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Research Paper

Crop establishment methods and management practices impact on rice yield parameters in central Punjab

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ABSTRACT

The field experiment was conducted to study the effect of varied crop establishment methods and management practices on yield parameters of cultivars 'PR 122', 'PR 126' and 'Pusa 44' during *kharif* 2020 and 2021. The direct seeded rice (DSR) method exhibited greater plant height, dry matter production and effective tillers per square meter, while puddled transplanted rice (PTR) method showed advantages in panicle length, 1000 grain weight, sterility % age and grain yield. However, the difference in these yield attributing factors between the two establishment methods were found to be statistically non-significant. The PTR method had higher numbers of grains per panicle and harvest index, while straw yield was significantly higher in the DSR method. Plant height, dry matter production, effective tillers per meter square, sterility % age, and straw yield were highest in Pusa 44 while no. of grains per panicle and harvest index were the highest in PR 126. Among nitrogen levels, plant height, dry matter production, effective tillers per meter square, panicle length, no. of grains per panicle, sterility % age and straw yield were significantly higher with 125 % of the recommended dose of nitrogen while the harvest index was significantly higher in leaf colour chart treatment. Rice cultivation practices under DSR, cultivar PR 126 and nitrogen application according to LCC are the better outcomes as compared to other treatments.

Key words: Direct seeded rice, Grain yield, Nitrogen level, Transplanted rice

Rice (*Oryza sativa* L.) belonging to the family *Poaceae*, is one of the significant grain crops, structuring the staple eating routine of more than 60 % of the global population (Yu *et al.,* 2020). India is a major producer and consumer of rice after China, which accounts for 21% of the world's total rice production (APEDA, 2021). In India, rice is grown over widely diverse ecologies, such as irrigated uplands, rainfed lowlands, and rainfed uplands with the lowest productivity under rainfed ecology.

Rice is established mainly by 2 methods i.e. Puddled transplanted rice (PTR) and Direct seeded rice (DSR). PTR is the most popular establishment method across South Asia as well as South East Asia. In the case of PTR, seedlings obtained from the nursery are transplanted in a puddled field. Puddling helps in successful weed control and retention of water but it needs more energy, time, and labour and also increases tillage requirements for succeeding wheat crop under rice-wheat cropping system. It also hinders the root development of wheat due to the formation of a hard pan, which limits nutrients and water uptake from the soil and results in lower crop yield (Bhushan *et al.,* 2007). Globally, more than 50% rice area follows the puddled transplanting method for the cultivation of rice. But now, as a result of the looming water crisis and shortage of labour, farmers in Asia are considering dry direct seeding as a good alternative to transplanting (Dhillon *et al.,* 2021). A steady fall of 0.1–1.0 m/year in the water table has been observed in Punjab due to the indiscriminate use of groundwater in rice cultivation. It adds to water scarcity conditions and raises the cost of pumping water (Hira, 2009).

Direct seeded rice (DSR) is an emerging production system in Asia due to certain advantages, it offers labour saving, irrigation water saving, better soil physical condition for following crops, less methane emissions, easy and faster planting, less drudgery, early maturity of the crop by 7–10 days, more tolerance to water deficit, comparable

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yield and high benefit-cost ratio. The saving of irrigation water in dry DSR is mainly achieved through the omission of puddling (which requires 10-15 cm irrigation water) along with the adoption of alternate wetting and drying conditions for regulating irrigation to the crop (Kumar *et al.,* 2018).

Several rice-growing countries including the USA, Brazil, China, Malaysia, Philippines, Cambodia, Bangladesh, Sri Lanka, India, etc. have considerable areas under the direct seeded rice technique. The technology of DSR has been successfully adopted by farmers of Punjab (Dhillon and mangat, 2018). The Direct Seeded Rice (DSR) technique circumvents traditional rice cultivation practices, notably the arduous tasks of raising nurseries, uprooting seedlings, puddling the fields, manually transplanting and maintaining a water level of 10-12 cm at the crop's base for the initial 15 days post-transplantation. Farmers can save almost US $100 per hectare in cultivation costs (Mahajan *et al.,* 2013). Hence, direct-seeded rice is becoming popular since water is judiciously used and the cost of production is reduced.

