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ASSESSING THE EFFECT OF THE DIRECTION OF TRANSPLANTING AND YIELD OF RICE (*ORYZA SATIVA* L.) UNDER DIFFERENT CROP GROWING ENVIRONMENTS

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ABSTRACT

This field experiment investigated the influence of transplanting date and direction on the growth and yield of rice (*Oryza sativa* L.) cultivar Sarjoo-52. The study was conducted during the Kharif season of 2022 at A.N.D. University of Agriculture and Technology, Kumarganj, Ayodhya, Uttar Pradesh, India. A factorial randomized block design with four replications was employed. Six treatments were implemented: transplanting dates on 14th July, 24th July and 3rd August, with two transplanting directions – North-South and East-West. Results revealed that rice transplanted on 14th July exhibited significantly superior growth parameters, including plant height, leaf area index, and dry matter accumulation, compared to later transplanting dates. Additionally, the North-South transplanting direction outperformed the East-West direction for these growth parameters. Furthermore, the 14th July transplanting date in the North-South direction produced significantly higher yield components including grain yield, straw yield, biological yield and harvest index compared to other treatments.

Key words : Transplanting date, Transplanting direction, Growth parameters, Yield components, Rice.

Introduction

Rice (*Oryza sativa* L.) is a vital food crop belonging to the grass family Poaceae. It serves as the staple diet for nearly half of the world's population and ranks among the top three major crops globally. Over 90% of rice production is consumed in Asian countries, where it holds immense significance as a dietary staple (Mohanty, 2013). In India, rice is crucial for food security and the livelihood of millions in rural households (Ghasal *et al*., 2016). It contributes a significant portion of calories (35-75%) for over 3 billion Asians and provides 27% of dietary energy, 20% of protein and 3% of dietary fat globally.

The date of transplanting significantly affects rice growth and yield. The optimal timing varies based on climate, variety, and other factors. Early transplanting (20 days after seeding) has shown higher yields compared to late transplanting (40 days). Early transplanted rice plants produce more tillers, grains per panicle and have a higher harvest index (Singh *et al*., 2010).

Transplanting, a critical stage in rice cultivation, involves moving young seedlings from a nursery to the main field. The direction of transplanting significantly impacts the growth, development, and overall yield of the rice crop. Proper seedling alignment influences factors like light interception, nutrient uptake, water efficiency and pest/disease management. It also affects plant spacing, facilitating optimal development and reducing competition for resources. Selecting the appropriate transplanting direction is vital to maximize rice yield potential.

Aligning rows parallel to the sun's path ensures uniform light distribution and minimizes shading between plants. Considering prevailing wind patterns helps minimize issues like lodging and nutrient uptake problems. Aligning rows perpendicular to the slope improves water flow and drainage, preventing water stagnation and reducing disease risks associated with excessive moisture (Britannica, 2024). The direction of transplanting also impacts weed management. Aligning rows in a direction that facilitates efficient weed control practices minimizes competition for resources. By considering these factors and implementing appropriate practices, farmers can optimize rice growth, development, and yield by effectively managing sunlight, wind, water, and weeds during the transplanting stage (Sakhtivel, 2004 and Krishnan *et al.*, 2019).

Materials and Methods

Location and Experimental site

The experiment was conducted during the kharif season of 2022 at the Student's Instructional Farm of Acharya Narendra Deva University of Agriculture & Technology, located in Kumarganj, Ayodhya, Uttar Pradesh, India (26°54' N, 81°82' E, 113 m asl). The site is situated within the Indo-Gangetic alluvial plains of Eastern Uttar Pradesh.

Meteorological data

Meteorological parameters including minimum and maximum temperatures, relative humidity (minimum and maximum), soil temperature (various depths), wind speed, evaporation, rainfall and sunshine hours were obtained from the University's agrometeorological observatory. During the yield development period (week-wise), the average maximum and minimum temperatures ranged from 10.1 to 42.1°C, relative humidity ranged from 38.8 to 93.8%, sunshine hours ranged from 1.4 to 9.1 hours, and total rainfall was 698.6 mm.

Experimental design and treatments

A factorial design with randomized block design (RBD) was employed for the experiment. Six treatment combinations were established, comprising three sowing dates (D1: July 14th, D2: July 24th, D3: August 3rd) and two transplanting directions (S1: North-South, S2: East-West). The experiment utilized the Sarjoo-52 rice variety.

