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Optimizing Yield and Profitability in Wet Direct-Seeded Rice: Comparative Analysis of Sowing Time and Establishment Methods in South-Eastern Rajasthan

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Abstract

A field experiment was carried out at Agricultural Research Station, Kota during *Kharif* 2019 and 2020 to evaluate the yield and profitability of different crop establishment methods under wet direct seeded system in comparison to the transplanting method. The experiment was laid out in split plot design where treatments comprised of two sowing times (normal and late sown) in main plots and four establishment methods in sub-plots (broadcasting, manual line sowing, drum seeding and transplanting). Results revealed that delayed sowing by 30 days reduced panicles/m^2, panicle weight and grain yield by 8.81, 16.42 and 15.87 respectively as compared to normal sowing. Transplanting method recorded maximum and significantly higher panicles/m^2 (307), panicle weight (4.13 g), test weight (25.08 g), grain yield (5.73 t/ha) and straw yield (8.09 t/ha) over wet direct seeded methods. Among wet-direct seeded methods, drum seeding method recorded maximum panicles/m^2 (286), panicle weight (3.78) and test weight (24.54) and grain yield (5.33) and was found at par with manual line sowing. Economic analysis reveals that the highest net returns (Rs. 87833/ha) was obtained under transplanting while drum seeding method (Rs. 85649/ha) was found at par with it. Drum seeding method reduced the cost of cultivation by Rs.7065/ha in comparison to the transplanting method (Rs. 45949/ha) and gave highest B:C ratio (3.22) which was statistically superior to transplanting (2.92) as well as manual line sowing (3.03) and broadcasting (2.85) methods. Use of a drum seeder for direct seeding of paddy under puddled conditions is found to be an alternative option to the transplanting in present study.

Keywords: B:C ratio, drum seeding, establishment methods, net returns, profitability, sowing time, wet direct seeded rice.

Introduction

Rice is India's leading staple food crop of which is consumed by about 65 percent of the population (Singh and Singh, 2020). India has the largest area (47.8 million hectares) under rice cultivation in the worlds and is the second largest producer (137.8 million tonnes) after China (Anonymous, 2025). In Rajasthan, paddy is cultivated in an area of 0.234 million hectare with an annual production of 0.57 million tonnes and average productivity of 2.46 t/ha. Kota zone comprising of 'Humid South-Eastern Plain Zone' contributes to nearly one-half of the rice area and production in Rajasthan (Anonymous, 2023).

Rice is mostly cultivated through the transplanting method. Due to labour shortages and rising labour costs in many regions, the need for alternatives to the conventional transplanting approach has grown in recent years. Higher costs and limited supply of farm labour often delays transplanting. When over-aged seedlings are transplanted, it results in lower rice yield and delays the planting of the succeeding crop which ultimately produces lower system yield. Growing

labour demand in non-agricultural sectors is causing labour shortages in agriculture, so it is necessary to achieve more yield with less labour (Chakraborty *et al*., 2017). The shortage of irrigation water jeopardizes the sustainability of the production of rice in irrigated situations (Chauhan *et al*., 2014). To deal with these problems associated with transplanting especially scarcity of labour and to save water and energy input under nursery raising system, wet direct seeded rice (Wet-DSR) is increasingly being recognised as an alternative to transplanting. The wet direct seeding technique, which aims to realize labour saving in paddy cultivation, has continued to gain popularity in recent years (Ryma Labad *et al.,* 2020).

The wet DSR is a system in which pre-germinated seeds are directly sown either by broadcasting or manual line sowing or by using the drum seeder in well puddled main field. Rice crop grown by DSR methods matures 7-10 days earlier compared to puddled transplanting, which allows timely sowing of the succeeding crop (Mishra *et al.*, 2023). Wet-DSR is also recommended when a late monsoon delays sowing, where after applying irrigation water and sprouted seeds, farmers can ensure timely planting through the direct seeding method (Kumar *et al.*, 2024).

Direct-seeded rice yield is reduced when seeds are sown too soon or too late. Numerous studies have reported that planting rice after onset of the monsoon season increased grain output because weed infestation was reduced (Mane and Raskar, 2002). On the other hand, extremely late seeding may shorten rice's vegetative and reproductive growth cycle, which would diminish crop yield. Therefore, research is required for optimizing the sowing window for wet DSR especially in areas where rice-wheat cropping system is dominates. The rising cost and scarcity of labour at peak periods demand to develop alternative methods to transplanting. However, yield levels and profitability of different crop establishment methods of wet DSR in comparison to the transplanting needed to be evaluated before promoting in the South-Eastern Rajasthan conditions. Therefore, a field experiment was carried out to evaluate the yield levels and profitability under different crop establishment methods of wet DSR in comparison to the transplanting under normal and late sown conditions.

