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Effect of Crop Establishment Methods on Growth Indices and Flowering of Lowland Rice (*Oryza sativa* L.)

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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Abstract

During the summer of 2019, a field trial at the Instructional cum Research Farm, S.G. College of Agriculture and Research Station, Jagdalpur, Chhattisgarh, India, examined how different establishment practices affected the growth and phenological development of rice. Among the methods compared, transplanting seedlings aged 20 days gave the most favourable overall growth response. It produced the highest leaf area index (LAI), crop growth rate (CGR), relative growth rate (RGR) during the first two observation intervals, and internodal length (8.81 cm). LAI rose between sowing and 60 days after sowing (DAS), before falling at 90 DAS.

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RGR similarly increased from 0–30 to 30–60 DAS and then decreased over 60–90 DAS, whereas CGR increased across the recorded intervals. With 20-day-old transplanted seedlings, RGR was 0.024, 0.027 and 0.017 g g^{-1} day^{-1} for 0–30, 30–60 and 60–90 DAS, respectively. This treatment also reached flower initiation earliest (67 days), followed by 50% flowering at 71 days. By comparison, broadcasting sprouted seeds delayed these stages to 77 and 88 days, respectively. The variation in time to 50% flowering was not statistically significant among treatments. Under the agro-climatic conditions investigated, transplanting 20-day-old rice seedlings was therefore associated with improved vegetative growth and earlier initiation of reproductive development.

Keywords: Crop establishment methods; leaf area index; crop growth rate; relative growth rate.

1. Introduction

As a major staple, rice contributes substantially to food security worldwide, especially in rural communities. The species, *Oryza sativa* L., belongs to Poaceae and is thought to have originated in Southeast Asia. It is described as a principal food source across 89 countries and is often called the 'Global Grain'. The expression 'Rice is Life' reflects its importance to India's food security (Jaiswal *et al.*, 2025). Globally, approximately 161 million hectares were reported under rice cultivation in 2011, with production of 678.7 million tonnes (Food and Agriculture Organization of the United Nations, 2009). Four production ecosystems have been identified for rice: irrigated areas account for 57%, rainfed lowlands for 31%, rainfed uplands for 9% and deep-water environments for 3% (Jaiswal *et al.*, 2024a). A further global estimate reports 782 million tonnes of rice produced on 167.1 million hectares. Among leading rice-producing countries, India occupies second position after China for both production and cultivated area (Food and Agriculture Organization of the United Nations, 2020; Ministry of Agriculture & Farmers Welfare, 2020).

A recent review described direct seeding and transplanting as contrasting rice-establishment practices that require different management approaches (Poojitha *et al.*, 2024). Field evidence from a temperate region also documented differences in crop performance and phenological measures between direct-seeded and transplanted rice (Mubarak *et al.*, 2025).

A variety of rice-growing systems and genotypes characterise Chhattisgarh, an important producer in India. Its designation as the 'Rice Bowl of India' reflects the crop's prominence in the state. The Northern Hills, Chhattisgarh Plains and Bastar Plateau form its three agro-climatic zones, in which cultivation practices differ. Rice-based cropping is widespread: one reported estimate gives 38.1 lakh ha under the crop, 80.4 lakh tonnes of production and a productivity of 2101 kg ha^{-1}. Farmers establish paddy either by transplanting into puddled fields or by direct seeding in unpuddled fields, using seed drills or broadcasting and subsequently practising beushening (Jaiswal *et al.*, 2024b). Another account places the state's rice area at approximately 3.98 million hectares and mean productivity at 3,002 kg ha^{-1} (Directorate of Extension Services, 2026). Summer rice occupies an estimated 116.47 thousand hectares and contributes 227.04 thousand tonnes to production. Of this seasonal area, 112.69 thousand hectares lie in the Chhattisgarh Plains, compared with 3.13 thousand hectares in the Northern Hills and 0.65 thousand hectares in the Bastar Plateau. Summer-rice acreage has expanded in all these zones apart from the Northern Hills. The Chhattisgarh Plains consistently have the highest productivity and contribute 90.69–97.96% of the state's cultivated summer-rice area and 89.58–98.88% of its summer-rice output (Singh *et al.*, 2018).

In a summer-rice field study, Mondal *et al.* (2024) observed that seedbed management, transplanting methods, and irrigation regimes influenced growth attributes, including leaf area index. Chowdhury *et al.* (2024) examined growth responses and vegetation indices in transplanted and direct-seeded rice under different nitrogen levels. Similarly, Jamsheed *et al.* (2026) reported significant differences in rice growth indices between transplanting and direct seeding under the tested nutrient-management practices.

