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Effect of Macro and Micro Nutrients on Transplanted vs. Direct Seeded Rice

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ABSTRACT

Rice (*Oryza sativa* L.) is an important cereal crop used as a daily staple food by most countries globally and is a major source of income for a large segment of the population. Manual transplanting and the high cost of NPK fertilizers have limited the area and production of rice per unit area. The research experiment was conducted at the Agricultural Research Institute (ARI), Ratta Kulachi, D.I.Khan, KPK, Pakistan, during the cropping season from July to November 2023. The objective of the present study was to compare various methods of paddy sowing and the application of different combinations of macro and micro-nutrients to increase production and minimize the use and cost of chemical fertilizers. The trial used a split-plot arrangement with three replications, comparing transplanted (TPR) vs. direct-seeded rice (DSR) methods against seven macro and micro-nutrient combinations. The results revealed that growth parameters, including the number of tillers (m^{-2}), leaf area index (LAI), and chlorophyll contents, were found statistically significant for the transplanted method of sowing rice. The yield attributes, such as 1000-kernel weight and paddy yield, were found statistically non-significant concerning sowing methods. However, plant height, number of spikelets, panicle length, and normal kernel percentage were recorded as maximum for direct-seeded rice. The fertiliser treatments showed statistically significant results in maximising growth and yield, including plant height, straw yield, leaf area index, paddy yield, and number of tillers (m^{-2}). The study concluded that transplanted rice with NPK (RFD+Zn) proved to the better under the agro-climatic conditions of D.I.Khan. The maximum kernel yield (5620 kg ha^{-1}) was recorded in transplanted rice with the RFD+Zn treatment.

INTRODUCTION

Rice (*Oryza sativa* L.) is a vital cereal crop, serving as the staple food and major source of income for the majority of the global population (Mohapatra et al., 2025). Pakistan ranks 10th globally in rice production. Rice is cropped annually on approximately 167 million hectares worldwide. It contributes 20% of the global energy source (Rana & Gill, 2025) and provides 13% per capita protein share across the globe. In Pakistan, rice is the second major cash and staple food crop after wheat, adding a 0.7% share to the Gross Domestic Product (GDP) in agriculture (Sikandar et al, 2024). However, the rice sector faces constraints like labour unavailability, decreased water resources, rising input costs, and climate variation, especially under traditional transplanted systems (Mushtaq, M et al., 2025).

Rice domestication began approximately ten thousand years ago. The two main species domesticated were Oryza sativa (Asian cultivated rice) and Oryza glaberrima (African cultivated rice). While African rice remains domesticated in West Africa, the Asian cultivated rice has spread globally. By the 16th century, *Oryza sativa* was introduced to West Africa, gradually becoming more popular and spreading worldwide (Luo et al., 2024). The direct-seeded method of rice (DSR) cultivation is an easy, cost-effective, and time-saving alternative to traditional transplanted rice. DSR cultivation uses less water and labour, matures earlier, and provides good paddy quality (Madzivanzira et al., 2018). DSR is practised on about 33 million hectares globally out of 161 million hectares under paddy cultivation (Ranguwal et al., 2024).

Traditional Rice-Wheat Cropping systems are declining due to water scarcity, leading to reductions in acreage and failure to achieve desired yields (Singh et al., 2024). Uneven precipitation cycles also cause moisture scarcity during critical crop stages.. Furthermore, high temperatures resulting from climate change pose a yield-limiting factor (Huang et al., 2025). Globally, the temperature is predicted to increase by 4.8°C by the end of the twenty-first century (Ghosh et al., 2025). In Pakistan, approximately 35% of paddy suffers from Boron (B) deficiency (Kamran et al., 2025). Therefore, achieving high yields necessitates the cultivation of high-yielding varieties with complete production packages, including required doses of macro and micronutrients.