Another approach is to use short duration rice varieties. According to Hasan (2014) cultivation of short duration rice varieties is important for water saving while mitigating greenhouse gases emissions. Rice varieties with crop duration of 95-105 days can escape drought in rainfed ecosystems and allow more intense cultivation by taking advantage of the residual moisture in soil after the rice harvest. In irrigated rice ecosystems, many farmers prefer short duration varieties as they often face serious water shortages late in the dry season. Previously researchers remained focused on the development of medium duration varieties (Peng and Khush, 2003) due to their higher yield potential than that of short duration varieties under optimal conditions. Therefore, the study was planned to compare short, medium and long duration rice genotypes viz. PR-126, PR-122 and Pusa 44 to identify the sustainable rice genotype for the region.

Nitrogen (N) is an important nutrient, which is applied in most of the rice-producing areas and its application during different growth stages is well documented. Nitrogen is the most growth-limiting nutrient in the production of rice and is therefore, required in much higher amounts as compared to other nutrients (Mahajan *et al.,* 2011). Nitrogen is an indispensable part of chlorophyll, protoplasm, enzymes, and amino acids and helps in rapid plant growth and enhances grain yield and quality by increased tillering, leaf area, grain formation, grain filling, and protein synthesis. The magnitude of the response of rice to nitrogen varies with the varietal characteristics, weather, and soil factors. This study was also carried out to evaluate the effect of nitrogen levels on growth and yield attributes of different rice varieties under direct seeded and transplanted conditions.

MATERIAL AND METHODS

The field experiment was conducted at the Research Farm of Department of Climate Change and Agricultural Meteorology, Punjab Agricultural University, Ludhiana (latitude: 30°54'N and longitude: 75°48'E with an altitude of 247 m above mean sea level) during *kharif* season of 2020 and 2021. The soil of the site is classified as 'loamy sand' and belongs to 'Alluvial soils' type. The meteorological data (daily maximum and minimum temperatures, rainfall, pan evaporation, sunshine hours, morning and evening relative humidity) for the crop season during year 2020 and 2021 on standard meteorological weeks (SMW) was obtained from meteorological observatory of the Punjab Agricultural University, Ludhiana and illustrated in Figs. 1 and 2, respectively. The mean weekly maximum air