However, the comparative responses of growth indices, internodal length, and flowering to the establishment practices examined under summer lowland conditions in the Bastar Plateau require further assessment.

The objective of this study was to evaluate the effects of six crop-establishment methods on leaf area index, crop growth rate, relative growth rate, internodal length, days to flower initiation, and days to 50% flowering of lowland rice during summer 2019 at Jagdalpur, Chhattisgarh.

2. Materials and Methods

The experiment took place in summer 2019 at the Instructional cum Research Farm of S.G. College of Agriculture and Research Station, Kumhrawand, Jagdalpur, Chhattisgarh, India, on loamy soil. The state extends from 17°30′ to 24°45′ N and from 70°30′ to 84°15′ E. Bastar was reported at 19°10′ N, 81°95′ E and 552 metres above mean sea level; the experimental locality of Kumhrawand, within Bastar district, is situated at 19°05′18″ N and 81°57′42″ E. Meteorological records supplied by S.G. CARS, IGKV, Jagdalpur, indicate 2313 mm of annual rainfall and a mean temperature of 31.6°C for 2019. Rainfall during crop growth totalled 137.50 mm. The highest temperature, 39.1°C, occurred in the second week of May, whereas the minimum, 12.2°C, was recorded in the second week of February. The fourth week of April had the greatest sunshine duration (9.3 hours). The experimental soil was classified as *Inceptisol*. A randomised complete block design (RCBD) was used, with four replications of six establishment treatments: T1, transplanting 20-day-old seedlings; T2, broadcasting normal seeds; T3, line sowing sprouted seeds; T4, broadcasting followed by Biasi (Beushening) at 25 DAS; T5, broadcasting sprouted seeds; and T6, line sowing normal seeds. MTU-1010 was the rice variety tested. Land preparation and basal fertiliser application preceded transplanting of nursery-raised seedlings on 25 February 2019. Transplanted plants were spaced 20 cm between rows and 10 cm within rows, and plots were prepared according to the requirements of the assigned establishment method. An N:P:K dose of 80:60:40 kg ha^{-1} was applied. All recommended phosphorus and potassium were incorporated at the time of transplanting or direct sowing, and 50% of the nitrogen was applied 30 days after crop establishment. To manage stem borer and rice leaf folder, chlorpyrifos at 2 ml L^{-1} was sprayed on two occasions, 15

and 45 days after transplanting. Harvesting at physiological maturity was carried out with sickles on 31 May 2019; the harvested material was sun-dried before manual threshing. Leaf area index (LAI), crop growth rate (CGR) and relative growth rate (RGR) were observed at 30, 60 and 90 DAS. The other observations comprised days to flower initiation, days to 50% flowering and internodal length at harvest. Following Gomez and Gomez (1984), the data were subjected to statistical analysis in which the F-value (variance ratio) assessed treatment effects, while standard errors and critical differences at the 5% probability level were used to assess significance.

3. Results and Discussion

3.1 Leaf Area Index (LAI)

The leaf area index (LAI) indicates the extent of growing crop foliage over a unit of ground area and is related to crop productivity. Table 1 reports measurements made at 30, 60 and 90 DAS. Across treatments, values generally rose up to 60 DAS and subsequently fell by 90 DAS as the crop senesced. The largest values at these three observations—2.36, 3.82 and 2.82—occurred where seedlings were transplanted at 20 days of age. Line sowing of normal seeds gave the next closest LAI response, with values of 1.96, 3.39 and 2.25, whereas broadcasting sprouted seeds produced the smallest canopy indices (0.42, 1.02 and 0.77). Broadcasting normal seeds and broadcasting followed by Biasi (beushening at 25 DAS) also gave higher indices than broadcasting sprouted seeds across the observation stages. The reported advantage of transplanting over most other treatments may reflect the greater control over plant arrangement and planting depth afforded by manual establishment. The relationship between establishment method and LAI is consistent with observations reported by Baloch *et al.* (2006).

