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Effect of rice establishment methods and crop diversification on growth, yield and economics of rice under rice-based cropping systems in Jharkhand

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Abstract

Rice-based cropping systems are predominant in this region; however, their productivity and profitability are often constrained by declining soil fertility, erratic rainfall distribution, low resource-use efficiency and conventional crop management practices. Therefore, adoption of suitable rice establishment methods along with diversification of rice-based cropping systems is essential for improving productivity and profitability. A field experiment was conducted during the kharif seasons of 2023 and 2024 to evaluate the effect of rice establishment methods and crop diversification on growth, yield attributes, productivity and economics of rice. The experiment comprised three rice establishment methods, viz., transplanting (M1), wet direct-seeded rice (M2) and dry direct-seeded rice (M3), and four cropping systems, viz., rice–wheat (CS1), rice–chickpea (CS2), rice–mustard (CS3) and rice–linseed (CS4). Rice establishment methods significantly influenced most of the growth and yield-attributing parameters. Transplanted rice recorded the highest plant height (109.94 and 113.44 cm), number of tillers (303.75 and 320.25 m⁻²) and dry matter accumulation (1057.00 and 1091.67 g m⁻²) in 2023 and 2024, respectively. Similarly, transplanting produced the maximum number of panicles (271.09 and 284.68 m⁻²), fertile grains panicle⁻¹ (116.25 and 130.75) and 1000-grain weight (24.71 and 25.13 g), whereas dry DSR recorded the lowest values for these parameters. Wet DSR remained intermediate for most growth and yield attributes and showed considerable improvement in the second year. Grain and straw yields increased in 2024 compared with 2023 under all establishment methods. Transplanting recorded the highest grain yield of 4347 and 4628 kg ha⁻¹ in 2023 and 2024, respectively, followed by wet DSR (4059 and 4340 kg ha⁻¹), while dry DSR recorded the lowest yield (3535 and 3817 kg ha⁻¹). However, wet DSR resulted in the highest net return (₹59,799 and ₹67,407 ha⁻¹) and benefit:cost ratio (2.48 and 2.67) in 2023 and 2024, respectively, indicating its economic advantage over transplanting despite slightly lower grain yield. Among cropping systems, rice–chickpea generally recorded the highest values for growth and yield attributes and showed the highest grain yield in 2024 (4609 kg ha⁻¹), net return (₹58,860 and ₹71,587 ha⁻¹) and B:C ratio (2.38 and 2.68) during 2023 and 2024, respectively. Overall, the results indicate that transplanting favoured growth and yield formation, whereas wet DSR provided a more favourable economic return. Rice–chickpea emerged as the most promising diversification option among the evaluated cropping systems.

Keywords: Rice establishment methods, transplanting, wet direct-seeded rice, dry direct-seeded rice, crop diversification, rice–chickpea system, grain yield, economics, rice-based cropping systems

1. Introduction

Rice (*Oryza sativa* L.) is one of the most important cereal crops in the world and serves as the staple food for more than half of the global population. In India, rice occupies approximately 51.27 million hectares with a production exceeding 150.18 million tonnes, playing a crucial role in ensuring food and nutritional security (Government of India, 2025). In Jharkhand, rice is the principal kharif crop and constitutes the foundation of the farming system in both upland and medium land situations. However, the productivity of rice-based systems in the region remains relatively low due to erratic rainfall, poor soil fertility, low input use efficiency and dependence on traditional crop establishment practices (Sanjeev Kumar *et al* 2025) [12]. Conventional puddled transplanted rice has been the predominant method of rice cultivation in eastern India because of its ability to suppress weeds and ensure better crop establishment.

Nevertheless, this method requires large quantities of water and labour, making rice cultivation increasingly expensive under changing socio-economic conditions (Farooq *et al.*, 2011) ^[3]. Rising labour scarcity, increasing production costs and declining water availability have encouraged the adoption of alternative crop establishment methods such as wet direct-seeded rice (Wet DSR) and dry direct-seeded rice (Dry DSR). These methods reduce labour requirements, save irrigation water and facilitate timely crop establishment (Kumar and Ladha, 2011) ^[7].

