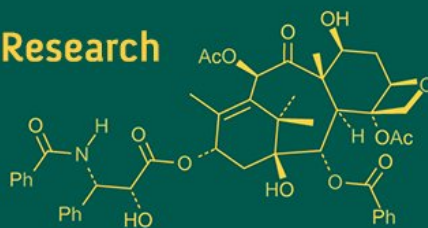


International Journal of Advanced Biochemistry Research



ISSN Print: 2617-4693
ISSN Online: 2617-4707
NAAS Rating (2026): 5.29
IJABR 2026; SP-10(8): 1670-1675
www.biochemjournal.com
Received: 30-05-2026
Accepted: 30-06-2026

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Effect of rice establishment methods and crop diversification on nutrients uptake by rice in rice-based cropping systems under acidic soils of Jharkhand

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DOI: <https://www.doi.org/10.33545/26174693.2026.v10.i8Sr.9645>

Abstract

A field experiment was conducted during 2023–24 and 2024–25 at the Krishi Vigyan Kendra (KVK) and Zonal Agricultural Research Station (ZARS), Darisai, East Singhbhum, Jharkhand, to evaluate the effect of rice establishment methods and crop diversification on nutrient content and nutrient uptake of rice under rice-based cropping systems. The experiment was laid out in a split plot design with three replications. Three rice establishment methods, viz., transplanting (M_1), wet direct-seeded rice (M_2) and dry direct-seeded rice (M_3), were assigned to main plots, while four cropping systems, viz., rice–wheat (CS_1), rice–chickpea (CS_2), rice–mustard (CS_3) and rice–linseed (CS_4), were allocated to sub-plots.

The pooled results showed that transplanting recorded significantly higher plant height (111.69 cm), tillers ($312.00\ m^{-2}$), dry matter accumulation ($1074.33\ g\ m^{-2}$), panicles ($277.89\ m^{-2}$), fertile grains panicle $^{-1}$ (123.50) and 1000-grain weight (24.92 g) than wet and dry DSR. Transplanting also recorded the highest grain yield ($4487\ kg\ ha^{-1}$), straw yield ($6482\ kg\ ha^{-1}$) and total N, P and K uptake (101.27, 19.31 and $107.53\ kg\ ha^{-1}$, respectively). Among cropping systems, rice–chickpea recorded superior growth and yield attributes and the highest grain yield ($4360\ kg\ ha^{-1}$), straw yield ($6389\ kg\ ha^{-1}$), total N uptake ($101.97\ kg\ ha^{-1}$), P uptake ($18.97\ kg\ ha^{-1}$) and K uptake ($107.31\ kg\ ha^{-1}$). Although transplanting produced the highest yield, wet DSR recorded the highest pooled net return ($\text{₹}63,603\ ha^{-1}$) and B: C ratio (2.57) among establishment methods. Rice–chickpea recorded the highest net return ($\text{₹}65,223\ ha^{-1}$) and a favourable B: C ratio (2.53) among cropping systems. The results indicated that transplanting maximized biological productivity and nutrient uptake, whereas wet DSR offered greater economic efficiency; rice–chickpea was the most productive and nutrient-efficient diversification option under the prevailing conditions of Jharkhand.

Keywords: Rice establishment methods, transplanting, wet direct-seeded rice, dry direct-seeded rice, crop diversification, rice–chickpea, nutrient uptake, nitrogen, phosphorus and potassium.

Introduction

Rice (*Oryza sativa* L.) is one of the most important cereal crops of the world and serves as the staple food for more than half of the global population. In India, rice occupies a prominent position in ensuring food and nutritional security and contributes substantially to the agricultural economy. Rice-based cropping systems dominate the eastern region of India, including Jharkhand, where rice is cultivated under diverse agro-ecological situations. Sustaining productivity of these systems requires efficient nutrient management and adoption of suitable crop establishment methods and diversified cropping systems.

