E-ISSN: 2618-0618
P-ISSN: 2618-060X

NAAS Rating (2025): 5.20
www.agronomyjournals.com
2025; 8(8): 535-538
Received: 24-05-2025
Accepted: 27-06-2025

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Agro-management strategies for delay sowing of rice (*Oryza sativa* L.)

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DOI: https://www.doi.org/10.33545/2618060X.2025.v8.i8h.3593

Abstract
The field experiment entitled "Agro-management strategies for delay sowing of rice (*Oryza sativa* L.)" was conducted during *kharif*, 2024 at Research cum Instructional Farm, Indira Gandhi Krishi Vishwavidyalaya, Raipur. The experimental field was *Vertisol*, neutral in reaction (pH 7.06), low in available nitrogen (144.20 kg ha^{-1}), medium in available phosphorus (18.9 kg ha^{-1}) and high in available potassium (376.7 kg ha^{-1}). The experiment was laid out in Randomized Block Design (RBD) with three replications. The treatments consisted; T1- Transplanting of 30 days old two seedlings on Aug 3, T2- Transplanting of 35 days old three seedlings on Aug 8, T3- Transplanting of 40 days old four seedlings on Aug 13, T4- Transplanting of 45 days old five seedlings on Aug 18, T5- Wet direct seeding with two seeds on Aug 3, T6- Wet direct seeding with three seeds on Aug 8, T7- Wet direct seeding with four seeds on Aug 13 and T8- Wet direct seeding with five seeds on Aug 18. The test variety was Vikram TCR.
The results reveal that significantly superior growth parameters i.e., plant height, number of tillers, leaf area, root length, root volume and root dry weight were observed under sowing of two seeds on August 3 in wet direct seeded and it was statistically at par with sowing of three seeds on August 8 or four seeds on August 13 in wet direct seeded condition and transplanting of 30 days old two seedlings on August 3. The significant variation on panicle length, test weight and harvest index were not found due to different treatments. The number of panicles was significantly higher under transplanting of 40 days old four seedlings on August 13 but it was statistically at par with transplanting of 30 days old two seedlings on August 3, transplanting of 35 days old three seedlings on August 8 and sowing of five seeds on August 18 in wet direct seeded. The sowing of two seeds on August 3 in wet direct seeded produced significantly higher panicle weight, number of filled grains, grain yield and straw yield and found statistically comparable with sowing of three seeds on August 8 or four seeds on August 13 in wet direct seeded and transplanting of 30 days old two seedlings on August 3. The sowing of two seeds on August 3 in wet direct seeded obtained highest gross return, net return and B:C ratio followed by sowing of three seeds on August 8 and transplanting of 30 days old two seedlings on August 3.

Keywords: Rice, delayed sowing, transplanting, wet direct seeding, seedling age, sowing interval, growth, yield, energetics, economics

Introduction

Rice (*Oryza sativa* L.) is the most vital cereal crop in the developing world, feeding over half the global population. It is typically grown as an annual grass and cultivated across more than 100 countries, from flooded lowlands to uplands. Of the 20 species in the *Oryza* genus, *O. sativa* dominates global cultivation, while *O. glaberrima* is minimally grown in Africa. Rice contributes 21% of global energy intake and 15% of protein, especially in Asia, where it provides 50-80% of daily calories for many. With a rising population, India's rice demand is expected to reach 125 million tonnes by 2025 (Kumar *et al*., 2007) [4]. Two primary rice establishment methods are used globally: transplanting and direct seeding (DSR). DSR includes dry seeding, wet seeding, and water seeding. In recent decades, wet DSR has gained prominence due to labor shortages and water scarcity. However, weed management remains a key challenge in DSR (Hassan & Upasani, 2015) [3].

India has the largest area under rice cultivation (~44.5 million ha) and is the second-largest producer (~136.7 million tonnes in 2022-23). Major rice-producing states include West Bengal, UP, Punjab, Odisha, AP, Bihar, and Chhattisgarh—known as the "Rice Bowl of India"—with a productivity of 3.8 t/ha. Timely sowing is crucial factor for maximizing rice yields (Pattar *et al*., 2001) [6]. Seedlings per hill also affect plant population and canopy structure, influencing yield. Sowing date affects vegetative growth, grain filling, and yield quality (Shahram *et al*., 2012) [7]. Furthermore, the optimal age for transplanting is determined by the growth duration of the rice variety and the specific environmental conditions of the field (Nandini Devi and Ibopishak, 2000) [5].

In delayed monsoon years, transplanting is often postponed, requiring adjustments in nursery management. Both early and late sowing can reduce yield due to extended crop cycles or immature panicles. Delay planting reduces the tiller production due to poor early establishment Baloch *et al*. (2002) [1].