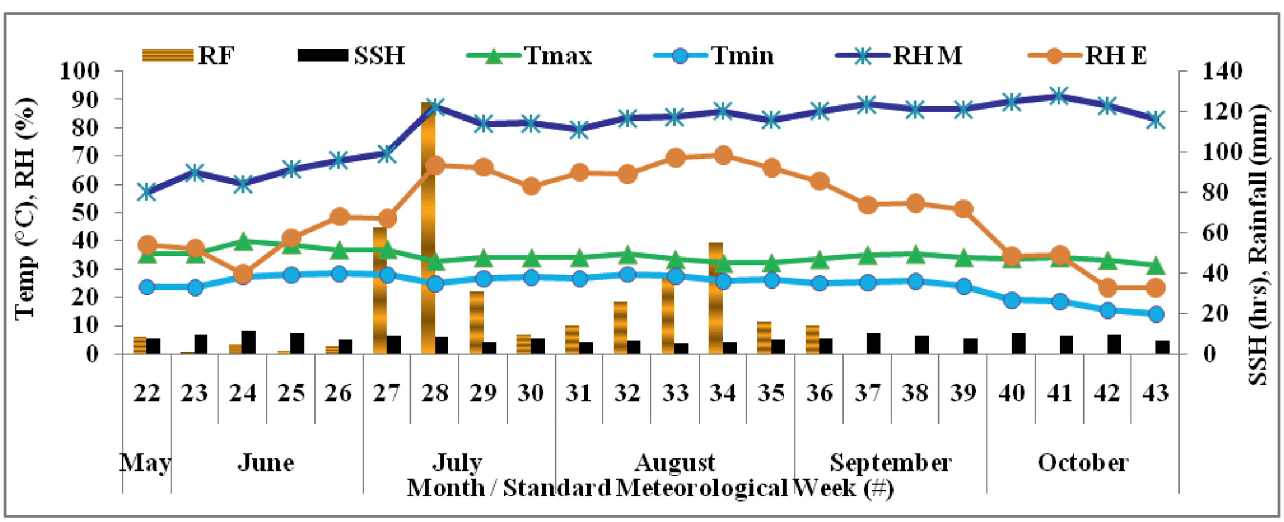

Fig. 1. Weekly meteorological data during rice crop season, *kharif* 2020

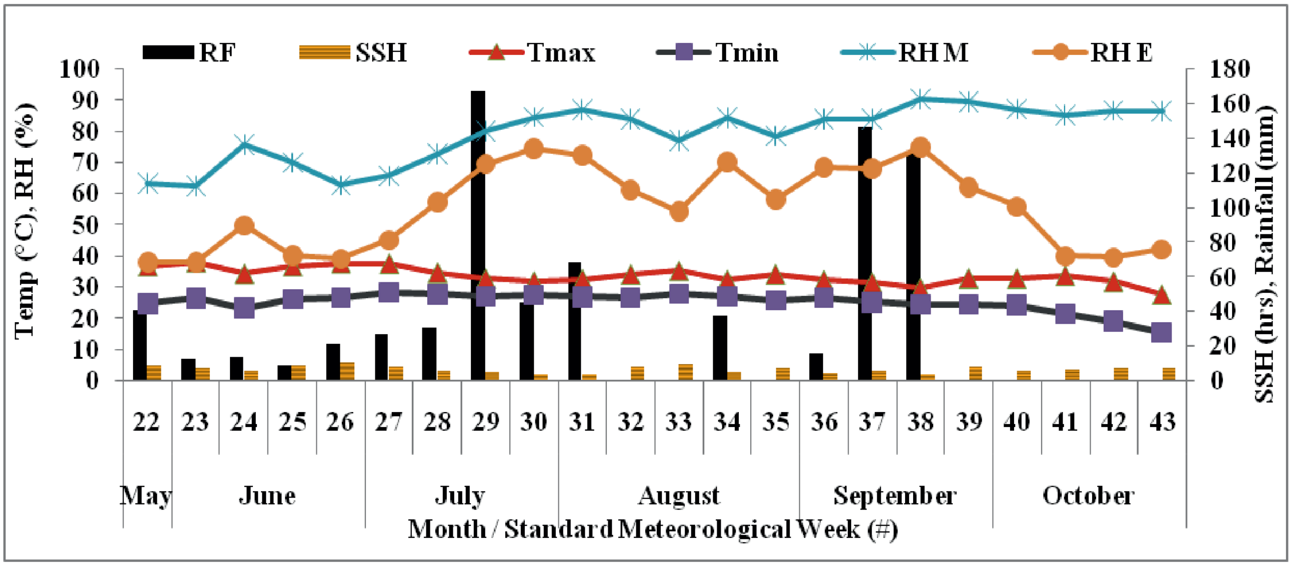

Fig. 2. Weekly meteorological data during rice crop season, *kharif* 2021

temperature during crop season ranged between 31.4 to 41.3 °C and 27.7 to 38.0 °C during 2020 and 2021, respectively. Average weekly minimum temperature ranged between 14.0 to 28.5 °C in 2020 and 15.6 to 28.5 °C in 2021. The average relative humidity (%) varied between 30.1 to 78.1 % and 36.4 to 82.7 % during the crop growing period in 2020 and 2021, respectively. The total amount of rainfall received during the crop growing period was more in 2021 (787.8 mm) than in 2020 (428.8 mm) and the maximum rainfall was received in the month of July (232.4 mm) during 2020 and 295.8 mm in September 2021.The total sunshine hours during the crop period in 2020 and 2021 were 173.7 hrs and 149 hrs, respectively. Due to cloudy weather less sunshine hours were recorded during *kharif* 2021.

