lowest test weight (22.57 g). The improved test weight in line-sown methods suggests better grain filling and kernel development, likely due to improved plant nutrition and reduced plant stress. Overall, mechanical line sowing emerged as the most effective establishment method, ensuring better tiller production, panicle formation, and grain yield potential due to enhanced plant spacing and nutrient utilization efficiency. Saha *et al.*, (2021) also reported higher number of productive tillers in line-sowing method of DSR.

Effective weed management plays a crucial role in optimizing rice yield by reducing competition for nutrients, moisture, and light. Among the weed control treatments (Table 2), manual weeding three times resulted in the

Table 3: Effect of establishment method and weed management practices on yield and harvest index of rice .

Treatment	Grain yield (t/ha)	Straw yield (t/ha)	Biological yield (t/ha)	Harvest Index (%)
Establishment methods				
M_1- Broadcasting	4.13	5.92	10.05	41.05
M_2- Manual line sowing	4.79	5.98	10.76	44.47
M_3- Mechanical line sowing	5.17	6.42	11.59	44.60
SEm±	0.091	1.05	0.194	0.128
CD (P=0.05)	0.36	4.13	0.76	0.50
Weed management				
W_1-Manual weeding 3 times	4.95	6.37	11.32	43.63
W_2-PE+ POE herbicide	4.67	6.10	10.77	43.30
W_3-PE+ manual weeding 2 time	4.85	6.22	11.08	43.78
W_4-Mechanical weeding 3 times	4.31	5.74	10.05	42.77
SEm±	0.065	0.083	0.146	0.145
CD (P=0.05)	0.19	0.25	0.43	0.43

Table 4: Effect of establishment method and weed management practices on economic returns of rice.

Treatment	Gross returns(Rs/ha)	Net returns(Rs/ha)	B:C ratio
Establishment methods			
M_1- Broadcasting 135739	87923	2.84	
M_2- Manual line sowing	155572	106706	3.19
M_3- Mechanical line sowing	167990	120874	3.57
SEm± 2928	2928	0.063	
CD (P=0.05) 11493	11493	0.25	
Weed management			
W_1-Manual weeding 3 times	161245	109932	3.14
W_2-PE+ POE herbicide	152296	107168	3.38
W_3-PE+ manual weeding 2 time	158095	107867	3.15
W_4-Mechanical weeding 3 times	140766	95703	3.13
SEm± 2112	2112	0.044	
CD (P=0.05) 6274	6274	0.13	

significantly highest number of tillers (343/m²) and panicles (303/m²), followed by application of Pendimethalin (PE) *fb* two manual weeding with 337 tillers/m² and 298 panicles/m². The lowest values were observed in mechanical weeding (310 tillers/m², 272 panicles/m²). The superior performance of manual weeding may be attributed to its effectiveness in removing weeds at different growth stages, thereby minimizing crop-weed competition throughout the critical growth phases. Maximum panicle weight was recorded in manual weeding (3.64 g), followed by Pendimethalin (PE) *fb* two manual weeding (3.44 g) and Pendimethalin (PE) *fb* Bispyribac sodium 35 g *a.i.*/ha (POE) (3.36 g). Panicle length exhibited a similar trend. The lower values in mechanical weeding might be due to ineffective control of the weeds, leading to competition that adversely affected panicle development. Likewise, manual weeding recorded significantly highest test weight (23.43 g), with herbicide-based treatments, pendimethalin (PE) *fb* two manual weeding and Pendimethalin (PE) *fb* Bispyribac sodium (POE), also showing competitive results (23.00 g and 23.23 g, respectively). Mechanical weeding resulted in the lowest test weight (22.68 g), possibly due to higher weed interference affecting grain filling.