Materials and Methods

A field experiment was conducted at the Research Farm of Agricultural Research Station, (25° 10' 57'' North Latitude, 75°50' 20'' East Longitude and 267 m above MSL) of Agriculture University, Kota, Rajasthan during two consecutive *Kharif* seasons of the 2019 and 2020 to study the effect of sowing time and different crop establishment methods under wet direct seeded rice system and its comparison with normal transplanting system. The region falls under agro-climatic zone V 'Humid South-Eastern Plain Zone' of Rajasthan. Soil of the experimental field was clay (Vertisols), alkaline in reaction (pH 7.40), medium in organic carbon (0.60%), low in available nitrogen (235 kg/ha), medium in phosphorus (24 kg/ha) and high in potassium (433 kg/ha).

The experiment was laid out in split plot design with three replications. Treatments consisted of two sowing times in main plots (S_1-Normal sowing, S_2-late sowing) and four crop establishment methods in sub-plots (M_1-Broadcasting of seeds, M_2-Manual line sowing of seeds with 20 cm row spacing, M_3-Line sowing of seeds using Drum seeder at 20 cm row spacing, M_4-Normal transplanting at 20x15 cm spacing.

Well levelled field was selected for the experimentation and it was well prepared by ploughing, harrowing and puddling. Further, after preparing plots as per design, individual plots were also levelled manually as per requirement of the Wet DSR. Rice variety Pusa Sugandha-5 was sown on 29th June and 30th July during *Kharif* 2019 and on 15th July and 16th August during *Kharif* 2020 as normal and late sown respectively.

Seeds of the rice were pre-germinated by soaking for 24 hours in water and after draining out the water the seeds were kept in and covered with wet gunny bags

for 24-36 hours to get sprouted seeds. Pre-germinated seeds were sown directly in the main field as per the treatments of wet DSR while for transplanting, seeds were sown in the nursery on the same day. After puddling of main field, soil was allowed to settle down and excess water was drained out one day before direct sowing to maintain thin layer of about 2-3 cm water in plots at the time of sowing. In broadcasting method, pre-germinated seeds were broadcasted in the main field. In manual line sowing, seeds were dropped manually in lines 20 cm apart. In Drum seeding method, the sprouted seeds were sown through drum seeder. Drum seeder is a low-cost (around Rs. 5000) piece of equipment that is used to directly plant pre-germinated (sprouted) paddy seeds in a field that has been puddled and leveled after the excess water has been drained. It typically consists of four hyperboloid-shaped drums that can plant eight lines in a single pass with a 20 cm row-to-row spacing (Singh *et al.,* 2016). Seed rate was kept 50 kg/ha for broadcasting method and 30 kg/ha for other methods. In transplanting treatment, 25 days old seedlings were transplanted at spacing of 20x15 cm row and plant spacings. To enable proper germination of seeds and establishment of seedlings, irrigation and drainage were managed for the next 8-10 days after sowing to maintain a thin film of water. After seedling establishment, the crop was irrigated to 5 cm depth at required intervals as per rainfall.

Recommended doses of fertilizers @ 120-60-40 kg/ha NPK were applied through urea, DAP, and MOP. 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. Weed management was common in all experimental plots *i.e.,* application of Bispyribac sodium @ 350 g ai/ha at 15-20 DAS followed by two hand weeding. Plant-protection measures were taken as per need.

The total rainfall received during crop season was 1366 mm and 641 mm during 2019 and 2020, respectively. The maximum temperature raged from 29.3°C to 39.6°C and 31.3°C to 38.9°C and minimum temperature from 17.4°C to 26.7°C and 15.3°C to 24.0°C during crop seasons of 2019 and 2020, respectively. While relative humidity values ranged from 55.6 to 92.9 and 39.7 to 89.6 percent during 2019 and 2020, respectively. The numbers of panicles were counted from a one-meter row length from two random rows in each plot, which was then expressed as number of panicles m^2. The above ground portion of plants of net plot area (17.28 m^2) was sun dried after harvest and then weighed to work out biological yield. Grain yield of net plots was recorded after manual threshing of harvested produce and then expressed as tonnes/ha. Straw yield was worked out by subtracting the grain yield from the biological yield. Based on prevailing market price of input used (seed, fertilizers, agrochemical etc.) and operational cost (nursery, field preparation, sowing/transplanting, irrigation, interculture, sprays, harvesting and winnowing etc.) and the output obtained from each treatment, economic analysis was done to workout net returns and B:C ratio. The data collected on different parameters were statistically analyzed using the Analysis of Variance approach, and the significant differences were assessed at 5% level of significance (Gomez and Gomez, 1984).