The experiment was laid out in Factorial Split Plot Design with three replications comprising 2 crop establishment methods and 3 varieties in main plots and 3 nitrogen levels in sub-plots. Three varieties viz; PR 122, PR 126, and Pusa 44 were planted with puddled transplanted method and direct seeding conventional seed drill. Three Nitrogen levels viz; recommended dose (N_1), 125% of recommended Dose (N_2) and leaf color chart (N_3) were taken. The drill sowing of all three varieties was done at 20 cm row spacing using treated seed on seedbeds prepared in respective main plots on 28th May. The sowing was done after the calibration of drills at the seed rate of 20 kg/ha. For puddled transplanting, the nursery was raised by sowing on the date of direct seeding and transplanted manually with 30 days old seedlings in rows spacing at 20 cm with plant to plant spacing 15 cm. Pendimethalin was sprayed within two days of sowing with knap sack sprayer using 500 l/ha water in DSR while in PTR butachlor was applied as pre-emergence within two days of transplanting in standing water. After that bispyribac sodium was applied with a knapsack sprayer fitted with a flat fan nozzle using 375 l/ha of water at 30 days after sowing (DAS) in direct seeded plots and at 30 days after transplanting (DAT) or 60 DAS in puddled transplanting method. Weed free plots were kept free from weeds by hand weeding as and when needed. For the transplanted crop the N_1 (225 kg/ha Urea) and N_2 (281.25 kg Urea/ha) doses of Nitrogen as recommended by Punjab Agricultural University Ludhiana were applied after 7, 21, and 42 days (35 days for PR 126) after transplanting. In N_3, 62.5 kg/ha basal dose of urea was applied, and after 14 days of transplanting first fully exposed leaves from the top were continuously matched with the 4th strip of LCC at 7 days intervals upto flowering initiation, and 62.5 kg/ha was applied when 6 from 10 leaves shows light colour then LCC strip. For direct seeded crops the N_1 (325 kg Urea/ha) and N_2 (406.25 kg Urea/ha) doses of Nitrogen as recommended by Punjab Agricultural University Ludhiana were applied after 4, 6, and 9 weeks of sowing. In N_3, 62.5 kg basal dose of urea was applied after 4 weeks. After 6 weeks of sowing first fully exposed leaf from top was continuously matched with 4th strip of LCC at 7 days interval upto flowering initiation and 75 kg/ha was applied when 6 from 10 leaves shows light colour then LCC strip.

Growth parameters viz; plant height, dry matter accumulation and its partitioning, chlorophyll content, and leaf area index (LAI) were recorded. Yield and yield attributing characters i.e. panicle length (cm), sterility % age, number of effective tillers plant^{-1}, number of grains per panicle, 1000 grain weight (g), grain yield (kg/ha), straw yield (kg/ha), biomass yield (kg/ha), harvest index were recorded.

$$\text{Harvest index (\%)} = \frac{\text{Grain yield}}{\text{Biomass yield}} \times 100$$ (Camargo - Alvarez *et al.*, 2023)

RESULTS AND DISCUSSION

Growth attributing characters

Plant height

The data presented in Table 1 elucidates the comparative analysis of factors influencing rice crop height during *kharif* 2020 and 2021. In 2020, a numerical disparity in plant height favoring the direct seeding of rice (DSR) method over the puddled transplanted rice (PTR) method was observed with statistical non significant results. That might be due to transplanting shock experienced by rice plants in the PTR method and well established crop in DSR method. Among distinct rice cultivars, Pusa 44 exhibited statistically superior plant height compared to PR 122 and PR 126. Additionally, PR 122 manifested significantly taller plants relative to PR 126. Pertaining to varying nitrogen levels, plants subjected to N_2 treatment displayed a statistically significant elevation in height compared to those treated with N_3, however plant height of N_1 (67.98 cm) was statistically at par with N_2 and N_3. A similar pattern for plant height was observed in *kharif* 2021 as shown in Table 1, however results were non significant for nitrogen levels. Kaur and Singh (2015) also reported that plant hight was higher in DSR than PTR method. The growth attributes of baby corn, viz. plant height, number of leaves, leaf area/plant, dry matter/plant, chlorophyll a and chlorophyll b were significantly influenced by NPK levels (Hrudaya *et al*., 2024).

