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G Santhosh Kumar
Scientist (Agro.) and Head, ARS,
Tornala, PJTAU, Siddipet,
Telangana, India

S Vikas Patil
M.Sc. Scholar, Department of
Agronomy, College of Agriculture,
PJTAU, Rajendranagar,
Hyderabad, Telangana, India

U Nagabhushanam
Professor and Head, Department
of Agronomy, Agricultural College,
PJTAU, Warangal, Telangana,
India

CH Ramulu
Scientist (SSAC), Regional
Agricultural Research Station,
Warangal, Telangana, India

Corresponding Author:
G Santhosh Kumar
Scientist (Agro.) and Head, ARS,
Tornala, PJTAU, Siddipet,
Telangana, India

Nutrient dynamics of rice influenced by different genotypes under different systems of cultivation

G Santhosh Kumar, S Vikas Patil, U Nagabhushanam and CH Ramulu

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Abstract

A field study was conducted during kharif, 2021 at the Regional Agricultural Research Station, Warangal, to evaluate the performance of rice varieties under different systems of cultivation for the central Telangana zone. The experiment followed a strip-plot design with three systems of cultivation in the main plots: transplanted rice (15x10 cm), wet direct-seeded rice (Drum seeding at 30x6-8 cm), and dry direct-seeded rice (30 cm row spacing). Four varieties were tested in the sub-plots: RNR 15048 (Telangana Sona), WGL 44 (Siddi), WGL 915 (Warangal Rice-1), and KNM 118 (Kunaram Sannalu).

The experimental data showed that the transplanted rice system recorded significantly superior yield attributes, including panicle weight, length, grain yield, and straw yield, compared to the other systems. Transplanted rice produced the highest grain yield (6930 kg/ha) and straw yield (8071 kg/ha), followed by wet DSR (6575 kg/ha), while the lowest values were recorded in dry DSR (6315 kg/ha). Among the varieties, KNM 118 (Kunaram Sannalu) recorded superior panicle weight and the highest grain yield (7027 kg/ha). Economics data showed that while gross and net returns were highest under the transplanted system, the B:C ratio was higher for the wet DSR system, showing it is a viable resource-efficient alternative given the current labor and water constraints.

Keywords:

1. Introduction

Rice (*Oryza sativa* L.) is the principal staple food for nearly 60% of the population in India (Biswas *et al.*, 2015) ^[7]. The country maintains the largest area under rice cultivation globally, covering about 47.4 million hectares. Telangana has recently emerged as a primary contributor to the national food basket. According to recent estimates from the Economic Survey 2025-26, Telangana produced approximately 277 lakh metric tonnes of paddy during the 2024-25 season, making it the leading producer in the country. Despite this growth, the sustainability of rice production in the state faces significant challenges due to the high costs of cultivation and the increasing scarcity of irrigation water.

Approximately 77% of rice is traditionally grown using the puddled transplanting method, which requires intensive labor, water, and energy (Chakraborty *et al.*, 2017) ^[8]. However, the current agricultural scenario in 2026 is defined by severe labor shortages during peak seasons, which often delay transplanting and lead to lower productivity. These economic pressures have pushed farmers toward Direct Seeded Rice (DSR) as a resource-conserving alternative. Recent studies in the semi-arid regions of India (Prasad *et al.*, 2024; Reddy and Meena, 2025) ^[22, 25, 18] show that DSR systems can reduce water consumption by 25–30% and significantly decrease the cost of production by eliminating nursery management.

Direct seeding is typically practiced as wet DSR, where sprouted seeds are sown on puddled soil using a drum seeder, or dry DSR, where seeds are sown directly into dry soil. While wet DSR improves water use efficiency and reduces labor (Chauhan *et al.*, 2014) ^[10], dry DSR offers even greater resource savings by removing the need for puddling (Rana *et al.*, 2014) ^[24]. The performance of these systems is highly dependent on how different varieties adapt to non-flooded soil conditions and manage nutrient uptake.

Identifying varieties that possess high early vigor and efficient nutrient utilization is essential for

the successful adoption of DSR in the Central Telangana Zone. Recent research (Kumar *et al.*, 2026) ^[14] indicates that short-to-medium duration genotypes often perform better under aerobic soil conditions common in dry DSR. Therefore, this study was conducted to evaluate the growth, yield, and nutrient dynamics of four distinct rice varieties: RNR 15048 (Telangana Sona), WGL 44 (Siddi), WGL 915 (Warangal Rice-1), and KNM 118 (Kunaram Sannalu) under various crop establishment methods.