Adopting direct seeding rice (DSR) is highly significant for farmers facing high input costs, as it reduces initial ploughing expenses and ensures timely crop maturity (Memon, 2024). The overall condition of the soil is also improved due to less disturbance caused by ploughing in the indirect seeding method (Hao et al, 2024). This study was conducted to compare different sowing methods and variable fertiliser doses (macro and micro-nutrients) to achieve higher paddy yield and net profit.

Current research has been conducted with the objective of 1) To evaluate the various planting methods for comparing the paddy yield. 2) To observe the effects of macro and micro nutrients on paddy growth and yield. 3) To recommend the best method of paddy sowing on clayey soils with better response of nutrients (macro and micro).

MATERIALS AND METHODS

Selection of site and methodology adopted

The experiment was conducted at the Agricultural Research Institute (ARI), Ratta Kulachi, D.I. Khan (KPK), Pakistan, during the cropping season from July to November 2023. The seedbed was prepared using normal ploughing followed by planking. The coarse rice variety KSK-133 was used. The experiment utilised a Randomised Complete Block Design (RCBD) with a split-plot arrangement and three replications. The plot size was 2.25 m^2 (1.5 m × 1.5 m). The nursery transplantation date for the transplanted method and the sowing date for the direct seeded method were July 15, 2023. An ideal nursery of approximately 32 days was transplanted. The two sowing methods (Transplanted rice and Direct-seeded rice) were placed in the main plot, and the fertiliser treatments were placed in the sub-plots.

Treatment Details

The recommended fertiliser dose (RFD) was 140:60:60 NPK kg ha^{-1}. Fertilisers were applied in the form of Urea, SOP (sulphate of potash), Phosphorus, Zinc, Boron, and Nitrogen.

Table 1

S. No.	Main Plot (Sowing Methods)	S. No.	Sub-Plots (Fertiliser Treatments)
M1	Transplanted rice (TPR)	T1	Control (No fertiliser)
M2	Direct-seeded rice (DSR)	T2	Recommended fertiliser dose (RFD) 140:60:60 NPK kg ha^{-1}
		T3	RFD + Zinc (18 kg ha^{-1})
		T4	RFD + Boron (8 kg ha^{-1})
		T5	½ N + RFD (P: K) + Zn (18 kg ha^{-1})
		T6	½ N + RFD (P: K) + B (8 kg ha^{-1})
		T7	RFD (NPK Kg ha^{-1}) + Zn + B

Nitrogen was applied in three split doses: the first at sowing, followed by the second and third doses at the maximum tillering and booting stage, respectively. Zinc (33%) was applied at 18 kg ha^{-1}, fifteen days after transplanting. Weed control used the weedicide Winsta (30% WP 100 gm.. Bispyribac sodium 180 g kg^{-1}).

Parameters/Variables Studied

Data was collected for fifteen variables:

1. Chlorophyll content (SPAD Value)
2. Leaf area index (LAI)
3. Crop growth rate (CGR) (g m^{-2} day^{-1})
4. Net assimilation rate (NAR) (g m^{-2} day^{-1})
5. Days to 50% heading
6. Plant height (cm)
7. Panicle length (cm)
8. Number of panicles (m^{-2})
9. Number of tillers (m^{-2})
10. Number of spikelets ($spike^{-1}$)
11. Normal kernel (%)
12. Sterility (%)
13. 1000-kernel weight (g)
14. Paddy yield (kg ha^{-1})
15. Straw yield (kg ha^{-1})

Statistical Analysis

The recorded data for each parameter were statistically analysed using the computer software STATISTIX-8.1 for the generation of ANOVA. Means were separated using the Least Significant Difference (LSD) test at the 5% level of probability.