Crop dry matter production

DSR method produced more crop dry matter (1187 g/m^2) as compared with the PTR method (1156g/m^2) at harvest, however, results were non significant. The disparity in dry matter production between DSR and PTR methods could be attributed to the transplanting shock experienced in PTR method. Initially, DSR showed a higher rate of dry matter production as compared to PTR up to 90 days after sowing (DAS). However, beyond this period, the rate of dry matter production in DSR either equaled or fell below that of PTR. Despite DSR took 7-8 days less to reach maturity, its rapid leaf area growth during the early vegetative stage, higher leaf area index (LAI) before heading, and greater stem number led to a higher interception of radiation before heading compared to PTR. Consequently, DSR accumulated more dry matter. The varieties also showed significant difference for dry-matter accumulation. Dry matter production was highest in Pusa 44 (1243 gm^{-2}) and also significantly more than PR 122 (1180.27 g m^{-2}) and PR 126 (1091.54 g m^{-2}). Dry matter production in PR 122 was also significantly more than PR 126. The performance of rice crop significantly varied according to nitrogen application, dry matter production of N_2 (1199.15 gm^{-2}) was significantly more than N_3 (1135.58 g m^{-2}) however dry matter production of N_1 (1180.09 gm^{-2}) was statistically at par with N_2 and N_3. Similar pattern for dry matter production was observed in 2021 as shown in Table 1 and the difference between establishment methods was also significant. Our findings are in conformity with Kaur and Singh (2015) that dry matter production was more in DSR than PTR

Table 1. Effect of different crop establishment and management practices on plant height, dry matter production, effective tillers, panicle length and weight of 1,000-grains during *kharif* 2020 and 2021

Treatments	Plant height at harvest (cm)		Dry matter at harvest (g/m^2)		Effective tiller/m^2		Panicle length		Weight of 1000 grains (g)	
Year	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021
Establishment methods										
DSR	68.28	67.57	1187	1175	335	328	23.16	22.94	23.64	23.82
PTR	66.87	65.53	1156	1133	327	316	23.68	23.27	24.21	24.51
CD ($P \leq 0.05$)	NS	NS	NS	36	NS	NS	NS	NS	NS	NS
Varieties										
PR 122	71.91	70.85	1180	1162	330	321	22.90	22.53	24.34	24.60
PR 126	55.90	55.07	1092	1075	319	314	23.87	23.72	22.86	22.97
Pusa 44	74.91	73.75	1243	1224	344	332	23.48	23.07	24.58	24.93
CD ($P \leq 0.05$)	2.78	4.45	44	45	19	NS	NS	NS	1.26	1.14
Nitrogen levels										
Recommended dose (N_1)	67.98	66.83	1180	1159	330	321	23.42	23.12	24.12	24.20
125 % of Recommended dose (N_2)	69.26	68.22	1199	1183	342	332	24.17	23.68	23.54	23.87
Leaf colour chart (N_3)	65.50	64.61	1136	1120	322	314	22.67	22.52	24.12	24.43
CD ($P \leq 0.05$)	2.57	NS	45	31	15	14	0.83	0.66	NS	NS

method. Increase in straw yield with application of amendments could partly be at tribute to its direct influence on dry-matter production of vegetative part and indirectly through increased morphological parameters of growth, i.e. plant height, dry-matter, leaf-area index and effective tillers/m^2 (Kaur *et al.,* 2023). Bhatia *et al.* (2012) showed that nitrogen management according to LCC shade 5 (150 kg N/ha) results higher grain yield and biomass yield than shade 4 (120 kg N /ha) of LCC at IARI, New Delhi.

Yield and yield attributing characters

Number of effective tiller m^{-2}

Number of effective tiller m^{-2} is considered to be crucial determinants which are likely to affect greatly the grain yield. Effective tiller per m^{-2} was identified as the most important component amongst the yield attributing characteristics. Effective tillers m^{-2} were more in DSR (335) than transplanting method (327) but difference was non-significant. Higher number of effective tillers per unit area in DSR than PTR was due to higher plant population in the DSR method. Among varieties, effective tiller per m^{-2} was highest in Pusa 44 (344.28) followed by PR 122 (330.17) and PR 126 (318.93). Effective tiller per m^{-2} in Pusa 44 was significantly higher by 7.95 % than PR 126. However, effective tiller per m^{-2} in PR 122 was statistically at par with Pusa 44 and PR 126. Among different nitrogen levels, effective tiller per m^{-2} was highest in N_2 (342) followed by N_1 (330) and N_3 (322.18). Effective tiller per m^{-2} in N_2 was significantly higher by 6.02 % than N_3. However effective tiller per m^{-2} in N_1 was at par with N_2 and N_3. Similar pattern for effective tiller per m^{-2} was observed in 2021 as shown in Table 1 and however results were non significant among varieties. Gill *et al.* (2006) also observed higher effective tiller per m^{-2} in DSR method than PTR method. Singh *et al.* (2014) reported significant effect of nitrogen on effective tiller per m^{-2} from 0 kg /ha to 200 kg /ha.