Rice establishment methods significantly influence crop growth, nutrient uptake, yield formation and economic returns. Earlier studies have reported that transplanted rice often produces superior growth and yield attributes due to better root establishment and nutrient availability, whereas direct-seeded rice systems may offer economic advantages through reduced cultivation costs (Pandey and Velasco, 2002; Chauhan *et al.*, 2015) ^[11, 2]. The relative performance of these methods, however, varies with agro-climatic conditions, soil characteristics and crop management practices.

Rice-based cropping systems dominate the agricultural landscape of eastern India, but continuous cultivation of conventional rice-based sequences has resulted in declining soil fertility and reduced system productivity (Gill and Ahlawat, 2006) ^[5]. Diversification of rice-based systems with suitable rabi crops such as wheat, chickpea, mustard and linseed offers opportunities to improve resource-use efficiency, enhance soil fertility and increase farm profitability. Crop diversification not only stabilizes productivity but also reduces production risks associated with climatic variability (Lal *et al.*, 2017) ^[8].

Among diversification options, inclusion of legumes such as chickpea is particularly important because of their ability to fix atmospheric nitrogen and improve soil nutrient status. Legume-based systems have been reported to enhance soil organic carbon, nutrient availability and subsequent crop productivity (Ghosh *et al.*, 2007) ^[4]. Wheat, mustard and linseed are also important rabi crops of Jharkhand, contributing significantly to food, oilseed and income security. Therefore, identification of suitable rice establishment methods and diversified cropping systems is essential for achieving sustainable agricultural intensification.

2. Materials and Methods

The field experiment was conducted at the Research Farm of Krishi Vigyan Kendra (KVK) and Zonal Agricultural Research Station (ZARS), Darisai, East Singhbhum under Birsa Agricultural University, Ranchi, Jharkhand during the kharif and rabi seasons of two consecutive years, 2023–24 and 2024–25. The experimental site is situated at 22°12' North latitude and 84°04' East longitude with an altitude of about 244 m above mean sea level. The region falls under the eastern plateau and hill region of Jharkhand and is characterized by sub-humid tropical climate with hot summer, moderate rainfall and cool winter season. The experimental field was medium land and sandy loam in texture with a bulk density of 1.40 Mg m⁻³, field capacity of 23.50%, and permanent wilting point of 10.90%. The soil was acidic in reaction (pH 5.60), containing 5.12 g kg⁻¹ organic carbon, 236 kg ha⁻¹ available nitrogen, 16.50 kg ha⁻¹ available phosphorus and 138 kg ha⁻¹ available potassium. The experiment was laid out in a Split Plot Design (SPD) with three replications. Rice establishment methods were assigned to the main plots, whereas cropping systems were allocated to the sub-plots. Main Plot Treatments (Rice Establishment Methods) M₁: Transplanting M₂: Wet direct-seeded rice (Wet DSR) under puddled conditions M₃: Aerobic rice (Dry DSR). Sub-Plot treatments (Cropping Systems) CS₁: Rice–Wheat CS₂: Rice–Chickpea CS₃: Rice–Mustard CS₄:

Rice–Linseed. Thus, twelve treatment combinations (3 × 4) were evaluated with three replications. The rice variety Sahbhagidhan was grown during the kharif season. In the rabi season, wheat variety DBW-187, chickpea variety Birsa Chana-3, mustard variety BBM-1 and linseed variety Priyam were cultivated according to their respective cropping systems. Observations on plant height, number of tillers, dry matter accumulation, yield attributes (panicle number, panicle length, fertile grains panicle⁻¹, sterile grains panicle⁻¹ and test weight), grain yield, straw yield and harvest index were recorded following standard procedures. Economic analysis included estimation of cost of cultivation, gross return, net return and benefit-cost ratio using prevailing market prices of inputs and outputs. Experimental data were subjected to analysis of variance (ANOVA) appropriate for a split plot design as described by Gomez and Gomez (1984) ^[6].