RESULTS AND DISCUSSION

Chlorophyll Content (SPAD Value)

The chlorophyll content was significantly affected by the methods of sowing (P=0.0430). The transplanted method obtained a high chlorophyll content (38.92 SPAD value) compared to the direct seeded method (34.87 SPAD value). This result is supported by (Pramanik et al., 2013). Fertiliser treatments revealed significant variation (P=0.0000). Treatment T5 (½ N+RFD (P: K) +Zn) produced the highest content (42.13 SPAD value). This indicates that the application of major macro nutrients and nitrogen doses enhances chlorophyll content (Lee et al., 2011). The interaction was also statistically significant (P=0.0033). The highest chlorophyll content (43.40 SPAD value) was recorded in T5 (½ N+RFD (P: K) +Zn) of transplanted rice. The lowest value (21.70 SPAD value) was recorded in the control treatment (T1) with direct-seeded rice.

Leaf Area Index (LAI)

LAI showed significant variation for the sowing method (P=0.0098). The transplanted method exhibited the highest LAI (3.29) compared to direct-seeded rice (2.24 LAI) (Tomar et al., 2018). Fertiliser treatments were highly significant (P=0.0000). The highest LAI (3.42) was found in T3 (RFD+Zn). This is in line with (Chaturvedi et al., 2005), who recorded higher LAI using nitrogen fertilisers. The interaction between methods and fertiliser treatments was statistically significant (P=0.0183). The maximum LAI (4.21) was noted in T3 (RFD+Zn) of transplanted rice. The lowest value (2.03 LAI) was recorded in T1 (control) of direct-seeded rice.

Crop Growth Rate (CGR)

CGR revealed significant variation statistically for the sowing method (P=0.0264). The transplanted method gave the highest CGR (6.44 g m^{-2} day^{-1}) compared to direct-seeded rice (5.59 g m^{-2} day^{-1}), which is supported by

Verma et al. (2015). Fertiliser treatments were highly significant (P=0.0004). The maximum CGR (7.77 g m^{-2} day^{-1}) was recorded in T3 (RFD+Zn), which was statistically similar to T2 (RFD) (6.57 g m^{-2} day^{-1}) and T7 (RFD (NPK) + Zn+B) (6.45 g m^{-2} day^{-1}). The minimum CGR (4.49 g m^{-2} day^{-1}) was recorded in T1 (control). The interaction was found non-significant (P=0.2307). However, the highest CGR was obtained from T3 (RFD+Zn) of transplanted rice (8.17 g m^{-2} day^{-1}).

Net Assimilation Rate (NAR)

The net assimilation rate (NAR) was found non-significant statistically for the sowing method (P=0.0953), fertiliser treatments (P=0.2654), and their interaction (P=0.9469). However, the maximum NAR (4.05 g m^{-2} day^{-1}) was recorded in direct-seeded rice. The highest NAR among treatments (4.17 g m^{-2} day^{-1}) was recorded in T7 (RFD+Zn+B).

Days to 50% Heading

Days to 50% heading showed significant variation in the sowing method (P=0.0034). The highest number of days (102.57 days) was recorded in direct-seeded rice, while the lowest (82.14 days) was recorded in the transplanted method. Fertiliser treatments (P=0.8497) and interaction (P=0.3700) were statistically non-significant. The maximum days (103.67 days) were obtained from the T1 (control) plot in direct-seeded rice.

Plant Height (cm)

The sowing method (P=0.0696) and interaction (P=0.1070) were found to be statistically non-significant. However, the maximum plant height (113.68 cm) was obtained from the transplanted plot. Fertiliser treatments were statistically significant (P=0.0000). The highest plant height (124.73 cm) was recorded in T3 (RFD+Zn), followed by T4 (RFD+B) (119.70 cm). The lowest plant height (102.22 cm) was recorded in T1 (control). This positive response to Zn aligns with findings from Siddika et al. (2024).

Panicle Length (cm)

Sowing methods (P=0.4404) and fertiliser treatments (P=0.1135) were non-significant. However, the maximum panicle length (27.29 cm) was recorded in the transplanted method. The interaction between factors was statistically significant (P=0.0325). The highest panicle length (28.83 cm) was recorded in direct-seeded rice with T6 (½ N+RFD (P: K) +B).