Growth Parameter measurements

Plant height (cm) : Five plants were randomly selected and tagged within each plot for height measurement at regular intervals (15, 30, 45, 60, 75, 90, and 105 days after transplanting (DAT)). Using a meter scale, plant height was measured from the soil surface to the highest point (apex) at each growth stage until harvest.

Leaf Area Index (LAI) : The leaf area of five plants from border rows was determined at 30, 60, and 90 DAT using a leaf area meter. The LAI was calculated using the formula by Watson (1952):

LAI = (Leaf Area) / (Ground Area)

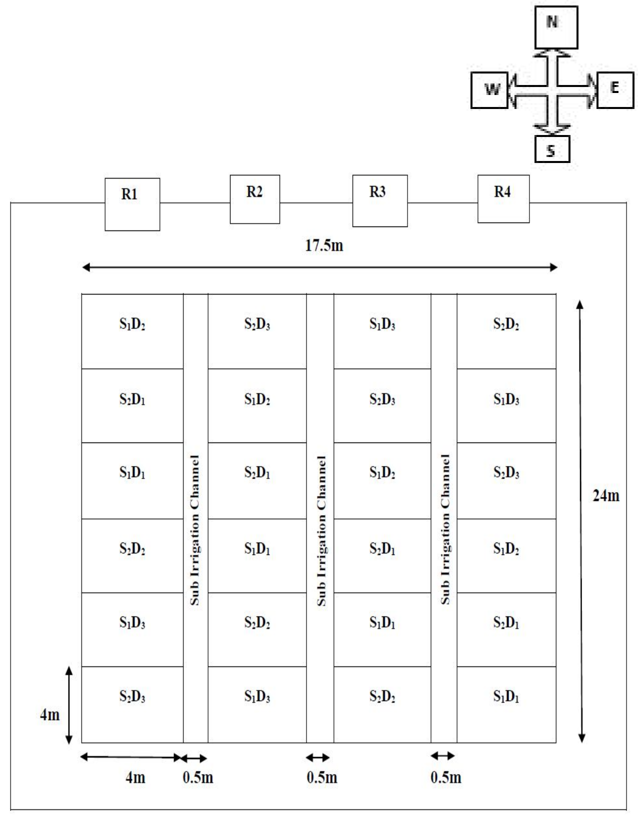

Fig. 1 : Field Layout.

Total Dry matter (g/m²) : Dry matter accumulation was measured at 30, 60, 90 DAT and harvest. Five plants were selected from border rows, cut near the ground surface, and collected in paper bags. Samples were cut into small pieces, sun-dried and then oven-dried at 60°C until constant weight was achieved. The final dry weight was recorded and converted to grams per square meter (g/m²).

Yield-Attributing Characters

Grain yield (q/ha) : The harvested produce from each net plot was manually threshed and the seeds were separated using winnowing. The weight of the seeds was recorded separately for each plot in kilograms (kg). The final weight was then converted into quintals (q) per hectare (ha).

Straw yield (q/ha) : After sun drying, the weight of the straw from each plot was recorded in kilograms (kg). The recorded weight was then expressed in quintals (q) per hectare (ha).

Biological yield (q/ha) : The above-ground parts of the plants were harvested from each plot after reaching maturity. The harvested plant material was weighed to determine the biological yield, which was expressed in quintals (q) per hectare (ha)

Biological yield = Grain yield + Straw yield

Harvest index (%) : The harvest index is the ratio of grain yield and biological yield; it was calculated by the following formula:

$$\text{Harvest index (\%)} = \frac{\text{Economic yield}}{\text{Biological yield}} \times 100$$

Statistical analysis

The collected experimental data underwent statistical analysis using the 'F' test procedure. A conclusion was drawn based on the results obtained at a significance level of 5%. The standard error of the mean (SEm) was calculated for each parameter, and the critical difference (C.D) at a 5% significance level was determined to compare the means of the treatments where the 'F' test yielded significant results.

Results

Growth parameters

Plant height (cm)

The study examined the influence of different agronomic practices on rice plant height, a critical factor impacting crop productivity. Analysis of plant height across various growth stages revealed significant variations attributed to growing environments and transplanting directions in Table 1. At 15 days after transplanting (DAT), plants transplanted on the 14th of July in an environment with a temperature of 32°C exhibited the tallest height at 30.1 cm, followed by those transplanted on the 24th of July at 28.9 cm and the 3rd of August at 28.0 cm. This trend continued throughout the growth stages, with the highest plant height recorded in the 14th July transplanting group at all subsequent stages until harvest. Moreover, the North-South transplanting direction consistently resulted in taller plants compared to the East-West direction. For instance, at 30 DAT, plants in the North-South direction reached a height of 41.1 cm, whereas those in the East-West direction measured 34.6 cm.