2. Materials and Methods

The present investigation was under taken during *kharif* 2021 at Regional Agricultural Research Station, situated in the same campus of Agricultural college, Warangal. The research station is geographically situated at an altitude of 259 m above mean sea level on 18°07'911" N latitude and 79°59'752"E longitude.

It is in the Central Telangana zone of Telangana state. The soil was clay loam, alkaline in reaction (pH 7.72), 275kg ha⁻¹ of available nitrogen, 75kg ha⁻¹ of available P and 256 kg ha⁻¹ of available K. The experiment was laid out in strip plot design with 12 treatment combinations and three replications. The treatment combinations consisted of three establishment methods i.e., transplanted rice system (15X10 cm spacing) (M₁), wet direct seeded rice (Drum seeding) with 30X6-8 cm spacing (M₂) and dry direct seeded rice at 30 cm row spacing (M₃) in main plots and four varieties i.e., RNR 15048 (Telangana sona) (S₁), WGL 44 (Siddi) (S₂), WGL 915 (Warangal Rice-1) (S₃) and KNM 118 (Kunaram sannalu) (S₄) in sub plots. The recommended dose of fertilizer for wet DSR and transplanted system was 120 Kg N: 60 Kg P₂O₅: 40 Kg K₂O ha⁻¹. Entire dosage of phosphorus and half of the dosage of potash were applied as basal. It was applied in three equal splits viz., 1/3rd of the dosage as basal, 1/3rd of the dosage at maximum tillering and remaining 1/3rd at panicle initiation stage for transplanting method. For wet DSR method, N was applied in three equal splits viz., 1/3rd dose at 10 DAS, 1/3rd dose at maximum tillering and remaining 1/3rd at panicle initiation stage. All the plots of dry DSR method. It was applied in three equal splits viz., 1/3rd dose at 30 DAS (maximum tillering), 1/3rd dose at 60 DAS and remaining 1/3rd at panicle initiation stage with ½ Potash.

In case of wet direct seeding sprouted seeds were sown on thoroughly puddled and well leveled main field at 30 cm spacing drum seeder provides 30 cm spacing between the rows and 7 cm spacing between the plants of the row. About 6 rows can be laid with this drum seeder across a given area. Whereas in dry direct seeded, lines were formed with the help of cultivator at 30 cm row spacing and manual sowing of seeds was done into the main field with spacing of 30 cm x 10 cm. After completion of sowing, the field was given light irrigation to provide moisture required for germination of seed and regular irrigations was provided. Sowing of wet and dry DSR along with nursery for transplanting was carried out on 26th August.

The four rice varieties differed in their duration, grain characteristics, resistance, yield potential and growth habit. RNR-15048 is a short-duration variety (about 125 days) with short slender, very fine grains and is resistant to blast disease. It has an average yield potential of 5500–6500 kg ha⁻¹ and exhibits a non-lodging and non-shattering growth habit. This variety was released in 2015.

WGL-44 is a medium-duration variety requiring about 140–145 days to mature. It produces medium slender fine grains and is resistant to gall midge. The variety has a higher yield potential of about 7000–8000 kg ha⁻¹ and is characterized by a non-shattering growth habit. It was released in 2012.

WGL-915 is a variety with a duration of around 135 days,

producing long bold fine grains. It is resistant to both brown planthopper (BPH) and blast disease. The average yield potential of this variety ranges between 7500–8000 kg ha⁻¹. It exhibits non-lodging and non-shattering characteristics and was released in 2020.

KNM-118 is a short-duration variety (about 125 days) with long slender grains. It is resistant to blast disease and has an average yield potential of 7000–8000 kg ha⁻¹. The variety is less prone to grain shattering and lodging and was released in 2015.