3. Results and Discussion

Effect of rice establishment methods and crop diversification on growth parameters of rice

Transplanting (M₁) recorded the highest plant height, tiller number and dry matter accumulation in both years. Plant height under M₁ increased from 109.94 cm in 2023 to 113.44 cm in 2024, tiller number from 303.75 to 320.25 m⁻², and dry matter accumulation from 1057.00 to 1091.67 g m⁻². Dry DSR (M₃) recorded the lowest values. Among cropping systems, rice-chickpea (CS₂) recorded the highest plant height (107.39 and 117.05 cm), tillers (294.00 and 331.33 m⁻²) and dry matter accumulation (1032.00 and 1119.88 g m⁻²) during 2023 and 2024, respectively. Rice-wheat (CS₁) generally recorded the lowest growth values. The better growth under transplanting may be attributed to more uniform crop establishment and favourable plant population, while the superior performance of rice-chickpea could be associated with the beneficial residual effect of the preceding legume. Mishra *et al.* (2012) ^[9] also evaluated different establishment methods specifically in a rice–chickpea system, demonstrating the importance of establishment practices for productivity of this cropping sequence. Similar differences among rice establishment methods have also been reported by Padma *et al.* (2023) ^[10], who observed differences in yield attributes and productivity among transplanting and DSR methods.

3.1 Effect of rice establishment methods and crop diversification on yield attributing characters of rice

Transplanting (M₁) produced the highest number of panicles, fertile grains panicle⁻¹ and 1000-grain weight in both years. Panicle number increased from 271.09 to 284.68 m⁻², fertile grains from 116.25 to 130.75 panicle⁻¹, and 1000-grain weight from 24.71 to 25.13 g between 2023 and 2024. Dry DSR recorded the lowest values for these attributes and the highest number of unfertile grains. Among cropping systems, rice-chickpea (CS₂) performed best, with 263.54 and 290.43 panicles m⁻², 112.78 and 132.67 fertile grains panicle⁻¹, and 24.35 and 26.03 g 1000-grain weight in 2023 and 2024, respectively. The better reproductive development under transplanting and rice-chickpea was reflected in their greater panicle formation and fertile grain production. Padma *et al.* (2023) ^[10] reported significant differences in panicles m⁻², panicle length, filled grains panicle⁻¹ and grain yield among rice establishment methods, with wet DSR performing particularly well under their experimental conditions. Thus, the present results confirm that the response of rice yield attributes to establishment method is strongly influenced by the production environment and management practices.

3.2. Effect of rice establishment methods and crop diversification on yield

Grain and straw yields were higher in 2024 than in 2023 across all treatments, indicating better overall crop performance in the second year. Transplanting (M1) recorded the highest grain yield of 4347 and 4628 kg ha⁻¹ and straw yield of 6162 and 6801 kg ha⁻¹ in 2023 and 2024, respectively. Dry DSR (M3) recorded the lowest grain yield of 3535 and 3817 kg ha⁻¹. Among cropping systems, rice-chickpea (CS2) produced the highest grain yield (4110 and 4609 kg ha⁻¹) and straw yield (5932 and 6846 kg ha⁻¹) in 2023 and 2024, respectively. Rice-wheat (CS1) recorded the lowest grain yield in both years (3882 and 4101 kg ha⁻¹).

The higher yield under transplanting was consistent with its greater tiller number, panicle number and fertile grains. The superior performance of rice-chickpea suggests a favourable contribution of legume-based diversification to rice productivity. Mishra *et al.* (2012)^[9] studied establishment methods in the rice-chickpea system and confirmed that crop establishment practices can substantially influence productivity of this sequence. Similarly, Banjara *et al.* (2022)^[11] emphasized that choice of crop establishment and cropping-system management substantially affects productivity of rice-based systems.