Leaf area index

The Leaf Area Index (LAI) serves as a critical indicator of canopy development and light interception efficiency in rice farming systems. In this study, LAI dynamics were thoroughly examined, considering the influence of growing environments and transplanting directions. The objective was to provide actionable recommendations for enhancing crop performance and productivity. The analysis revealed a notable elevation in LAI values with earlier transplanting dates and a North-South directional orientation. Specifically, plants transplanted earlier, particularly on July 14th, exhibited higher LAI values throughout the growth stages,

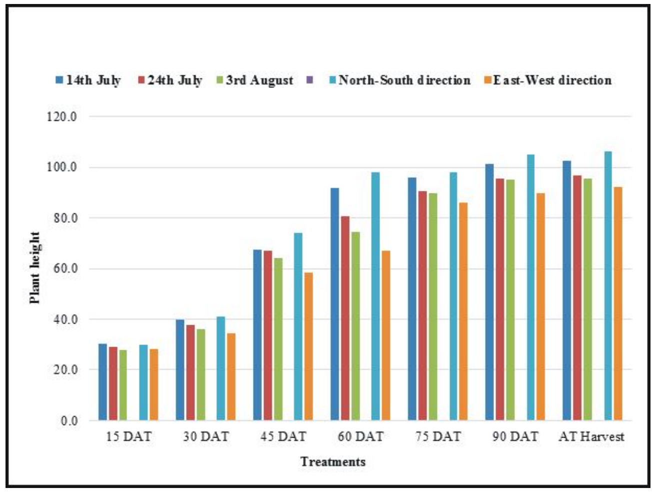

Fig. 2 : Plant height (cm) at different DAT in rice as affected by different growing environments and transplanting.

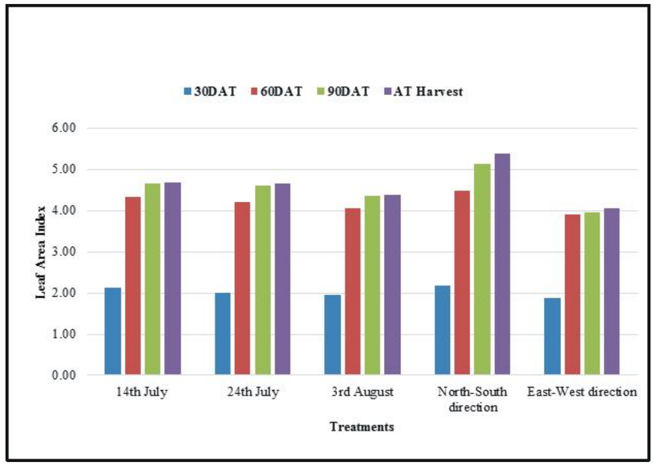

Fig. 3 : Leaf area index at different DAT in rice as affected by different growing environments and transplanting direction.

culminating in significantly higher values at harvest. For instance, at harvest, the LAI values for crops transplanted on July 14th were 4.69, while those transplanted on July 24th and August 3rd recorded slightly lower LAI values of 4.65 and 4.38, respectively. Furthermore, the North-South directional orientation consistently resulted in higher LAI values compared to the East-West direction across all growth stages. For instance, at harvest, crops transplanted in the North-South direction recorded an LAI of 5.38, whereas those in the East-West direction recorded an LAI of 4.05.

Total dry matter (g/m²)

Total dry matter accumulation is a crucial determinant of crop biomass production and resource utilization efficiency in rice cultivation. This study aimed to assess the impact of growing environments and transplanting directions on total dry matter accumulation throughout various growth stages, thereby identifying actionable

Table 1 : Plant height at different days after transplanting (DAT) of rice as affected by growing environments and transplanting direction.