Materials and Methods

A field experiment was conducted at Research cum Instructional Farm, College of agriculture IGKV, Raipur, Chhattisgarh. The experimental field was *Vertisol*, neutral in reaction (pH 7.06), low in available nitrogen (144.20 kg ha^{-1}), medium in available phosphorus (18.9 kg ha^{-1}) and high in available potassium (376.7 kg ha^{-1}). The experiment was laid out in Randomized Block Design (RBD) with three replications. The treatments consisted; T1- Transplanting of 30 days old two seedlings on Aug 3, T2- Transplanting of 35 days old three seedlings on Aug 8, T3- Transplanting of 40 days old four seedlings on Aug 13, T4- Transplanting of 45 days old five seedlings on Aug 18, T5- Wet direct seeding with two seeds on Aug 3, T6- Wet direct seeding with three seeds on Aug 8, T7- Wet direct seeding with four seeds on Aug 13 and T8- Wet direct seeding with five seeds on Aug 18. The test variety was Vikram TCR.

The field was prepared post-winter harvest using a tractor-drawn cultivator, followed by planking, puddling, and levelling. Irrigation and drainage channels were also laid. Crop residues and weeds were removed before transplanting. Dry bed nursery was prepared with raised beds (20 cm height). Regular irrigation and weeding ensured healthy seedling growth until transplanting. Seedlings of different ages were uprooted manually and transplanted at a spacing of 20 × 10 cm, with 2-5 seedlings hill^{-1} as per treatment. A fertilizer dose of 120:60:40 kg N:P_2O_5: K_2O ha^{-1} was applied using urea, SSP, and MOP. Phosphorus, potassium, and half the nitrogen were applied basally; the rest of the nitrogen was top-dressed at active tillering and panicle initiation stages. Irrigation was maintained at 5 ± 2 cm depth during vegetative stages. Puddling and transplanting were done under flooded conditions. Manual harvesting was done at physiological maturity using serrated sickles. Border rows and hills were excluded. Harvested bundles were field-dried, weighed, and recorded. Manual threshing was done using wooden sticks. Cleaned grain was weighed using an electronic balance.

Economic analysis was performed by calculating the cost of cultivation (₹ ha^{-1}), which included expenses on fertilizers, labor, and all field operations such as ploughing, weeding, irrigation, harvesting, threshing, and winnowing, based on prevailing market prices. Gross returns (₹ ha^{-1}) were computed using the market price of rice for the year 2022, and net returns (₹ ha^{-1}) were obtained by subtracting the cost of cultivation from gross returns. The benefit-cost (B:C) ratio was then calculated by dividing gross returns by the total cost of cultivation.

Results and Discussion

The data presented in the table 1 shows the tillering behaviour and rooting pattern of rice under under delayed condition significant variations were observed in plant height, number of tillers hill^{-1}, and dry matter accumulation (g hill^{-1}), while plant population remained unaffected. The highest values are for T5-sowing of two seeds under wet direct seeding on August 3.

Growth parameters

The plant height, dry matter accumulation, leaf area and root length were highest under sowing of two seeds on August 3 in wet direct seeded and also found comparable with sowing of three seeds on August 8 or four seeds on August 13 in wet direct seeded condition and transplanting of 30 days old two seedlings on August 3.

The number of total tillers was highest in sowing of two seeds on August 3 under wet direct seeded but it was statistically at par with sowing of three seeds on August 8 except 25 DAS/DAT, transplanting of 30 days old two seedlings on August 3 at 50 DAT/DAS and transplanting of 30 days old two seedlings on August 3, sowing of four seeds on August 13 under wet direct seeded at 75 and 100 DAT/DAS.

The root volume was highest under sowing of two seeds on August 3 in wet direct seeded and it was at par with sowing of three seeds on August 8 in wet direct seeded. At 50 DAT/DAS, sowing of four seeds on August 13 in wet direct seeded and transplanting of 30 days old two seedlings on August 3 were also found comparable with above treatments. The root dry weight was maximum under sowing of two seeds on August 3 in wet direct seeded and statistically at par with sowing of three seeds on August 8 in wet direct seeded and transplanting of 30 days old two seedlings on August 3 Giri and Subudhi (2007) [2].

The dry matter accumulation and root dry weight was significantly reduced under transplanting of 45 days old five seedlings on August 18 which was at par with transplanting of 40 days old four seedlings on August 13 and sowing of five seeds on August 18 in wet direct seeded Surekha *et al*., (2013) [8].

Yield

The grain and straw yield were recorded highest under sowing of two seeds on August 3 in wet direct seeded and it was at par with sowing of three seeds on August 8 in wet direct seeded and yield was significantly reduced under transplanting of 45 days old five seedlings on August 18.

Economics

The gross return, net return, B:C ratio, energy output input ratio, energy use efficiency and energy productivity were maximum under sowing of two seeds on August 3 in wet direct seeded.