Table 1. Effect of crop establishment methods on Leaf Area Index (LAI) of rice

	Treatments	LAI		
		30 DAS	60 DAS	90 DAS
T_1	Transplanting of 20 days old seedling	2.36	3.82	2.82
T_2	Broadcasting of normal seeds	1.19	2.31	1.87
T_3	Line sowing of sprouted seeds	1.30	2.86	1.97
T_4	Broadcasting + Biasi (beushening at 25 DAS)	1.24	2.55	1.94
T_5	Broadcasting of sprouted seeds	0.42	1.02	0.77
T_6	Line sowing of normal seeds	1.96	3.39	2.25
SEm±		0.19	0.24	0.18
CD (P = 0.05)		0.59	0.77	0.56

3.2 Internodal Length

Internodal length was assessed at harvest, with the treatment comparisons given in Table 2. Transplanting seedlings at 20 days (T1) yielded the longest internodes (8.81 cm). A comparatively close length of 8.23 cm was obtained through line sowing of normal seeds. Values for line-sown sprouted seeds, line-sown normal seeds and broadcasting with Biasi (beushening at 25 DAS) were 8.00, 8.23 and 7.95 cm, respectively; these treatments were statistically similar and exceeded broadcasting sprouted seeds. Transplanted rice attained greater plant height during growth, which was offered as an explanation for its longer internodes. More favourable establishment under transplanting may also have facilitated rooting and nutrient acquisition, thereby supporting subsequent elongation of the stem. Broadcasting sprouted seeds gave the shortest internodes, at 7.00 cm. In that treatment, irregular establishment, differences in plant population and intensified competition for resources may have limited vegetative development. Findings of a similar nature were described by Kumhar *et al.* (2018) and Jia *et al.* (2023).

Table 2. Effect of crop establishment methods on internodal length at harvest

Treatments		Internodal length (cm) At harvest
T_1	Transplanting of 20 days old seedling	8.81
T_2	Broadcasting of normal seeds	7.90
T_3	Line sowing of sprouted seeds	8.00
T_4	Broadcasting + Biasi (beushening at 25 DAS)	7.95
T_5	Broadcasting of sprouted seeds	7.00
T_6	Line sowing of normal seeds	8.23
SEm±		0.19
CD (P = 0.05)		0.61

3.3 Crop Growth Rate (CGR)

Table 3 compares CGR over 0–30, 30–60 and 60–90 DAS. The rates were modest in the first interval, with relatively small differences among methods apart from broadcasting sprouted seeds, but increased appreciably after 30 DAS. Transplanting 20-day-old seedlings (T1) produced 0.07, 0.19 and 0.33 g plant^{-1} day^{-1} in the three periods, the highest rates recorded. During 0–30 DAS, line sowing sprouted seeds and broadcasting with Biasi (beushening at 25 DAS) gave statistically comparable rates to transplanting.

T1 remained the leading method at 30–60 and 60–90 DAS (0.19 and 0.33 g plant^{-1} day^{-1}), while line sowing normal seeds gave the closest response among the other practices. Broadcasting sprouted seeds consistently gave the lowest CGR values: 0.02, 0.04 and 0.14 g plant^{-1} day^{-1}. These results resemble those of Rahman *et al.* (2020).

Table 3. Effect of crop establishment methods on Crop Growth Rate (CGR) of rice

Treatments		Crop Growth Rate (CGR) (g plant^{-1} day^{-1})		
		0-30 DAS	30-60 DAS	60-90 DAS
T_1	Transplanting of 20 days old seedling	0.07	0.19	0.33
T_2	Broadcasting of normal seeds	0.04	0.06	0.17
T_3	Line sowing of sprouted seeds	0.06	0.12	0.25
T_4	Broadcasting + Biasi (beushening at 25 DAS)	0.05	0.09	0.21
T_5	Broadcasting of sprouted seeds	0.02	0.04	0.14
T_6	Line sowing of normal seeds	0.06	0.15	0.29
SEm±		0.01	0.01	0.01
CD (P = 0.05)		0.02	0.03	0.04

3.4 Relative Growth Rate (RGR)

Relative growth rate (RGR) varied with both crop age and establishment practice (Table 4). In every treatment, the rate rose from the first interval (0–30 DAS) to 30–60 DAS, but was lower during 60–90 DAS. For broadcasting sprouted seeds, the respective rates were 0.009, 0.011 and 0.007 g g^{-1} day^{-1}, the lowest values among the practices evaluated. Transplanting 20-day-old seedlings produced values of 0.024, 0.027 and 0.017 g g^{-1} day^{-1} across the same intervals. Under line sowing normal seeds, RGR was 0.022 and 0.025 g g^{-1} day^{-1} during the first two intervals, respectively; both values were statistically comparable with those of the transplanted treatment. Higher plant stature, leaf area and tiller number were considered possible contributors to the greater biomass accumulation and growth observed under these establishment practices (Jaiswal *et al.*, 2020). Theerthana *et al.* (2021) likewise documented increases in plant height, LAI and CGR with manual transplanting at different crop stages, demonstrating the importance of establishment practice for rice growth. In related work, Durga and Anitha (2021) found relatively high RGR during early and active vegetative development, followed by lower values later in the season. They linked the later reduction partly to leaf loss and changes in the accumulation of plant dry matter. This explanation is in keeping with the decrease recorded during 60–90 DAS in the present field trial.