Treatments	Plant height (cm)						
Crop Growing Environments/ Temperature	15 DAT	30 DAT	45 DAT	60 DAT	75 DAT	90 DAT	AT harvest
14th July/ 32^{0}C	30.1	39.8	67.6	92.0	95.8	101.3	102.1
24th July/ 29^{0}C	28.9	37.6	67.1	80.8	90.5	95.6	96.3
3rd August/ 29^{0}C	28.0	36.2	64.1	74.5	89.7	95.3	95.7
SEm±	**0.19**	**0.74**	**1.07**	**2.06**	**2.64**	**3.21**	**3.41**
CD (5%)	**NS**	**2.26**	**3.26**	**6.27**	**8.04**	**9.78**	**10.38**
Transplanting Directions							
N-S direction	29.9	41.1	74.3	97.9	98.0	105.0	106.4
E-W direction	28.1	34.6	58.3	66.9	86.0	89.8	92.4
SEm±	**0.15**	**0.61**	**0.88**	**1.68**	**2.16**	**2.62**	**2.87**
CD(5%)	**NS**	**1.83**	**2.64**	**5.12**	**6.51**	**7.91**	**8.72**

Table 2 : Leaf Area Index (LAI) at different dates of transplanting of rice as affected by growing environments and transplanting direction.

Treatments	Leaf Area Index (LAI)			
Crop Growing Environments/ Temperature	30DAT	60DAT	90DAT	At harvest
14th July/ 32^{0}C	2.14	4.32	4.66	4.69
24th July/ 29^{0}C	2.00	4.20	4.61	4.65
3rd August/ 29^{0}C	1.96	4.04	4.36	4.38
SEm±	**0.040**	**0.094**	**0.136**	**0.148**
CD(5%)	**NS**	**0.285**	**0.414**	**0.477**
Transplanting Directions				
N-S direction	2.18	4.47	5.13	5.38
E-W direction	1.89	3.90	3.96	4.05
SEm±	**0.033**	**0.077**	**0.111**	**0.137**
CD(5%)	**NS**	**0.231**	**0.335**	**0.414**

strategies for optimizing biomass yield. The analysis revealed notable variations in total dry matter accumulation across different growing environments. Specifically, rice crops transplanted on the 14th of July at a temperature of 32°C exhibited the highest dry matter accumulation at all growth stages, with values of 196.8 g/m² at 30 DAT, 385.3 g/m² at 60 DAT, 856.4 g/m² at 90 DAT, and 1271.0 g/m² at harvest. Conversely, crops transplanted on the 3rd of August at 29°C displayed the lowest dry matter accumulation, with values of 188.1 g/m² at 30 DAT, 362.4 g/m² at 60 DAT, 814.0 g/m² at 90 DAT and 1207.8 g/m² at harvest. Furthermore, the directional orientation of transplanting significantly influenced total dry matter accumulation. Rice crops transplanted in the North-South direction consistently exhibited higher dry matter accumulation compared to those transplanted in the East-West direction. For instance, at harvest, crops transplanted in the North-South direction recorded a total dry matter of 1269.3 g/m², whereas those transplanted in the East-West direction yielded 1122.0 g/m².

Yield

Grain yield (q/ha)

The data on rice grain yield at different growth stages, as depicted in Table 4 and Fig. 5, illustrates notable variations influenced by diverse treatments. Analysis reveals significant disparities in grain yield across varying growing conditions during the growth phases. Notably, the highest grain yield was attained on July 14th, totalling 49.45 q/ha, followed by July 24th at 44.82 q/ha and August 3rd at 40.50 q/ha. Moreover, examining the effect of transplanting directions, it is evident that the North-South orientation (S1) yielded the highest grain yield, reaching 50.08 q/ha, while the East-West direction (S2) registered the lowest yield at 41.76 q/ha. These findings underscore the significance of both temporal factors, such as transplanting dates and spatial factors, such as directional orientation, in influencing rice grain yield, thus emphasizing the need

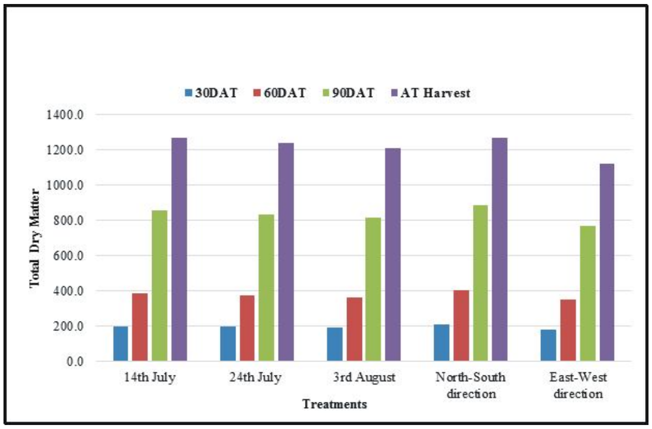

Fig. 4 : Total dry matter (g/m²) at different DAT in rice as affected by different growing environments and transplanting direction.