Table 1: Effect of delayed sowing on various growth attributes of rice at 50 DAT/DAS.

Treatment	Plant height (cm)	Total tillers (No. m^{-2})	Leaf area (cm^2 $hill^{-1}$)	Root volume (cm^3)	Dry matter accumulation (g $hill^{-1}$)
T1- Transplanting of 30 days old 2 seedlings on Aug 3	71.07	286.00	790.13	8.12	12.39
T2- Transplanting of 35 days old 3 seedlings on Aug 8	68.07	250.00	632.53	7.32	11.05
T3- Transplanting of 40 days old 4 seedlings on Aug 13	63.53	170.00	584.00	2.59	6.66
T4- Transplanting of 45 days old 5 seedlings on Aug 18	54.00	134.00	474.16	2.15	5.99
T5-Wet direct seeding with 2 seeds on Aug 3	80.17	348.00	873.00	9.48	15.00
T6-Wet direct seeding with 3 seeds on Aug 8	72.93	326.00	834.40	9.11	13.93
T7-Wet direct seeding with 4 seeds on Aug 13	68.08	270.00	698.80	7.84	12.29
T8-Wet direct seeding with 5 seeds on Aug 18	63.60	224.00	632.47	5.20	8.68
SEm±	4.41	21.31	39.95	1.67	0.93
CD(P=0.05)	13.38	64.65	121.19	5.06	2.72

Table 2: Effect of delay sowing on grain yield, straw yield and harvest index of rice

Treatment	Grain Yield (t ha^{-1})	Straw yield (t ha^{-1})	Harvest Index (%)
T1- Transplanting of 30 days old 2 seedlings on Aug 3	4.17	7.29	36.37
T2- Transplanting of 35 days old 3 seedlings on Aug 8	3.50	6.13	36.33
T3- Transplanting of 40 days old 4 seedlings on Aug 13	3.26	5.70	36.38
T4- Transplanting of 45 days old 5 seedlings on Aug 18	2.02	3.53	36.39
T5-Wet direct seeding with 2 seeds on Aug 3	4.57	8.00	36.37
T6-Wet direct seeding with 3 seeds on Aug 8	4.25	7.44	36.34
T7-Wet direct seeding with 4 seeds on Aug 13	4.03	7.05	36.37
T8-Wet direct seeding with 5 seeds on Aug 18	3.43	6.00	36.36
SEm±	0.29	0.50	0.01
CD(P=0.05)	0.87	1.52	NS

Table 3: Economics of rice under delay sowing condition

Treatment	Cost of cultivation (₹ ha^{-1})	Gross return (₹ ha^{-1})	Net return (₹ ha^{-1})	B: C
T1- Transplanting of 30 days old 2 seedlings on Aug 3	48998	106747	57749	2.18
T2- Transplanting of 35 days old 3 seedlings on Aug 8	49653	89045	39392	1.79
T3- Transplanting of 40 days old 4 seedlings on Aug 13	50308	82929	32621	1.65
T4- Transplanting of 45 days old 5 seedlings on Aug 18	50963	51384	420	1.01
T5-Wet direct seeding with 2 seeds on Aug 3	41318	116253	74935	2.81
T6-Wet direct seeding with 3 seeds on Aug 8	41973	108803	66829	2.59
T7-Wet direct seeding with 4 seeds on Aug 13	42628	102511	59882	2.40
T8-Wet direct seeding with 5 seeds on Aug 18	43283	87267	43983	2.02

Conclusion
Sowing of two seeds on August 3 or three seeds on August 8 or four seeds on August 13 under wet direct seeding and transplanting of 30 days old two seedlings on August 3 found to be comparable and significantly superior over rest of the treatments for number of tillers, root length, root volume and root dry weight. The growth parameters and yield were significantly increased either sowing of two seeds on August 3 or three seeds on August 8 or four seeds on August 13 under wet direct seeding and it was statistically at par with transplanting of 30 days old two seedlings on August 3.

The gross return, net return, B:C ratio, energy output input ratio, energy use efficiency and energy productivity were maximum under sowing of two seeds on August 3 in wet direct seeded.

Acknowledgements
The authors express sincere gratitude to the head of the department, major advisor, all the advisory committee members and field in charge, Research cum Instructional Farm, Department of Agronomy, Indira Gandhi Krishi Vishwavidyalaya, Raipur, 492012 (Chhattisgarh), India for generously providing the essential facilities needed to conduct this research

Authors contribution
The experiment was conceptualized and designed by Dr. A. K. Verma, executed the experiment and performed data analysis. Akki Jhansi Rani wrote the manuscript under the supervision of A. K. Verma.

Research content
The research content of the manuscript is original and has not been published elsewhere.

Conflict of Interest
The authors declare no conflict of Interest.

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