Yield

Rice yield was significantly influenced by establishment methods and weed management strategies, as depicted in Table 3. Various agronomic parameters such as grain yield, straw yield, biological yield, and harvest index are key indicators of crop performance and efficiency. The highest grain and straw yield of 5.17 t/ha and 6.42 t/ha; respectively were recorded under mechanical line sowing, followed by manual line sowing (4.79 t/ha and 5.98 t/ha), while the lowest grain and straw yield were observed under broadcasting at 4.13 t/ha and 5.92 t/ha; respectively. The significantly higher grain yield under mechanical line sowing can be attributed to better seed placement, uniform spacing, reduced plant competition, and improved resource availability compared to broadcasting. The higher straw yield in mechanical line sowing is a result of better vegetative growth due to uniform crop stand and enhanced tillering. Broadcasting results in uneven plant distribution, causing intra-plant competition, which limits tiller production and grain formation, leading to lower yield. The harvest index (HI) is an important indicator of how efficiently a plant converts total biomass into economic yield (grain yield). The higher HI in mechanical line sowing and manual line sowing indicates better partitioning of assimilates towards grain production rather than excessive vegetative growth.

Weed competition is a major constraint in rice production, significantly reducing crop yields. Effective weed control enhances nutrient availability, improves plant health, and optimizes yield potential. Three manual weeding recorded significantly highest grain yield of 4.95 t/ha, followed by Pendimethalin (PE) *fb* two manual weeding (4.85 t/ha). Herbicidal application of Pendimethalin (PE) *fb* Bispyribac sodium (POE) resulted in grain yield of 4.67 t/ha, while the lowest yield was observed under mechanical weeding (4.31 t/ha). Similarly, highest straw and biological yields were observed with three manual weeding (6.37 t/ha and 11.32 t/ha, respectively). However, significantly higher harvest index was recorded with the application of Pendimethalin (PE) *fb* two manual weeding (43.78%). These results are in conformity to Chaudhary *et al.*, (2018) and Devi and Singh (2018).

Economics

Economic analysis of data (Table 4) clearly shows that among the crop establishment methods, mechanical line sowing recorded significantly highest net returns (Rs. 1,20,874/ha) and B:C ratio of 3.57, making it the most economically viable option. Manual line sowing fetched

net returns of Rs. 1,06,706/ha and a B:C ratio of 3.19, showing good profitability over broadcasting but lower efficiency than mechanical line sowing. Shen *et al.*, (2013) also reported that line-sowing increased the benefit.

Among weed management treatments, manual weeding three times provided the highest net returns (Rs. 1,09,932/ha), but the B:C ratio (3.14) was significantly lower than Pendimethalin (PE) *fb* Bispyribac sodium (POE), which fetched a B:C ratio of 3.38. This suggests that while manual weeding ensures effective weed control, herbicide-based management is more cost-effective. The treatment Pendimethalin (PE) *fb* manual weeding also performed well, yielding net returns of Rs. 1,07,867/ha with a B:C ratio of 3.15. The statistically significant differences in net returns and B:C ratios among treatments highlight the critical role of effective weed management in enhancing profitability.

Conclusion

In conclusion, mechanical line sowing using seed drill proved to be the most effective establishment method of dry DSR for optimizing resource utilization and higher yield. It resulted in significantly higher grain yield of 5.17 t/ha and proved to be more economical with 3.57 B:C ratio than other methods. For weed management, manual weeding three times at 20, 40 and 60 DAS provided the best weed control and recorded highest grain yield of 4.95 t/ha, but it was found expensive due to high labor input. Therefore, application of Pendimethalin (PE) 1 kg *a.i.*/ha *fb* two manual weeding at 20 and 40 DAS or Pendimethalin 1 kg *a.i.*/ha (PE) *fb* Bispyribac sodium 35 g *a.i.*/ha (POE) found to be more practical alternative. Thus, an integrated approach, combining mechanical line sowing with a balanced weed management strategy, ensures higher productivity and economic returns of dry DSR. The study will be helpful for popularizing dry DSR system and realizing higher profitability in South-eastern Rajasthan.

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