Nutrient uptake by rice is largely governed by crop growth, biomass production, soil nutrient availability and management practices. Nitrogen (N), phosphorus (P) and potassium (K) are the primary nutrients required for optimum crop growth and productivity. Efficient uptake and utilization of these nutrients not only enhance crop yield but also improve nutrient use efficiency and maintain soil fertility (Ladha *et al.*, 2005)^[8]. Therefore, assessment of nutrient content and uptake provides valuable information regarding nutrient dynamics and sustainability of cropping systems. Conventional puddled transplanting has long been the dominant method of rice cultivation in eastern India because of its ability to ensure better crop establishment and effective weed suppression. However,

Increasing labour scarcity, rising production costs and water limitations have encouraged the adoption of alternative establishment methods such as wet direct-seeded rice (Wet DSR) and dry direct-seeded rice (Dry DSR). These methods have been reported to reduce labour requirements and production costs while maintaining satisfactory crop performance (Farooq *et al.*, 2011; Kumar and Ladha, 2011) [3, 7, 8]. Rice establishment methods influence root growth, nutrient availability and nutrient absorption, thereby affecting nutrient uptake and productivity. Crop diversification is another important strategy for enhancing sustainability of rice-based systems. Continuous cultivation of cereal-based sequences often leads to nutrient mining, deterioration of soil health and reduced productivity (Sanjeev Kumar *et al.* 2025) [1, 11]. Diversification with legumes, oilseeds and other crops can improve nutrient cycling, resource-use efficiency and economic returns (Gill and Ahlawat, 2006) [5]. Inclusion of legumes such as chickpea in cropping systems is particularly beneficial because of their ability to fix atmospheric nitrogen through symbiotic associations, thereby improving soil fertility and nutrient availability for succeeding crops (Ghosh *et al.*, 2007) [4]. Several studies have demonstrated that legume-based cropping systems enhance nutrient uptake and nutrient use efficiency due to improved soil biological activity, greater organic matter addition and enhanced nutrient recycling. The residual effects of legumes often result in higher nutrient availability and better crop performance in succeeding rice crops. Similarly, oilseed crops such as mustard and linseed contribute to diversification and efficient utilization of available resources under rainfed and irrigated production systems. Nutrient concentration in grain and straw reflects the quality of produce, whereas total nutrient uptake indicates the capacity of the crop to absorb and utilize available nutrients. Evaluation of nutrient uptake under different rice establishment methods and diversified cropping systems is therefore essential for developing sustainable nutrient management strategies. Information on nutrient uptake also helps in understanding nutrient removal patterns and formulating appropriate fertilizer recommendations for maintaining long-term soil productivity.

Materials and Methods

A field experiment was conducted during the kharif seasons of 2023–24 and 2024–25 at the Research Farm of Krishi Vigyan Kendra (KVK) and Zonal Agricultural Research Station (ZARS), Darisai, East Singhbhum, Jharkhand, India. The experimental site is situated at 22°12' N latitude and 84°04' E longitude with an altitude of approximately 244 m above mean sea level. The region falls under the Eastern Plateau and Hill Region of Jharkhand and is characterized by a sub-humid tropical climate with hot summers, moderate rainfall and cool winters. The experimental soil was sandy loam in texture, acidic in reaction (pH 5.6), low in available nitrogen (236 kg ha⁻¹), medium in available phosphorus (16.50 kg ha⁻¹) and available potassium (138 kg ha⁻¹), with an organic carbon content of 5.12 g kg⁻¹. 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 Birs Chana-3, mustard variety BBM-1 and linseed variety Priyam were cultivated according to their respective cropping systems. Representative grain and straw samples were collected at harvest, oven-dried, ground and analyzed for nitrogen, phosphorus and potassium content. Nitrogen content in grain and straw samples was determined by the modified Kjeldahl digestion and distillation method as described by Jackson (1973) [6]. Phosphorus content was estimated by the vanadomolybdate yellow colour method using a spectrophotometer following wet digestion of plant samples (Jackson, 1973) [6]. Potassium content was determined using a flame photometer after di-acid digestion of plant samples (Jackson, 1973) [6]. Nutrient uptake by grain and straw was calculated using the following formula: Nutrient uptake (kg ha⁻¹) = Nutrient content (%) × Yield (kg ha⁻¹) / 100 Total nutrient uptake was computed by summing nutrient uptake through grain and straw. The experimental data were subjected to analysis of variance (ANOVA) appropriate for a split plot design as described by Gomez and Gomez (1984). Treatment means were compared using the Critical Difference (CD) test at the 5 per cent level of significance. The coefficient of variation (CV%) was calculated to assess experimental precision.