Number of Panicle (m^{-2})

The sowing method showed significant variation (P=0.0067). The transplanted method produced a higher number of panicles (371.48 m^{-2}) compared to direct-seeded rice (301.38 m^{-2}) (Rashid et al., 2009). Fertiliser treatments (P=0.0000) and interaction (P=0.0000) were highly significant. T3 (RFD+Zn) produced the maximum number of panicles (379.50 m^{-2}). The interaction maximum (450.67 m^{-2}) was observed in T3 (RFD+Zn) with transplanted rice.

Number of Tillers (m^{-2})

The sowing method showed significant variation (P=0.0053). The transplanted method produced a higher number of tillers (385.95 m^{-2}) compared to DSR (312.43 m^{-2}) (Ishfaq et al., 2020). Fertiliser treatments (P=0.0000) and interaction (P=0.0000) were highly significant. The highest number of tillers (391.83 m^{-2}) was recorded in T3 (RFD+Zn). The maximum interaction value (467 m^{-2}) was also found in T3 (RFD+Zn) with transplanted rice.

Number of Spikelets ($panicle^{-1}$)

The number of spikelets was found non-significant statistically for the sowing method (P=0.0665), fertiliser treatments (P=0.2670), and interaction (P=0.5951). However, the maximum number of spikelets (12.83 $panicle^{-1}$) was recorded in T3 (RFD+Zn).

Normal Kernel (%)

Normal kernel percentage was found non-significant statistically for the sowing method (P=0.2129), fertiliser treatments (P=0.3751), and interaction (P=0.8805). However, the maximum normal kernels (88.23%) were recorded in T3 (RFD+Zn).

Sterility (%)

Sterility percentage was statistically non-significant for the sowing method (P=0.2398), fertiliser treatments (P=0.3708), and interaction (P=0.8757). The minimum sterility (9.08%) was recorded in T3 (RFD+Zn) of direct-seeded rice. High sterility is often linked to high temperature during pollination.

1000-kernel Weight (g)

The sowing method was found non-significant (P=0.1390). However, transplanted rice produced maximum kernel weight (25.66 g). Fertiliser treatments (P=0.0000) and interaction (P=0.0019) were statistically significant. The maximum 1000-kernel weight (30.17 g) was recorded in T3 (RFD+Zn). The maximum interaction value (32 g) was obtained from T3 (RFD+Zn) with transplanted rice (Nawaz et al., 2013; Gebrekidan et al., 2006).

Paddy Yield (kg ha^{-1})

The sowing method was found non-significant (P=0.1326). Transplanted rice gave a slightly higher yield (4205.7 kg ha^{-1}) than direct-seeded rice (4059 kg ha^{-1}). Fertiliser treatments (P=0.0000) and interaction (P=0.0008) were statistically significant. The highest kernel yield (5413.3 kg ha^{-1}) was recorded in T3 (RFD+Zn). The maximum interaction yield (5620 kg ha^{-1}) was recorded in T3 (RFD+Zn) with transplanted rice (Zayed et al., 2011). The minimum yield (2313.3 kg ha^{-1}) was recorded in T1 (Control) with direct-seeded rice.

Straw Yield (kg ha^{-1})

The sowing method showed significant variation (P=0.0042). The transplanted method produced a higher straw yield (3854.8 kg ha^{-1}) compared to direct-seeded rice (3428.1 kg ha^{-1}) (Tomar et al., 2020). Fertiliser treatments were significant (P=0.0000). The maximum straw yield (4991.7 kg ha^{-1}) was recorded in T3 (RFD+Zn). The interaction was non-significant (P=0.3312). However, maximum straw yield (5200 kg ha^{-1}) was received from the plots that were transplanted with T3 (RFD+Zn).

Table 2
Effect of Sowing Methods (Transplanted vs. Direct Seeded Rice) on Growth and Yield Parameters.