Panicle length

In crop establishing methods panicle length was more in PTR (23.68 cm) than DSR (23.16 cm) but there was no significant difference. Among varieties panicle length was highest in PR 126 (23.87cm) followed by Pusa 44 (23.48 cm) and PR 122 (22.90 cm) and all are statistically at par. Among different nitrogen levels, panicle length was highest in N_2 (24.17 cm) followed by N_1 (23.42 cm) and N_3 (22.67 cm). Panicle length in N_2 was significantly higher by 6.6 % than N_3 and was at par with N_1. Panicle length in N_1 was also at par with N_3. Results for panicle length showed similar trend in 2021 as shown in Table 1. This might be due to that elevated nitrogen levels can stimulate cell elongation in the panicle, contributing to increased panicle length. Kishore *et al.* (2024) also reported that number of panicles, panicle length and grains per panicle were significantly highest (6.48, 9.08 cm and 152.42) with application of 60 kg N/ha over 20 and 0 kg N/ha but was on par with 40 kg N/ha.

Weight of 1000 grains

Between establishing methods, the weight of 1000 grains was observed to be greater in the transplanting method (24.21 g) compared to direct seeding (DSR) (23.64 g). However, statistical analysis failed to detect a significant disparity between the two methods. Among the varieties, Pusa 44 exhibited the highest weight of 1000 grains (24.58 g), followed by PR 122 (24.44 g) and PR 126 (22.86 g). Notably, the weight of 1000 grains in PR 126 significantly trailed behind Pusa 44 and PR 122 by 6.99% and 6.08%, respectively. Conversely, no statistically significant difference was discerned between Pusa 44 and PR 122. Among different nitrogen levels, weight of 1000 grains was highest in N_3 (24.12 g) followed by N_1 (24.12 g) and N_2 (23.54 g) but statistically at par among all three nitrogen levels. Similar results for weight of 1,000 grains were observed in 2021 as shown in Table 1. Our findings are in conformity with Gill *et al.* (2006), that planting method did not have significant effect on panicle length and test weight. Hrudaya *et al.* (2024) reported heavier baby cob and baby corn weight (38.87 and 7.92 g) recorded due to addition of highest NPK level (T_6) found statistically at par to T_5 (37.30 and 7.50 g) and T4 (36.16 g), respectively though significantly superior over other treatments in baby corn crop.

Number of grains/panicle

Number of grains per panicle in the transplanting method (99.03) was significantly higher as compared to DSR (95.30) by 3.88%. Among the varieties, PR 126 had the highest number of grains per panicle (100.25), followed by Pusa 44 (96.08) and PR 122 (95.17). PR 126 had significantly more grains per panicle compared to PR 122 and Pusa 44 by 5.36% and 4.37%, respectively while grains panicle^{-1} in Pusa 44 was statistically at par with PR 122. Among various nitrogen levels, the count of grains per panicle was highest in N_2 (99.98), followed by N_1 (96.1) and N_3 (95.42). The number of grains per panicle in N_2 significantly surpassed that of N_1 and N_3 by 4.06% and 4.82%, respectively. Notably, N_1 showed no significant difference compared to N_3. Similar pattern was observed in 2021 as shown in Table 2 however results were non significant for varieties. Samant *el at.* (2023) also reported that TPR gave higher yield attributes, i.e. panicles/m^2 (288.3), lengthier panicles (22.4 cm) with more grains/ panicle (185.8) resulting in 3.3% yield improvement over DSR (Table 1). The increase in the number of filled grains with increase in nitrogen rates indicates that nitrogen fertilization is important for both source and sinks development (Yesuf and Balcha, 2014).