Results and Discussion

Effect of rice establishment methods and crop diversification on growth and yield attributes of rice

Pooled data showed that rice establishment methods significantly affected most growth and yield attributes. Transplanting recorded the maximum plant height (111.69 cm), number of tillers (312.00 m⁻²), dry matter accumulation (1074.33 g m⁻²), panicles (277.89 m⁻²), fertile grains panicle⁻¹ (123.50) and 1000-grain weight (24.92 g), followed by wet DSR and dry DSR. The superiority of transplanting was associated with better crop establishment and greater biomass production, which ultimately favoured panicle development and grain formation. Among cropping systems, rice-chickpea (CS₂) generally performed best, recording the highest plant height (112.22 cm), tillers (312.66 m⁻²), dry matter accumulation (1075.94 g m⁻²), panicles (276.98 m⁻²) and fertile grains panicle⁻¹ (122.72). The superior performance of rice following chickpea may be associated with improved nutrient availability and the beneficial residual effects of the preceding legume. Rice-linseed, rice-mustard and rice-wheat followed in most growth and yield attributes. The present results are broadly consistent with Padma *et al.* (2023) [9], who observed significant differences in panicles, panicle length, filled grains and grain yield among different rice establishment methods. However, their study also showed that wet DSR could perform competitively with transplanting, demonstrating that establishment-method responses depend on soil, water and crop-management conditions.

Effect of rice establishment methods and crop diversification on grain and straw yield

Transplanting recorded the highest pooled grain yield of 4487 kg ha⁻¹, significantly exceeding wet DSR (4200 kg

ha^{-1}) and dry DSR (3676 kg ha^{-1}). Similarly, straw yield was highest under transplanting (6482 kg ha^{-1}), followed by wet DSR (6204 kg ha^{-1}) and dry DSR (5640 kg ha^{-1}). The higher yield under transplanting corresponded with greater tiller production, panicle number, fertile grains panicle $^{-1}$ and dry matter accumulation. Thus, the yield advantage was mainly the cumulative effect of better establishment and superior yield components. These findings agree with Padma *et al.* (2023) [9], who demonstrated that crop establishment method significantly influenced yield attributes and grain yield of rice. However, other studies have reported comparable or even superior yield under DSR under favourable conditions. Chandra *et al.* (2021) [2] reported competitive performance of DSR with conventional transplanting in Bihar, highlighting the importance of establishment conditions and management practices. Among cropping systems, rice-chickpea produced the highest grain yield (4360 kg ha^{-1}) and straw yield (6389 kg ha^{-1}), followed by rice-linseed, rice-mustard and rice-wheat. The higher productivity under rice-chickpea was consistent with its superior growth, panicle production and fertile grain formation. The result suggests that diversification with chickpea created a more favourable production environment for the succeeding rice crop.

Effect of rice establishment methods and crop diversification on harvest index

Harvest index did not differ significantly among rice establishment methods or cropping systems. Nevertheless, transplanting recorded the numerically highest pooled harvest index (40.92%), followed by wet DSR (40.38%) and dry DSR (39.40%). Among cropping systems, rice-chickpea recorded the highest value (40.54%), whereas rice-wheat recorded the lowest (40.13%). The numerically higher harvest index under transplanting and rice-chickpea was consistent with their higher fertile grain production and grain yield.

Effect of rice establishment methods and crop diversification on economics

A contrasting response was observed for economic performance. Although transplanting produced the highest grain yield, wet DSR recorded the highest pooled net return ($\text{₹}63,603 \text{ ha}^{-1}$) and B:C ratio (2.57), compared with $\text{₹}62,843 \text{ ha}^{-1}$ and 2.30 under transplanting and $\text{₹}51,922 \text{ ha}^{-1}$ and 2.31 under dry DSR. Thus, the slightly lower biological yield of wet DSR was compensated by its better economic efficiency. Among cropping systems, rice-chickpea recorded the highest pooled net return ($\text{₹}65,223 \text{ ha}^{-1}$) and a B:C ratio of 2.53, followed by rice-linseed ($\text{₹}58,639 \text{ ha}^{-1}$; 2.38), rice-mustard ($\text{₹}57,662 \text{ ha}^{-1}$; 2.35) and rice-wheat ($\text{₹}56,299 \text{ ha}^{-1}$; 2.32). The economic advantage of rice-chickpea was consistent with its higher rice productivity and nutrient uptake. The economic advantage of alternative establishment methods has also been reported by Padma *et al.* (2023) [9], who found wet DSR to be economically superior among several establishment methods because of its favourable returns. Similarly, Chandra *et al.* (2021) [2] reported that DSR could provide attractive economic returns under Bihar conditions.