S. No.	Parameter	Unit	Transplanted Rice (TPR) Mean	Direct Seeded Rice (DSR) Mean	Statistical Significance (P-value)	Overall Grand Mean
Growth Parameters						
1	Chlorophyll Content (SPAD Value)	SPAD Value	38.92 a	34.87 b	0.0430	36.900
2	Leaf Area Index (LAI)	LAI	3.29 a	2.24 b	0.0098	2.7736
3	Crop Growth Rate (CGR)	g m^{-2} day^{-1}	6.44 a	5.59 b	0.0264	6.0200
4	Net Assimilation Rate (NAR)	g m^{-2} day^{-1}	2.20 NS	4.05 NS	0.0953	3.1301
5	Days to 50% Heading	Days	82.14 a	**102.57 b**	0.0034	92.357
6	Plant Height	cm	113.68 ^{NS}	110.36 NS	0.0696	112.02
7	Panicle Length	cm	27.29 ^{NS}	26.33 NS	0.4404	26.816
8	Number of Panicles	m^{-2}	371.48 a	301.38 b	0.0067	336.43
9	Number of Tillers	m^{-2}	385.95 a	312.43 b	0.0053	349.19
Yield Components						
10	Number of Spikelets	$panicle^{-1}$	12.81 ^{NS}	11.38 ^{NS}	0.0665	12.095
11	Normal Kernel	%	83.14 ^{NS}	85.39 ^{NS}	0.2129	84.265
12	Sterility	%	16.81 ^{NS}	14.67 ^{NS}	0.2398	15.745
13	1000-kernel Weight	g	25.66 ^{NS}	24.47 ^{NS}	0.1390	25.071
14	Paddy Yield	kg ha^{-1}	4205.7 ^{NS}	4059 ^{NS}	0.1326	4132.4
15	Straw Yield	kg ha^{-1}	3854.8 a	3428.1 b	0.0042	3641.4

CONCLUSION AND RECOMMENDATIONS

The experiment aimed to compare the effect of macro and micro nutrients on transplanted vs. direct-seeded rice using an RCBD with split-plot arrangements and three replications. The coarse variety KSK-133 was used, and the recommended NPK dose was 140:60:60 Kg ha^{-1}. Nitrogen was applied in three split doses, and Zinc (18 kg ha^{-1}) was applied 15 days after transplanting.

Key findings for growth parameters revealed that the transplanted method yielded higher values for chlorophyll content, LAI, CGR, and number of tillers (m^{-2}). Notably, the maximum chlorophyll content (43.40 SPAD value) was found in T5 (½ N+RFD (P: K) +Zn) with transplanted rice, and the maximum LAI (4.21) was recorded in T3 (RFD+Zn) with transplanted rice.

Yield parameters showed that the interaction between sowing methods and fertiliser treatments was highly significant for 1000-kernel weight and kernel yield. The maximum kernel yield (5620 kg ha^{-1}) was recorded in T3 (RFD+Zn) with transplanted rice. The maximum straw yield (4991.7 kg ha^{-1}) was also recorded in T3 (RFD+Zn). Despite the higher yields, the difference in yield between transplanted and direct-seeded rice overall was not statistically significant.

It is concluded that the fertiliser interaction with sowing methods produced significant paddy yield differences. The highest paddy yield of (5620 kg ha^{-1}) was recorded from transplanted rice with T3 (RFD+Zn). Furthermore, the direct-seeded paddy with the same fertiliser treatments, T3 (RFD+Zn), gave the second highest paddy yield (5206.7 kg ha^{-1}). All fertiliser treatments significantly outperformed the control group. There was no significant yield difference between transplanted and direct-seeded rice overall, although transplanted paddy offered a slightly higher overall yield. The sterility percentage was found to be non-significant due to favourable environmental conditions.

For obtaining the maximum paddy yield, the application of the recommended dose of NPK along with Zinc (RFD+Zn) is recommended for transplanted rice, followed closely by the same fertiliser treatment in direct-seeded rice. Higher doses of major nutrients along with variable doses of micronutrients can be investigated for further enhancement of paddy yield on the clayey soils of Dera Ismail Khan.

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