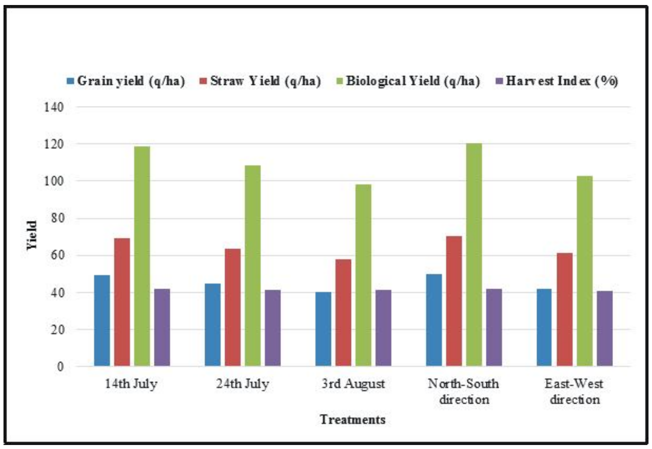

Fig. 5 : Yield in rice as affected by different growing environments and transplanting direction.

Table 3 : Total dry matter at different dates of transplanting of rice as affected by growing environments and transplanting direction

Treatments	Total dry matter (g/m²)			
Crop Growing Environments/ Temperature	**30DAT**	**60DAT**	**90DAT**	**At harvest**
14th July/ 32⁰C	196.8	385.3	856.4	1271.0
24th July/ 29⁰C	194.6	374.5	835.9	1238.2
3rd August/ 29⁰C	188.1	362.4	814.0	1207.8
SEm±	**5.19**	**11.47**	**21.76**	**27.45**
CD (5%)	**15.78**	**34.57**	**66.20**	**80.72**
Transplanting Directions				
N-S direction	206.9	402.9	888.3	1269.3
E-W direction	180.8	349.3	769.2	1122.0
SEm ±	**4.24**	**9.37**	**17.77**	**22.60**
CD (5%)	**12.88**	**28.23**	**53.55**	**68.09**

for strategic planning and management in rice cultivation practices.

Straw yield (q/ha)

The findings regarding straw yield in rice cultivation, as illustrated in Table 4 and Fig. 5, demonstrate notable disparities influenced by diverse growth conditions and transplant treatments. Examination of the data indicates marked variations in straw yield across different growth stages and environments. Specifically, the analysis reveals that the highest straw yield was attained on July 14th, registering at 69.07, followed by July 24th at 63.57 and August 3rd at 57.87. Regarding the impact of transplanting directions, it is evident that the North-South direction (S1) yielded the highest straw yield, reaching 70.08, while the East-West direction (S2) yielded the lowest straw yield at 61.26. These observations underscore the importance of considering both temporal and spatial factors in optimizing straw yield in rice cultivation practices.

Biological yield (q/ha)

The data presented in Table 4 and Fig. 5 delineate the recorded information concerning the biological yield of rice at distinct growth phases, considering diverse treatments. The findings underscore notable discrepancies in the biological yield across varied growing conditions throughout the developmental stages. Upon scrutiny of the table, it is discernible that the peak biological yield was documented on July 14th (the initial transplanting date), registering at 118.52, succeeded by July 24th (the second transplanting date) at 108.39 and August 3rd (the third transplanting date) at 98.37. Analysis of the influence of transplanting orientations reveals that the North-South direction (S2) yielded the highest biological yield, recording 120.16, while the East-West direction (S2) yielded the lowest biological yield at 103.02. These findings underscore the intricate relationship between transplanting strategies and biological yield in rice cultivation.

Harvest Index (%)

The data recorded on the harvest index of rice across various growth stages, as presented in Table 4 and Fig. 5, underscore notable disparities influenced by diverse treatments. Examination of the findings reveals substantial variations in the harvest index across different growing conditions throughout growth. Notably, the highest harvest index was observed on July 14th, registering at 41.72, succeeded by July 24th at 41.35 and August 3rd at 41.17, signifying

Table 4 : Yield in rice as affected by different growing environments and transplanting directions.