3.3 Effect of rice establishment methods and crop diversification on harvest index

Harvest index showed relatively smaller differences among treatments compared with yield. Transplanting recorded 41.35 and 40.48% in 2023 and 2024, respectively, compared with 39.59 and 39.22% under dry DSR. Among cropping systems, rice-chickpea (CS2) recorded the highest harvest index (40.87 and 40.20%), followed by rice-linseed and rice-mustard, whereas rice-wheat recorded 40.53 and 39.72%. The relatively higher harvest index under transplanting and rice-chickpea indicates comparatively efficient partitioning of accumulated biomass

towards grain production. Interestingly, harvest index declined slightly in 2024 despite higher grain yield, which indicates that total biological production increased sufficiently to offset the increase in grain yield. The importance of selecting suitable crop combinations for improving overall productivity and resource-use efficiency of rice-based systems has also been emphasized by Tuti *et al.* (2019), Sanjeev Kumar *et al.* (2026)^[15, 13].

3.4 Effect of rice establishment methods and crop diversification on economics

The economic response differed from the yield response. Although transplanting produced the highest grain yield, wet DSR (M2) recorded the highest net return among establishment methods, with ₹59,799 and ₹67,407 ha⁻¹ and B:C ratios of 2.48 and 2.67 in 2023 and 2024, respectively. Transplanting recorded net returns of ₹59,141 and ₹66,544 ha⁻¹, with B:C ratios of 2.23 and 2.38, whereas dry DSR gave the lowest net return in both years.

Among cropping systems, rice-chickpea (CS2) was the most profitable, recording net returns of ₹58,860 and ₹71,587 ha⁻¹ and B:C ratios of 2.38 and 2.68 during 2023 and 2024, respectively. Rice-wheat recorded comparatively lower net returns of ₹53,374 and ₹59,223 ha⁻¹. Thus, wet DSR and rice-chickpea emerged as economically promising options, even though transplanting and rice-chickpea generally produced superior biological performance.

The higher profitability of wet DSR may be attributed to reduced establishment expenditure compared with transplanting. Padma *et al.* (2023)^[10] also reported higher economic returns and B:C ratio under suitable wet-DSR establishment compared with several other establishment methods. Likewise, Satapathy *et al.* (2021)^[14] reported that appropriate wet-DSR sowing methods combined with effective weed management can provide good productivity and profitability.

Table 1: Effect of rice establishment methods and crop diversification on growth parameters of rice at harvest during kharif 2023 and 2024

Treatments	Plant height (cm)		Number of tillers (m ⁻²)		Dry matter accumulation (gm ⁻²)	
	2023	2024	2023	2024	2023	2024
Rice establishment methods						
M1: Transplanting	109.94	113.44	303.75	320.25	1057.00	1091.67
M2: Wet DSR	103.94	108.11	294.75	311.75	1011.25	1046.75
M3: Dry DSR	97.56	101.65	273.75	290.75	935.00	972.00
SEm±	1.86	1.91	4.30	4.39	21.66	21.31
CD(P=0.05)	7.31	7.53	16.90	17.24	85.05	83.69
Cropping system						
CS1: Rice-wheat	100.87	102.86	288.00	298.00	981.00	1006.00
CS2: Rice-chickpea	107.39	117.05	294.00	331.33	1032.00	1119.88
CS3: Rice-mustard	102.93	104.93	290.00	300.00	988.67	1008.66
CS4: Rice-linseed	104.08	106.08	291.00	301.00	1002.66	1012.66
SEm±	2.29	2.41	7.04	7.08	31.12	31.09
CD(P=0.05)	NS	7.17	NS	21.04	NS	92.37
CV (%)	6.62	6.72	7.26	6.90	9.32	8.99

Table 2: Effect of rice establishment methods and crop diversification on yield attributing characters of rice during kharif 2023 and 2024