Effect of rice establishment methods and crop diversification on nitrogen uptake by rice

Pooled analysis revealed a significant effect of rice establishment methods on N uptake. Transplanted rice (M_1) recorded the highest total N uptake ($101.27 \text{ kg ha}^{-1}$),

followed by wet DSR (M_2 , 93.60 kg ha^{-1}) and dry DSR (M_3 , 81.64 kg ha^{-1}). Under transplanting, N uptake in grain and straw was 58.70 and 42.57 kg ha^{-1} , respectively. The greater N uptake under transplanting was mainly associated with its higher dry matter production, panicle number and grain and straw yield, which provided greater biomass for N accumulation. Similar results were reported by Brar and Bhullar (2013) [1], who observed greater N uptake by manually transplanted rice than by different direct-seeding schedules. Their findings support the present observation that better crop establishment under transplanting can enhance nutrient acquisition and accumulation in rice.

Among cropping systems, rice-chickpea (CS_2) recorded the highest total N uptake ($101.97 \text{ kg ha}^{-1}$), followed by rice-linseed (92.31 kg ha^{-1}), rice-mustard (89.88 kg ha^{-1}) and rice-wheat (85.52 kg ha^{-1}). The higher N uptake in rice-chickpea may be attributed to the beneficial residual effect of chickpea and improved N availability to the succeeding rice crop. The result is also consistent with the importance of diversified rice-based systems in nutrient cycling reported by Sharma and Sharma (2002) [12], who demonstrated substantial differences in NPK removal and nutrient balance among rice-based cropping systems.

Effect of rice establishment methods and crop diversification on phosphorus uptake by rice

Establishment methods significantly affected P uptake. Transplanting recorded the maximum total P uptake (19.31 kg ha^{-1}), followed by wet DSR (17.92 kg ha^{-1}) and dry DSR (15.78 kg ha^{-1}). Grain and straw P uptake under transplanting were 11.78 and 7.54 kg ha^{-1} , respectively. The higher P uptake under transplanting was associated with greater crop growth and biomass production, which increased the total amount of P accumulated in plant tissues. Brar and Bhullar (2013) [1] similarly reported significantly greater P utilization by manually transplanted rice than by direct-seeded rice under their experimental conditions.

Among cropping systems, rice-chickpea recorded the highest total P uptake (18.97 kg ha^{-1}), followed by rice-linseed (17.68 kg ha^{-1}), rice-mustard (17.28 kg ha^{-1}) and rice-wheat (16.76 kg ha^{-1}). The greater P uptake in rice-chickpea may be related to improved crop growth and nutrient availability following the legume component. The present trend also agrees with the broader findings of Sharma and Sharma (2002) [12] that crop sequence strongly influences nutrient removal and cycling in rice-based systems.

Effect of rice establishment methods and crop diversification on potassium uptake by rice

Potassium uptake followed a trend similar to N and P. Transplanting recorded the highest total K uptake ($107.53 \text{ kg ha}^{-1}$), followed by wet DSR ($100.94 \text{ kg ha}^{-1}$) and dry DSR (90.66 kg ha^{-1}). Grain and straw K uptake under transplanting were 12.68 and 94.85 kg ha^{-1} , respectively. The higher K uptake under transplanting was primarily associated with greater biomass production and higher grain and straw yields. The lower uptake under dry DSR corresponded with its comparatively lower growth and yield performance. A similar improvement in N, P and K uptake has been reported by others. Among cropping systems, rice-chickpea recorded the highest total K uptake ($107.31 \text{ kg ha}^{-1}$), followed by rice-linseed (99.71 kg ha^{-1}), rice-mustard (97.78 kg ha^{-1}) and rice-wheat (94.02 kg ha^{-1}). The greater K uptake under rice-chickpea was consistent with its greater dry matter production and grain and straw yield. The

substantial K removal observed in the present experiment is important from a soil-fertility perspective because Sharma and Sharma (2002) ^[12], (Sanjeev Kumar *et al* 2026) ^[10] reported that K can be heavily removed in intensive rice-based systems, emphasizing the need for adequate K

replenishment. Thus, the present study indicates that transplanting was the most effective establishment method for maximizing nutrient uptake, while rice-chickpea was the most favourable cropping system for improving N, P and K acquisition by rice.