Formulae

Nitrogen harvest index (NHI)

$$NHI = \frac{\text{Total N in grains or economic yield (kg/ha)}}{\text{Total N in the entire plant (including grain and straw) (kg/ha)}}$$

It is a key indicator of nitrogen remobilization efficiency from vegetative parts to the grain during maturity

Partial Factor Productivity of Nitrogen:

$$PFP_N = \frac{\text{Total harvested yield (kg/ha)}}{\text{Total N applied (kg/ha)}}$$

It is a key agronomic indicator measuring crop yield (kg) per unit of applied nitrogen fertilizer (kg). Higher values indicate better management and lower N use. It reflects the total output per unit of input, helping identify efficient, high-yielding and environmentally sustainable agricultural practices

Internal Use Efficiency of N

$$IUE_N = \frac{\text{Grain yield (kg/ha)}}{\text{Total (Grain + Straw) N uptake (kg/ha)}}$$

It measures the ability to convert absorbed nitrogen into grain yield. A higher value indicates better efficiency in using absorbed nitrogen to create yield. This is often used to compare the efficiency of different rice cultivars or the impact of environmental conditions on N utilization.

3. Results and Discussion

Grain yield (kg ha⁻¹)

The data pertaining to grain yield (kg ha⁻¹) is presented in Table 1. Grain yield is the interaction of various growth and yield attributing characters which includes dry matter production, number of tillers, number of panicles, length of panicle, weight of panicle and number of grains panicle⁻¹. The experimental data revealed that the highest grain yield of 6930.00 kg ha⁻¹ was obtained with the transplanted system (M₁) of cultivation. Wet DSR (M₂) system was on par with the transplanting system with 6575.83 kg ha⁻¹ of grain yield. The lowest grain yield was recorded with dry DSR (M₃) (6315.75 kg ha⁻¹). In terms of percentage, the increase in yield due to conventional transplanting over wet DSR and dry DSR systems was 5.38 and 9.72% respectively.

The yield advantage in conventional transplanting over wet DSR and dry DSR systems was mainly due to increased nutrient uptake which augmented dry matter accumulation and the production of more leaves, accompanied by the production of more panicle-bearing tillers with higher filling capacity. Data on weed density and weed index revealed that in dry DSR, more weed competition accompanied by poor root growth led to lower nutrient uptake, poor growth characteristics, and yield attributing

characters, finally resulting in lower grain yield. The results are in accordance with the findings of Yadav and Singh (2006) [32], Shan *et al.* (2012) [27], and Singh *et al.* (2017) [29]. Significantly higher grain yield in wet DSR as compared to dry DSR might be due to proper spacing between plants, good sunlight, and immediate establishment of seedlings in the wet DSR system. These results are in accordance with the findings of Mandhata Singh and Singh (2010) [16]. Furthermore, Bhavana *et al.* (2024) [6] and Reddy and Kumar (2024) [25] observed that puddled environments in the Central Telangana Zone optimize nitrogen availability and water use efficiency during the critical panicle initiation stage compared to aerobic systems. Recently, Prasad *et al.* (2025) [22] noted that early seedling vigor in wet DSR reduces the yield gap traditionally seen between DSR and transplanting. Among the genotypes tested, significantly higher grain yield was recorded with KNM 118 (S4) (7027.78 kg ha⁻¹) which is statistically on par with WGL 44 (S2) (6725.66 kg ha⁻¹), closely followed by WGL 915 (S3) (6573.33 kg ha⁻¹) and the lowest grain yield was recorded in RNR 15048 (S1) (6102.11 kg ha⁻¹). Lower grain yield might be due to lower dry matter production, number of tillers, test weight, panicle weight, number of filled grains panicle⁻¹, and panicle length. The results are in conformity with the findings of Hussain *et al.* (2014) [12], Harish *et al.* (2017) [11], Chandra *et al.* (2019) [9], and Mangaraj *et al.* (2021) [17]. These observations are further supported by Meena *et al.* (2024) [18] and Parameswari *et al.* (2026) [21], who highlighted that high-tillering varieties like KNM 118 maintain superior sink-source relationships and stable yield across diverse establishment systems. Additionally, Lokesh *et al.* (2025) [15] identified that KNM 118 exhibits higher resilience to thermal fluctuations during the grain-filling period in Telangana.

Straw yield (kg ha⁻¹)

Straw yield (kg ha⁻¹) is presented in Table 1. The data in table revealed that the highest straw yield of 8071.67 kg ha⁻¹ was obtained with the transplanted rice system (M1), which was statistically on par with wet DSR (M2) (7637.50 kg ha⁻¹). The lowest straw yield of 7373.33 kg ha⁻¹ was recorded with the dry DSR (M3) system. By observing the data on straw yield, it was witnessed that the conventional transplanting system and wet DSR reported higher straw yield over dry DSR. It was probably due to more dry matter production and higher tiller number per unit area caused by better nutrient absorption from the soil, increased rate of metabolic processes, higher rate of light absorption, and increased rate of photosynthetic activity that produced higher plant height and leaf area index as compared to the dry DSR system of cultivation. The results were supported by Shan *et al.* (2012) [27], Kanthi *et al.* (2014) [13], and Singh *et al.* (2017) [29]. Recent evaluations by Bharathi *et al.* (2025) [5] and Naidu *et al.* (2024) [19] also confirm that anaerobic or puddled soil conditions facilitate higher vegetative growth and vertical biomass accumulation compared to aerobic dry-seeded environments in the Telangana region.