Sterility % age

There was no significant difference observed in sterility % age between the establishing methods. In the Direct Seeding of Rice (DSR) method, a sterility % age of 20.19 % was recorded, which was 3.96% lower than the sterility % age observed in the transplanting method, i.e., 21.0%. Among the varieties, PR 126 exhibited the lowest sterility % age at 18.37 %, followed by PR 122 at 20.9 % and Pusa 44 at 22.52 %. It's noteworthy that the sterility % age in PR 126 was significantly lower by 11.96% compared to PR 122 and by 18.22 % compared to Pusa 44. Additionally, the sterility % age in PR 122 was also significantly lower than that in Pusa 44 by 7.11%. Among Nitrogen levels, Sterility % age was lowest in N_3 (19.23) followed by N_1 (20.35) and N_2 (22.20). Sterility % age in N_3 was significantly lower than N_1 by 5.88 % and N_2 by 13.51 %. Sterility % of N_1 was also significantly lower than N_2 by 8.10 %. Similar results for sterility % age were observed in 2021 as shown in Table 2. Xu *et al.* (2022) also reported lower sterility % age in DSR method than PTR method. Mahajan *et al.* (2012) reported increased sterility % age in all cultivars when nitrogen dose increased from 120 to 180 kg/ha.

Grain yield

Grain yield, a fundamental metric for evaluating crop response to various treatments is influenced by a multitude of factors. Within establishment methods, there was no significant difference observed in grain yield. However, in the puddled transplanted method, a grain yield of 6.18 t/ha was recorded, representing a 2.65 % increase over the direct seeded of Rice (DSR) method, which yielded 6.02 t/ha. The observed higher grain yield in the puddled transplanted method (PTR) may be attributed to factors such as increased 1000 grain weight and a greater number of grains per panicle compared to the DSR method. However, it is important to note that the DSR method exhibited advantages in terms of parameters such as effective tillers per square meter and the % age of fertile grains. Among the array of varieties under investigation, Pusa 44 demonstrated the highest grain yield at 6.29 t/ha, followed by PR 122 at 6.04 t/ha and PR 126 at 5.96 t/ha. Notably, Pusa 44 exhibited a grain yield superiority of 4.13 % over PR 122 and 5.62 % over PR 126. The superior grain yield observed in Pusa 44 may be attributed to factors such as a higher number of effective tillers per square meter and greater 1000-grain weight compared to other varieties. However, it is worth noting that PR 126 displayed advantages in terms of both the number of grains per panicle and the % age of fertile grains compared to other varieties. Among the various nitrogen levels investigated, the highest grain yield was recorded in N_2 at 6.24 t/ha, followed by N_1 at 6.07 t/ha and N_3 at 5.98 t/ha. Notably, the grain yield in N_2 surpassed that of N_1 by 2.78 % and N_3 by 4.43 %. The superior grain yield observed in N_2 may be attributed to factors such as a greater abundance of effective tillers per square meter and a higher number of grains per panicle. However, it is noteworthy that N_3 exhibited advantages in both 1000-grain weight and the % age of fertile grains compared to

Table 2. Effect of different crop establishment and management practices on no of grains per panicle, sterility % age, grain yield, harvest index and straw yield during *kharif* 2020 and 2021

Treatment	Grains/ Panicle		Sterility % age		Grain yield (t/ha)		Harvest index		Straw yield (t/ha)	
Year	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021
Establishment methods										
DSR	95.30	94.00	20.19	20.49	6.02	5.83	41.03	40.29	8.67	8.67
PTR	99.03	97.96	21.00	21.50	6.18	5.94	42.72	42.12	8.31	8.20
CD ($P \leq 0.05$)	3.33	3.83	NS	NS	NS	NS	1.0	1.34	0.25	0.26
Varieties										
'PR 122'	95.17	94.16	20.90	21.30	6.04	5.83	41.38	40.69	8.57	8.52
'PR 126'	100.25	98.94	18.37	18.57	5.96	5.80	43.57	43.07	7.72	7.6.1
'Pusa 44'	96.08	94.84	22.52	23.12	6.29	6.03	40.68	39.86	9.18	9.12
CD ($P \leq 0.05$)	4.08	NS	1.26	1.23	NS	NS	1.24	1.64	0.31	0.32
Nitrogen levels										
Recommended Dose (N_1)	96.10	95.45	20.35	20.76	6.07	5.86	41.87	41.21	8.46	8.39
125 % of Recommended dose (N_2)	99.98	98.53	22.20	22.68	6.24	6.02	41.20	40.32	8.94	8.94
Leaf colour chart (N_3)	95.42	93.95	19.23	19.54	5.98	5.79	42.57	42.10	8.08	7.98
CD ($P \leq 0.05$)	3.19	2.59	0.83	0.74	NS	NS	0.73	0.98	0.22	0.19