Results and Discussion

Yield attributes

Yield attributes were significantly influenced by the sowing time and crop establishment methods (**Table 1**). Crop sown on normal sowing time recorded significantly higher panicles/m^2, panicle weight and test weight over delayed sowing. Pooled data of two years shows that delayed sowing of crop by 30 days resulted in 8.81, 16.42 and 3.40 per cent reduction in panicles/m^2, panicle weight and test weight, respectively as compared to the normal sowing. In addition to reducing weed crop competition, normal sowing increased the availability of all growth components, particularly light and nutrients, which is advantageous for improved growth and yield characteristics (Nazir *et al.,* 2022).

Table 1: Effect of sowing time and establishment methods on yield attributes and yield of wet-direct seeded rice (pooled data of two years)

Treatments	Panicles/ m^2	Panicle weight (g)	Test weight (g)	Grain yield (t/ha)	Straw yield (t/ha)	Biological yield (t/ha)	Harvest index (%)
Sowing time							
S_1-Normal Sowing	295	4.08	24.98	5.68	5.04	13.72	41.29
S_2- Delayed sowing	269	3.41	24.13	4.80	7.13	11.92	39.94
SEm±	3.908	0.048	0.111	0.047	0.07	0.117	0.026
CD (P=0.05)	13.52	0.164	0.38	0.163	0.244	0.406	0.08
Establishment methods							
M_1-Broadcasting	257	3.38	24.13	4.72	7.07	11.79	39.78
M_2-Manual line sowing	277	3.68	24.47	5.16	7.53	12.69	40.44
M_3-Drum seeding	286	3.78	24.54	5.33	7.65	12.98	40.89
M_4-Normal transplanting	307	4.13	25.08	5.73	8.09	13.83	41.34
SEm±	3.910	0.066	0.154	0.072	0.100	0.157	0.277
CD (P=0.05)	11.21	0.19	0.44	0.207	0.286	0.450	0.79

SEm =Standard Error of the Mean CD (P=0.05): Critical difference at 5% level of significance

Among establishment methods, transplanting method recorded maximum panicles/m^2 (307), panicle weight (4.13g) and test weight (25.08) which were found significantly higher over all three Wet-DSR methods. Several workers have also reported higher yield attributes under transplanted rice in comparison to wet DSR (Kumar *et al.,* 2018, Ramesh *et al.,* 2023). Among Wet DSR methods, drum seeding treatment resulted in maximum panicles/m^2 (286), panicle weight (3.78) and test weight (24.54), however, manual line sowing was found at par with it. On the other hand, broadcasting method resulted in significantly lowest values of panicles/m^2 (257) and panicle weight (3.38 g) than other establishment methods. It might be due to higher competition among the plants under the broadcasting where plants had uneven stand geometry. Also, more uniform seedling establishment and deep penetration of roots might have facilitated efficient nutrient uptake in line sowing methods. These results are in close conformity with those reported by Kumar and Chinnamuthu (2022). Further, manual line sowing and drum seeding treatments were found to be statistically at par in this respect. Results shows that test weight of grains did not differ significantly among all three wet-DSR methods.

Yield

The results presented in **Table 1** reveal that that normal sown crop recorded significantly higher grain (5.70 t/ha), straw (8.04 t/ha) and biological (13.74 t/ha) yields over delayed planting. It was observed that on a pooled basis; grain and straw yields were reduced to the extent of 15.87 and 12.85 per cent, respectively due to 30 days of delayed sowing. This might be attributed to a relatively longer vegetative phase, better growth and yield attributes under normal sown crop than late sown as also reported by Dileep *et al*., (2018).