Treatments	No of panicles m ⁻²		Length of panicles (cm)		Fertile grains panicle ⁻¹		Unfertile grains panicle ⁻¹		1000 grain weight(g)	
	2023	2024	2023	2024	2023	2024	2023	2024	2023	2024
Rice establishment methods										
M1: Transplanting	271.09	284.68	23.85	23.98	116.25	130.75	16.01	11.26	24.71	25.13
M2: Wet DSR	260.06	274.54	23.59	23.75	111.25	125.25	17.70	12.95	23.96	24.47
M3: Dry DSR	239.98	254.41	23.07	23.23	102.58	115.83	19.53	14.78	23.46	23.97
SEm±	5.29	5.05	0.20	0.20	1.56	1.54	0.29	0.35	0.17	0.19
CD(P=0.05)	20.78	19.84	NS	0.73	6.14	6.04	1.15	1.39	0.65	0.75
Cropping system										
CS1: Rice-wheat	252.11	262.00	23.33	23.48	107.11	119.00	18.46	14.13	23.74	23.75
CS2: Rice-chickpea	263.54	290.43	23.81	23.96	112.78	132.67	17.27	10.61	24.35	26.03
CS3: Rice-mustard	255.19	265.12	23.39	23.54	109.56	121.44	17.81	13.81	23.97	24.09
CS4: Rice-linseed	257.33	267.30	23.49	23.64	110.67	122.67	17.43	13.43	24.10	24.22
SEm±	7.37	7.21	0.53	0.52	2.63	2.64	0.60	0.57	0.56	0.55
CD(P=0.05)	NS	21.43	NS	NS	NS	7.85	NS	1.69	NS	1.65
CV (%)	8.59	7.97	6.77	6.65	7.15	6.39	10.17	13.10	6.96	6.79

Table 3: Effect of rice establishment methods and crop diversification on yield, harvest index and economics of rice during kharif 2023 and 2024

Treatments	Grain yield (kg ha ⁻¹)		Straw yield (kg ha ⁻¹)		Harvest index (%)		Net return (Rs ha ⁻¹)		B:C Ratio	
Rice establishment methods	2023	2024	2023	2024	2023	2024	2023	2024	2023	2024
M1: Transplanting	4347	4628	6162	6801	41.35	40.48	59141	66544	2.23	2.38
M2: Wet DSR	4059	4340	5835	6573	41.04	39.73	59799	67407	2.48	2.67
M3: Dry DSR	3535	3817	5381	5899	39.59	39.22	48329	55515	2.22	2.40
SEm±	66.43	104.65	64.64	71.31	0.52	0.54	1416	2312	0.04	0.05
CD(P=0.05)	260.9	410.9	253.8	280.0	NS	NS	5561	9079	0.14	0.20
Cropping system										
CS1: Rice-wheat	3882	4101	5681	6206	40.53	39.72	53374	59223	2.25	2.39
CS2: Rice-chickpea	4110	4609	5932	6846	40.87	40.20	58860	71587	2.38	2.68
CS3: Rice-mustard	3944	4149	5763	6280	40.55	39.72	54903	60420	2.29	2.42
CS4: Rice-linseed	3986	4186	5795	6365	40.68	39.60	55888	61390	2.31	2.44
SEm±	139.3	131.6	144.6	120.9	0.95	0.93	3105	2839	0.07	0.07
CD(P=0.05)	NS	391.1	NS	359.3	NS	NS	NS	8435	NS	0.20
CV (%)	10.49	9.26	7.48	5.64	7.05	7.04	16.7	13.48	9.42	8.30

4. Conclusion

The two-year study revealed that rice establishment method and crop diversification substantially influenced the growth, yield attributes, yield and economic performance of rice. Transplanting (M1) consistently recorded superior plant growth, panicle number, fertile grains, 1000-grain weight and grain and straw yield compared with wet DSR and dry DSR. However, wet DSR (M2) provided higher economic returns and B:C ratio because of its comparatively lower establishment cost. Among cropping systems, rice–chickpea (CS2) consistently performed best, recording higher plant growth, yield attributes, grain and straw yield, harvest index and economic returns than rice–wheat, rice–mustard and rice–linseed. Performance of most parameters was improved during 2024 compared with 2023, indicating better overall crop performance in the second year. Considering both productivity and profitability, wet DSR combined with rice–chickpea emerged as a promising rice-based production system, while transplanting remained superior for achieving maximum rice growth and yield.

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