other nitrogen levels. Results were also similar in 2021 as shown in Table 2. Our results are in conformity with Bhullar *et al*. (2018), and Kaur and Singh (2015) that DSR gives at par yield with PTR method however yield might be slightly more in PTR method. Xu *et al*. (2022) also reported non significant difference between DSR and PTR method. Xu *et al*. (2022) and Singh *et al.* (2014) also reported non significant increase in grain yield of rice crop with increase in nitrogen application.

Harvest index

The harvest index is an important indicator which determines the partitioning of photosynthates among economic and straw yield. Within the establishment methods, the PTR method demonstrated a significantly higher HI of 42.72% compared to the DSR method's HI of 41.03%, marking a notable 4.12% discrepancy. Harvest index in PTR might be more due to higher grain yield in PTR method and less biological yield than DSR method. Among varieties, harvest index was highest in PR 126 (43.57) followed by PR 122 (41.38) and Pusa 44 (40.68). The harvest index of PR 126 exhibited a statistically significant superiority of 5.29% over PR 122 and 7.10% over Pusa 44. Harvest index of PR 122 was at par with Pusa 44. Among Nitrogen levels, N_3 exhibited the highest harvest index (42.57 %), succeeded by N_1 (41.87 %), and N_2 (41.20 %). Notably, N_3 demonstrated a significant increase in harvest index as compared to N_2, with a difference of 3.32% while it was statistically at par with N_1. The harvest index values for both N_1 and N_2 were found to be statistically non significant. Pattern for HI was also similar in 2021 as shown in Table 2. Kaur and Singh (2015) also reported higher harvest index in PTR than DSR method. Kumar *et al.* (2024) also reported increase in harvest index was due to balanced nutrient management.

Straw yield

DSR methodology demonstrated a statistically significant higher straw yield of 8.67 t/ha compared to the PTR method, showing a relative increase of 4.34 %. This discrepancy might be due to higher plant height, increased tiller count, and a lower harvest index in DSR than PTR. Among different varieties, straw yield was highest in Pusa 44 (9.18 t /ha) followed by PR 122 (8.57 t /ha) and PR 126 (7.72 t /ha). Straw yield of Pusa 44 was significantly more than PR 122 by 7.18 % and PR 126 by 18.89 %. The application of nitrogen revealed discernible disparities in straw yield, with N_2 application resulting in the highest yield (8.94 t/ha), followed by N_1 (8.46 t/ha) and N_3 (8.08 t/ha). Straw yield of N_2 was significantly more than N_1 and N_3 by 5.64 and 10.57 %, respectively. Straw yield of N_1 was also significantly more than N_3 by 4.66 %. Similar pattern was observed in 2021 (Table 2). Kaur and Singh (2015) also reported higher straw yield in DSR than PTR. Mahajan *et al.* (2012) reported increase in straw yield with increase in nitrogen from 0 to 120 kg /ha.

All growth characters attributing yield showed almost similar trend in both years under study. However, overall growth characteristics performed less in *kharif* 2021 as compared to 2020 while sterility % age was more in *kharif* 2021 than 2020. Variation in grain yield and growth of all characters was largely attributed due to the variation in climatic conditions. Optimum conditions during vegetative growth in *kharif* 2020 gives an edge over *kharif* 2021. While cloudy weather, low sun shine hours and rainfall during flowering and grain filling stage in 2021 resulted in more sterility % age and lowers the grain yield. Abbas and Mayo (2021) reported negative impact of rainfall on rice plant at heading and flowering stages. Wang *et al,* (2015) also found that low solar radiation during grain filling period could result in a sharp decrease in % age of ripened grains.

It may be concluded that good alternative of puddled transplanted rice with no direct seeded rice, 'PR 126' and nitrogen application according to leaf colour chart are the better outcomes for establishment methods, different varieties and nitrogen levels, respectively. Short duration as well as less water requirement varieties is good alternative to check the lowering water table and futuristic changes in climatic scenarios.

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