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

Treatments	Plant height (cm)	Number of tillers (m ⁻²)	Dry matter accumulation (gm ⁻²)	No of panicles m ⁻²	Length of panicles (cm)	Fertile grains panicle ⁻¹	1000 grain weight(g)
Rice establishment methods	Pooled	Pooled	Pooled	Pooled	Pooled	Pooled	Pooled
M1: Transplanting	111.69	312.00	1074.33	277.89	23.92	123.50	24.92
M2: Wet DSR	106.02	303.25	1029.00	267.30	23.67	118.25	24.21
M3: Dry DSR	99.60	282.25	953.50	247.19	23.15	109.21	23.71
SEm±	1.33	3.07	15.19	3.65	0.14	1.09	0.12
CD(P=0.05)	4.35	10.01	49.49	11.91	0.45	3.57	0.41
Cropping system							
CS1: Rice-wheat	101.87	293.00	993.50	257.06	23.40	113.06	23.74
CS2: Rice-chickpea	112.22	312.66	1075.94	276.98	23.89	122.72	25.18
CS3: Rice-mustard	103.93	295.00	998.67	260.15	23.47	115.50	24.03
CS4: Rice-linseed	105.08	296.00	1007.67	262.32	23.57	116.67	24.16
SEm±	1.66	4.99	21.99	5.15	0.37	1.86	0.39
CD(P=0.05)	4.77	14.32	63.10	14.78	NS	5.34	NS
CV (%)	6.66	7.07	9.14	8.27	6.70	6.74	6.86

Table 2: 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	Pooled	Pooled	Pooled	Pooled	Pooled
M1: Transplanting	4487	6482	40.92	62843	2.30
M2: Wet DSR	4200	6204	40.38	63603	2.57
M3: Dry DSR	3676	5640	39.40	51922	2.31
SEm±	61.97	48.12	0.37	1356	0.03
CD(P=0.05)	201.9	156.7	NS	4416	0.10
Cropping system					
CS1: Rice-wheat	3992	5944	40.13	56299	2.32
CS2: Rice-chickpea	4360	6389	40.54	65223	2.53
CS3: Rice-mustard	4047	6022	40.14	57662	2.35
CS4: Rice-linseed	4086	6080	40.14	58639	2.38
SEm±	95.8	94.2	0.66	2104	0.05
CD(P=0.05)	274.9	270.4	NS	6035	0.14
CV (%)	9.85	6.53	7.03	14.99	8.80

Table 3: Effect of rice establishment methods and crop diversification on total nutrient uptake (kg ha⁻¹) by rice during kharif 2023 and 2024

Treatments	Nitrogen uptake (kg ha ⁻¹)			Phosphorus uptake (kg ha ⁻¹)			Potassium uptake (kg ha ⁻¹)		
Rice establishment methods	Pooled			Pooled			Pooled		
	Grain	Straw	Total	Grain	Straw	Total	Grain	Straw	Total
M1: Transplanting	58.70	42.57	101.27	11.78	7.54	19.31	12.68	94.85	107.53
M2: Wet DSR	54.00	39.60	93.60	10.86	7.06	17.92	11.70	89.23	100.94
M3: Dry DSR	46.87	34.77	81.64	9.45	6.33	15.78	10.19	80.47	90.66
SEm±	0.63	0.78	1.01	0.17	0.05	0.19	0.18	1.14	1.01
CD(P=0.05)	2.07	2.57	3.31	0.57	0.16	0.63	0.61	3.72	3.32
Cropping system									
CS1: Rice-wheat	49.88	35.64	85.52	10.17	6.58	16.76	10.97	83.05	94.02
CS2: Rice-chickpea	58.20	42.76	101.97	11.49	7.48	18.97	12.36	94.95	107.31
CS3: Rice-mustard	51.81	38.07	89.88	10.46	6.82	17.28	11.27	86.52	97.78
CS4: Rice-linseed	52.87	39.44	92.31	10.67	7.02	17.68	11.49	88.23	99.71
SEm±	1.36	1.11	2.09	0.23	0.17	0.32	0.25	1.78	1.77
CD(P=0.05)	3.92	3.18	6.00	0.67	0.49	0.92	0.72	5.12	5.08
CV (%)	10.88	12.08	9.61	9.31	10.44	7.71	9.25	8.57	7.52