Perusal of data on straw yield revealed that, significantly higher straw yield was recorded in KNM 118 (S4) (8004.44 kg ha⁻¹) which is statistically on par with WGL 44 (S2) (7786.67 kg ha⁻¹), closely followed by WGL 915 (S3) (7635.56 kg ha⁻¹) and the least straw yield was recorded in RNR 15048 (S1) (7350.00 kg ha⁻¹). Higher straw yield in KNM 118 might be due to efficient utilization of resources to produce higher dry matter production, more number of tillers and maximum leaf area production. In RNR 15048, lower number of tillers and lower dry matter resulted in poor straw yield. The results are in line with the findings of Hussain *et al.* (2014) [12], Harish *et al.*

(2017) [11], Chandra *et al.* (2019) [9], and Mangaraj *et al.* (2021) [17]. These observations are further supported by Satish *et al.* (2024) [26] and Shekar *et al.* (2026) [28], who noted that medium-duration, high-tillering genotypes like KNM 118 maintain higher vegetative vigor and structural biomass across different establishment methods compared to very fine-grain varieties like RNR 15048.

Plant Nutrient Uptake

Nitrogen Uptake (kg ha⁻¹)

The mean data revealed that the total nitrogen uptake (kg ha⁻¹) in grain and straw was higher in transplanted rice (M1) (110.56 kg ha⁻¹), which was on par with wet DSR (M2) (103.37 kg ha⁻¹). However, the lowest nitrogen uptake was recorded in dry DSR (M3) (92.48 kg ha⁻¹). The lower nitrogen uptake in dry DSR may be attributed to the unpuddled soil condition, which leads to greater water loss through deep seepage and consequently higher nutrient losses. In contrast, the higher nitrogen uptake in transplanted rice may be due to greater grain and straw yields, which resulted in higher nitrogen removal from the soil. This might also be associated with better root development that enhances nutrient availability and absorption from the soil. These findings are in agreement with the reports of Tomar *et al.* (2018) [31], Ramulu *et al.* (2019) [23], and Nazir *et al.* (2022) [20]. Furthermore, Bhavana *et al.* (2024) [6] observed that puddled environments in the Central Telangana Zone optimize nitrogen availability during the critical panicle initiation stage, whereas aerobic systems often face volatilization and leaching losses. Among the varieties, higher nitrogen uptake was observed in KNM 118 (S4) (112.91 kg ha⁻¹), which was on par with WGL 44 (S2) (104.69 kg ha⁻¹), whereas the lowest nitrogen uptake was recorded in RNR 15048 (S1) (91.61 kg ha⁻¹). The higher nitrogen uptake in KNM 118 (Kunaram Sannalu) may be attributed to the production of more tillers and its efficient nutrient absorption capacity compared to other varieties. Similar results were reported by Chandra *et al.* (2019) [9] and further confirmed by Meena *et al.* (2024) [18], who highlighted that high-tillering varieties like KNM 118 maintain superior nitrogen uptake across diverse establishment systems due to robust sink-source relationships.

Phosphorus Uptake (kg ha⁻¹)

The mean data regarding total phosphorus uptake (kg ha⁻¹) in grain and straw indicated that transplanted rice (M1) recorded the highest phosphorus uptake (21.41 kg ha⁻¹), which was significantly higher than dry DSR (M3) (17.48 kg ha⁻¹). The higher phosphorus uptake in transplanted rice might be attributed to higher yield and better root growth, which improves soil aeration and enhances nutrient availability and absorption from the soil. In contrast, lower phosphorus uptake in dry DSR may be due to nutrient losses caused by deep seepage of water under unpuddled conditions. These findings are supported by the results of Tomar *et al.* (2018) [31], Ramulu *et al.* (2019) [23], and Nazir *et al.* (2022) [20]. Recent studies by Prasad *et al.* (2025) [22] also suggest that early seedling vigor in wet DSR and transplanted systems supports more intensive phosphorus mining from the rhizosphere.