Table 4. Effect of crop establishment methods on Relative Growth Rate (RGR) of rice

Treatments		Relative Growth Rate (RGR) (g plant^{-1} day^{-1})		
		0-30 DAS	30-60 DAS	60-90 DAS
T_1	Transplanting of 20 days old seedling	0.024	0.027	0.017
T_2	Broadcasting of normal seeds	0.011	0.014	0.009
T_3	Line sowing of sprouted seeds	0.020	0.023	0.015
T_4	Broadcasting + Biasi (beushening at 25 DAS)	0.018	0.021	0.013
T_5	Broadcasting of sprouted seeds	0.009	0.011	0.007
T_6	Line sowing of normal seeds	0.022	0.025	0.018
SEm±		0.002	0.002	0.001
CD (P=0.05)		0.006	0.007	0.004

Table 5. Effect of crop establishment methods on Days to flower initiation and 50% flowering

Treatments		Days to flower initiation	Days to 50 % Flower
T_1	Transplanting of 20 days old seedling	67	71
T_2	Broadcasting of normal seeds	76	80
T_3	Line sowing of sprouted seeds	70	76
T_4	Broadcasting + Biasi (beushening at 25 DAS)	73	79
T_5	Broadcasting of sprouted seeds	77	88
T_6	Line sowing of normal seeds	68	75
SEm±		1.07	1.04
CD (P = 0.05)		3.37	NS

3.5 Days to Flower Initiation and 50% Flowering

The onset of flowering marks the shift from vegetative development to the reproductive phase and accompanies changes in the allocation of biomass. Table 5 compares the time taken to initiate flowers and to attain 50% flowering under the six establishment practices. Flower initiation occurred latest following broadcasting of sprouted seeds (77 days); this exceeded the timing under the other treatments significantly, except for broadcasting normal seeds (76 days). The intervals to initiation under line sowing sprouted

seeds and broadcasting with Biasi (beushening at 25 DAS) were statistically comparable. Transplanting 20-day-old seedlings and line sowing normal seeds were likewise similar, requiring 67 and 68 days, respectively; transplanting nevertheless had the smallest numerical value. In this experiment, flower initiation occurred earlier after transplanting than after the direct-sowing treatments. Although the observed times to 50% flowering ranged from 71 days for transplanting to 88 days for broadcasting sprouted seeds, differences among treatments were not statistically significant. Broadcasting normal seeds required 80 days and had the next longest time to 50% flowering. Temperature, photoperiod and plant developmental status are among the factors governing rice flowering. By contrast with the earlier initiation observed here, Lee *et al.* (2021) reported that transplanting shock can suppress initial growth and postpone heading relative to direct seeding.

4. Summary and Conclusions

Under the conditions of the present study, the most favourable vegetative performance was associated with transplanting rice seedlings aged 20 days. Relative to the alternative methods, this practice generally produced higher leaf area index, crop growth rate, relative growth rate and internodal length, and flower initiation occurred earlier. Broadcasting sprouted seeds, by comparison, yielded the weakest growth measurements and the latest flowering. Although transplanting gave the earliest numerical time to 50% flowering, the treatment differences for this variable were not statistically significant. The results therefore support consideration of transplanting 20-day-old seedlings as an establishment option for encouraging rice growth and timely initiation of reproduction in the agro-climatic conditions examined.

5. Limitations

This field experiment was conducted at one location during a single summer season using one rice variety, so its findings may not be generalisable to other seasons, genotypes or agro-climatic conditions. The reported observations focus on growth indices, internodal length and flowering; they do not independently establish comparative effects on grain yield, resource-use efficiency or economic performance. In addition, the differences among treatments in days to 50% flowering were statistically non-significant and should not be interpreted as demonstrated treatment effects.

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Declaration of AI Use

This manuscript was prepared through the intellectual contributions of the author(s) to the study design, data analysis, interpretation of results, and scholarly content. ChatGPT, Claude and Perplexity were used solely to assist with grammatical refinement and reference formatting during manuscript revision. The author(s) accept full responsibility for the accuracy, integrity, and final content of the manuscript.

Competing Interests

Authors have declared that they have no known competing financial interests OR non-financial interests OR personal relationships that could have appeared to influence the work reported in this paper.

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