Among crop establishment methods, transplanting method recorded maximum grain (5.73 t/ha), straw (8.09 t/ha) and biological (13.83 t/ha) yields, which were found significantly higher over direct seeded methods. The higher number of panicles/m^2, panicle weight/plant, and test weight of rice might be the primary causes of the maximum grain yield under transplanting. Optimum plant population and uniform crop geometry under the transplanting might have facilitated better nutrient uptake of plants. The outcome closely matched the findings of Netam *et al.,*

(2016). According to Miller *et al.,* (1991), panicles/m² were found to be the most significant component among the yield attributes, explaining 89% of the yield variation. Samra and Dhillon (2000) and Prasad *et al.,* (2001) also reported that puddled transplanted rice produced a higher yield than line sowing of sprouted seed and puddling with disseminating sprouted seed.

Among Wet DSR methods, drum seeding treatment recorded maximum grain (5.33 t/ha), straw (7.65 t/ha) and biological (12.98 t/ha) yields, however, manual line sowing was found at par with it. On the other hand, broadcasting method recorded lowest grain (4.72 t/ha) and straw yields (7.07 t/ha) which were found statistically lower than other methods. The lower yields in the broadcasting as compared to line sowing methods could be ascribed to the reason that plants sown in broadcasting did not have a specific distance and uniform space which might have caused higher competition among the plants. Further, greater developments of yield attributes under line sowing might be the primary cause for higher grain and straw yields. Chinnam *et al.,* (2018) and Deksha *et al.,* (2021) also reported better results with drum seeding method.

Data analysis also reveals that harvest index was recorded maximum under transplanting (41.34), which was found at par with drum seeding method (40.89). Relatively more improvement in yield attributes might have increased grain yield and corresponding high harvest index under transplanting and drum seeding methods. While, broadcasting method recorded lowest harvest index (39.78) which might be ascribed to poor development of yield attributes under uneven crop geometry.

Economic returns

Economic analysis of two years pooled data (**Table 2**) reveals that significantly higher net returns (Rs. 132564/ha) and B:C ratio (3.25) were obtained under normal sowing time as compared to the delayed sowing time. Among the different establishment methods, transplanting method fetched the highest net returns (Rs. 87833/ha) which was significantly higher over broadcasting (Rs. 71156/ha) and manual line sowing (Rs.80467/ha) methods, however, drum seeding method (Rs. 85649/ha) was found at par with it. The higher net income in the transplanting and drum seeding methods were attributed to the higher yields. Broadcasting method fetched significantly lowest net returns due to reduced grain and straw yield.

Table 2: Effect of sowing time and establishment methods on economic returns of wet-dry direct seeded rice (pooled data of two years)

Treatments	Gross cost of cultivation (Rs./ha)	Gross returns (Rs./ha)	Net returns (Rs./ha)	B:C ratio
Sowing time				
S_1-Normal Sowing	40933	132564	91631	3.25
S_2- Delayed sowing	40933	111879	70946	2.76
SE m±	-	1090.6	1090.6	0.027
CD (P=0.05)	-	3774	3774	0.09
Establishment methods				
M_1-Broadcasting	38984	110140	71156	2.85
M_2-Manual line sowing	39914	120381	80467	3.03
M_3-Drum seeding	38884	124533	85649	3.22
M_4-Normal transplanting	45949	133832	87883	2.92
SE m±	-	1650.8	1650.8	0.041
CD (P=0.05)	-	4735	4735	0.12

Further economic analysis reveals that drum seeding method reduced the average cost of cultivation by Rs.7065/ha in comparison to the transplanting method. As a result, drum seeding fetched the highest B:C ratio (3.22) which was found statistically superior over transplanting (2.92), broadcasting (2.85) as well as manual line sowing (3.03) methods. Singh and Singh (2010) also found that the drum seeding strategy increased net returns and the B:C ratio. Lower B:C ratio in manual line sowing as compared to drum seeding is ascribed to the greater number of labour needed for manual planting. These outcomes are consistent with the research conducted by Gill and Walia (2013) and Deksha *et al.,* (2021).

Conclusion

Based on the findings of the present experiment, it may be concluded that sowing in wet-direct seeded methods should be completed preferably up to 15th July. Use of a drum seeder for direct sowing of pre-germinated paddy seeds under puddled conditions may be an alternative option to the transplanting method. Direct seeding through drum seeder fetched equivalent net returns to the transplanting. Drum seeding reduced the cost of cultivation by Rs.7065/ha in comparison to the transplanting and fetched maximum B:C ratio (3.22). Therefore, wet direct seeding techniques may be useful for the farmers under labour scarcity situations and need upscaling among the farmers through field demonstrations.

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