Table 4: Effect of rice establishment methods and crop diversification on NPK content (%) of rice grain during 2023 and 2024

Treatments	NPK content of rice grain (%)								
	Nitrogen			Phosphorus			Potassium		
Rice establishment methods	2023	2024	Pooled	2023	2024	Pooled	2023	2024	Pooled
M1: Transplanting	1.225	1.226	1.226	0.255	0.256	0.255	0.287	0.288	0.287
M2: Wet DSR	1.225	1.226	1.226	0.255	0.256	0.255	0.287	0.288	0.287
M3: Dry DSR	1.224	1.225	1.225	0.254	0.255	0.255	0.286	0.287	0.287
SE(m)±	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
CD(P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Cropping system									
CS1: Rice-wheat	1.223	1.224	1.224	0.254	0.255	0.255	0.286	0.287	0.287
CS2: Rice-chickpea	1.227	1.228	1.224	0.255	0.256	0.256	0.287	0.288	0.288
CS3: Rice-mustard	1.223	1.224	1.224	0.254	0.255	0.255	0.286	0.287	0.287
CS4: Rice-linseed	1.226	1.227	1.224	0.254	0.255	0.255	0.286	0.287	0.287
SE(m)±	0.002	0.002	0.002	0.001	0.001	0.001	0.001	0.001	0.001
CD(P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
CV (%)	0.485	0.485		0.790	0.787		0.702	0.699	

Table 5: Effect of rice establishment methods and crop diversification on NPK content (%) of rice straw during 2023 and 2024

Treatments	NPK content of rice straw (%)								
	Nitrogen			Phosphorus			Potassium		
Rice establishment methods	2023	2024	Pooled	2023	2024	Pooled	2023	2024	Pooled
M1: Transplanting	0.545	0.555	0.550	0.105	0.107	0.106	1.366	1.386	1.376
M2: Wet DSR	0.545	0.555	0.550	0.104	0.106	0.105	1.365	1.385	1.375
M3: Dry DSR	0.543	0.553	0.548	0.103	0.105	0.104	1.364	1.384	1.374
SE(m)±	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
CD(P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Cropping system									
CS1: Rice-wheat	0.543	0.553	0.548	0.104	0.106	0.105	1.357	1.377	1.367
CS2: Rice-chickpea	0.547	0.557	0.552	0.105	0.107	0.106	1.373	1.393	1.383
CS3: Rice-mustard	0.543	0.553	0.548	0.104	0.106	0.105	1.367	1.387	1.377
CS4: Rice-linseed	0.544	0.554	0.549	0.103	0.105	0.104	1.363	1.383	1.373
SE(m)±	0.002	0.002	0.002	0.001	0.001	0.001	0.004	0.004	0.004
CD(P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
CV (%)	1.182	1.161		2.162	2.121		0.839	0.827	

Table 6: Effect of rice establishment methods and crop diversification on NPK uptake (kg/ha) of rice grain during 2023 and 2024