Treatments	Yield			
Crop Growing Environments/ Temperature	**Grain Yield (q/ha)**	**Straw Yield (q/ha)**	**Biological Yield (q/ha)**	**Harvest Index (%)**
14th July/ 32^{0}C	49.45	69.07	118.52	41.72
24th July/ 29^{0}C	44.82	63.57	108.39	41.35
3rd August/ 29^{0}C	40.50	57.87	98.37	41.17
SEm±	**0.71**	**1.00**	**1.68**	**0.16**
CD (5%)	**2.16**	**3.05**	**5.10**	**0.49**
Transplanting Directions				
N-S direction	50.08	70.08	120.16	41.68
E-W direction	41.76	61.26	103.02	40.54
SEm ±	**0.58**	**0.82**	**1.37**	**0.13**
CD (5%)	**1.76**	**2.49**	**4.17**	**0.40**

temporal influences on harvest efficiency. Moreover, assessing the impact of transplanting directions unveils distinct patterns. The North-South direction (S1) notably yielded the highest harvest index at 41.68, while the East-West direction (S2) exhibited the lowest index at 40.54. These findings underscore the significance of spatial arrangement in crop cultivation practices, suggesting that certain orientations may optimize resource utilization and ultimately enhance harvest efficiency.

Discussion

The observed variations in rice plant height highlight the practical implications of optimizing agronomic practices, particularly in transplanting strategies. Early transplanting, exemplified by the taller plants in the July 14th group, promotes greater height accumulation due to longer vegetative growth periods. Similarly, favouring the North-South directional orientation over East-West aligns with the concept of better light interception and canopy development, resulting in increased plant height. These findings stress the importance of tailored agronomic approaches in rice cultivation to optimize plant growth and overall crop productivity, echoing previous research (Ma *et al*., 2016 and Singh *et al*., 2018).

Furthermore, variations in Leaf Area Index (LAI) values across different transplanting dates and directions hold significant implications for rice crop management and productivity enhancement strategies. Higher LAI values associated with earlier transplanting dates suggest that timely transplantation contributes to better canopy development and light interception efficiency, consistent with previous findings (Wassmann *et al*., 2009). Additionally, the influence of transplanting directions on LAI underscores the importance of spatial arrangement in rice cultivation, with the North-South direction promoting superior light interception and canopy coverage, critical for photosynthesis and crop productivity (Dingkuhn *et al*., 2008).

Regarding total dry matter accumulation, observed variations highlight the influence of growing environments and transplanting directions on biomass yield in rice cultivation systems. Early transplanting on July 14th led to enhanced biomass production, attributed to favourable environmental conditions and longer growth duration. Conversely, delayed transplanting on August 3rd resulted in reduced dry matter accumulation, possibly due to shorter growth duration and unfavourable environmental conditions. The influence of transplanting directions on dry matter accumulation further emphasizes the importance of spatial arrangement in optimizing resource utilization and biomass production, with the North-South direction facilitating superior light interception and distribution, and favourable microclimatic conditions (Xu *et al*., 2015 and Patel *et al*., 2015).

Additionally, the variations in grain yield underscore the intricate interplay between growing environments and transplanting strategies in rice cultivation. Early transplanting, coupled with the North-South directional orientation, consistently yielded higher grain yields, emphasizing the need for meticulous planning in field operations (Singh *et al*., 2010). Fluctuations in straw yield highlight the significant impact of transplanting dates and directions on biomass production, further underscoring the importance of timely field operations and spatial arrangement in enhancing overall crop productivity.

Similarly, analysis of biological yield reveals the multifaceted influence of growing environments and transplanting directions on crop productivity, with early transplanting and the North-South direction facilitating higher yields. These findings stress the importance of holistic approaches considering both temporal and spatial factors in rice cultivation management. Finally, examination of the harvest index indicates enhanced resource utilization for grain production with early transplanting and preference for the North-South direction, echoing the critical importance of optimal transplanting strategies and spatial arrangement in maximizing rice crop productivity and sustainability, consistent with prior research (Wassmann *et al.*, 2009).

Conclusion

This study emphasizes optimizing agronomic practices and spatial arrangements in rice cultivation to boost crop performance. Early transplanting and preferred directional orientations are crucial for taller plants, improved canopy development, and increased plant height. Timely transplantation extends vegetative periods, promoting height accumulation, while the North-South directional orientation enhances light interception and canopy coverage. Moreover, the research highlights the importance of timing and spatial factors in rice crop management, with early transplanting leading to better canopy development and light interception. Additionally, the North-South orientation enhances dry matter accumulation by optimizing resource utilization and creating favourable microclimatic conditions. Farmers can optimize rice production by tailoring transplanting practices to their specific growing environments by implementing these findings.

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