Treatments	NPK uptake (kg/ha) of rice grain								
	Nitrogen			Phosphorus			Potassium		
Rice establishment methods	2023	2024	Pooled	2023	2024	Pooled	2023	2024	Pooled
M1: Transplanting	53.250	56.742	54.995	11.081	11.844	11.462	12.472	13.325	12.898
M2: Wet DSR	49.735	53.223	51.478	10.331	11.090	10.711	11.630	12.479	12.055
M3: Dry DSR	43.285	46.774	45.028	8.988	9.743	9.366	10.120	10.964	10.542
SE(m)±	0.845	1.295	0.773	0.185	0.274	0.165	0.206	0.307	0.185
CD(P=0.05)	3.319	5.084	2.519	0.725	1.076	0.538	0.808	1.207	0.602
Cropping system									
CS1: Rice-wheat	48.345	50.229	49.286	10.051	10.474	10.262	11.315	11.786	11.551
CS2: Rice-chickpea	49.188	56.585	52.885	10.235	11.810	11.022	11.518	13.285	12.401
CS3: Rice-mustard	48.629	50.816	49.722	10.109	10.596	10.353	11.380	11.924	11.652
CS4: Rice-linseed	48.864	51.355	50.109	10.140	10.690	10.415	11.415	12.029	11.722
SE(m)±	1.732	1.663	1.200	0.365	0.353	0.254	0.409	0.395	0.284
CD(P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
CV (%)	9.975	9.379		10.134	9.540		10.094	9.491	

Table 7: Effect of rice establishment methods and crop diversification on NPK uptake (kg/ha) of rice straw during 2023 and 2024

Treatments	NPK uptake (kg/ha) of rice straw								
	Nitrogen			Phosphorus			Potassium		
Rice establishment methods	2023	2024	Pooled	2023	2024	Pooled	2023	2024	Pooled
M1: Transplanting	33.585	37.751	35.668	6.450	6.694	6.572	84.173	94.283	89.228
M2: Wet DSR	31.808	36.485	34.146	6.088	6.381	6.235	79.640	91.037	85.338
M3: Dry DSR	29.234	32.644	30.939	5.533	5.783	5.658	73.413	81.679	77.546
SE(m)±	0.349	0.397	0.264	0.070	0.051	0.043	0.860	0.963	0.646
CD(P=0.05)	1.370	1.560	0.861	0.274	0.202	0.14	3.379	3.781	2.104
Cropping system									
CS1: Rice-wheat	30.865	34.338	32.602	5.910	6.080	5.995	77.080	85.433	81.257
CS2: Rice-chickpea	32.432	38.112	35.272	6.203	6.617	6.410	81.466	95.425	88.445
CS3: Rice-mustard	31.314	34.747	33.030	5.996	6.190	6.093	78.760	87.089	82.924
CS4: Rice-linseed	31.559	35.309	33.434	5.986	6.258	6.122	78.996	88.051	83.524
SE(m)±	0.805	0.690	0.530	0.148	0.145	0.104	1.948	1.734	1.304
CD(P=0.05)	NS	NS	1.520	NS	NS	0.297	NS	NS	3.740
CV (%)	7.112	5.505		6.880	6.372		6.874	5.523	

Table 8: Effect of rice establishment methods and crop diversification on total NPK uptake (kg/ha) of rice during 2023 and 2024

Treatments	Total NPK uptake(kg/ha) of rice								
	Nitrogen			Phosphorus			Potassium		
Rice establishment methods	2023	2024	Pooled	2023	2024	Pooled	2023	2024	Pooled
M1: Transplanting	86.835	94.493	90.663	17.531	18.538	18.034	96.645	107.608	102.126
M2: Wet DSR	81.543	89.708	85.625	16.419	17.471	16.945	91.270	103.515	97.393
M3: Dry DSR	72.519	79.418	75.968	14.521	15.526	15.024	83.533	92.644	88.088
SE(m)±	0.855	1.440	0.837	0.212	0.278	0.175	0.814	1.045	0.662
CD(P=0.05)	3.356	5.653	2.727	0.833	1.093	0.569	3.194	4.103	2.157
Cropping system									
CS1: Rice-wheat	79.210	84.567	81.888	15.960	16.554	16.257	88.395	97.219	92.807
CS2: Rice-chickpea	81.620	94.697	88.157	16.438	18.427	17.432	92.984	108.709	100.847
CS3: Rice-mustard	79.943	85.563	82.753	16.105	16.786	16.445	90.140	99.013	94.577
CS4: Rice-linseed	80.423	86.664	83.543	16.125	16.947	16.536	90.412	100.080	95.246
SE(m)±	2.054	1.742	1.346	0.421	0.409	0.293	2.059	1.695	1.333
CD(P=0.05)	NS	5.174	3.863	NS	1.214	0.842	NS	5.036	3.825
CV (%)	7.117	5.898		7.337	6.883		6.316	4.792	

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