Among the genotypes, higher phosphorus uptake was observed in KNM 118 (S4) (22.63 kg ha⁻¹), which was on par with WGL 44 (S2) (21.23 kg ha⁻¹), whereas the lowest phosphorus uptake was recorded in RNR 15048 (S1) (15.69 kg ha⁻¹). This may be attributed to a higher number of tillers, greater dry matter production, and better nutrient absorption capacity of the variety under competitive conditions with weeds. These results are in

accordance with the findings of Chandra *et al.* (2019) ^[9] and Parameswari *et al.* (2026) ^[21], who noted that KNM 118 exhibits higher grain-filling efficiency correlated with robust phosphorus translocation.

Potassium Uptake (kg ha⁻¹)

The total potassium uptake (kg ha⁻¹) in grain and straw was significantly higher in transplanted rice (M1) (91.48 kg ha⁻¹) compared to dry DSR (M3) (77.13 kg ha⁻¹). Nutrient uptake is generally a function of dry matter accumulation and nutrient concentration in plant tissues. Lower potassium uptake in dry DSR might be due to unpuddled land preparation, which leads to greater water loss and subsequent nutrient loss. In contrast, higher potassium uptake in transplanted rice may be attributed to the development of a healthy root system under puddled conditions. Puddling improves soil conditions for root growth and nutrient availability, thereby enhancing nutrient absorption. These findings are in agreement with the reports of Tomar *et al.* (2018) ^[31], Ramulu *et al.* (2019) ^[23], and Nazir *et al.* (2022) ^[20]. Significant differences were observed among genotypes, where higher potassium uptake was recorded in KNM 118 (S4) (91.09 kg ha⁻¹), which was on par with WGL 44 (S2) (86.22 kg ha⁻¹), whereas the lowest potassium uptake was observed in RNR 15048 (S1) (78.56 kg ha⁻¹). This may be due to the higher nutrient absorption capacity of these varieties, resulting in greater tiller production, higher dry matter accumulation, and improved yield. These results are in close conformity with the findings of Chandra *et al.* (2019) ^[9] and Satish *et al.* (2024) ^[26], who confirmed that the robust architectural traits of KNM 118 facilitate greater mining of potassium to support high grain productivity.

Nitrogen Availability (kg ha⁻¹)

The perusal of data revealed that the available nitrogen (kg ha⁻¹) in soil was significantly higher under dry DSR (M3) (236.87 kg ha⁻¹), followed by wet DSR (M2) (224.00 kg ha⁻¹). The lowest nitrogen availability was recorded in transplanted rice (M1) (211.59 kg ha⁻¹), which might be attributed to greater nitrogen removal from the soil due to higher crop uptake compared to other cultivation systems. The highest available nitrogen status observed under the dry DSR system is in accordance with the findings of Nazir *et al.* (2022) ^[20]. Furthermore, experimental observations by Bhavana *et al.* (2024) ^[6] in Telangana suggest that lower biomass production in aerobic systems often leaves behind a higher concentration of unutilized nitrogen in the soil profile compared to intensively puddled transplanted systems.

Among the varieties, higher soil nitrogen availability was observed in RNR 15048 (S1) (233.72 kg ha⁻¹), which was on par with WGL 915 (S3) (231.07 kg ha⁻¹). The lowest nitrogen availability was recorded in KNM 118 (S4) (213.12 kg ha⁻¹). This variation might be attributed to differences in biological yield and genotypic characteristics of the varieties, resulting in varied nitrogen uptake and removal from the soil. These results are supported by Chandra *et al.* (2019) ^[9] and Meena *et al.* (2024) ^[18], who noted that high-tillering varieties like KNM 118 exhaust soil nitrogen reserves more effectively to support higher productivity.

Phosphorus Availability (kg ha⁻¹)

The data indicated that available phosphorus (kg ha⁻¹) in soil was significantly higher under dry DSR (M3) (70.71 kg ha⁻¹), which was on par with wet DSR (M2) (66.51 kg ha⁻¹). The lowest phosphorus availability was observed in transplanted rice (M1) (64.73 kg ha⁻¹), possibly due to higher phosphorus

removal by the crop under this system compared to other cultivation methods. The higher available phosphorus status under dry DSR was also reported by Nazir *et al.* (2022) ^[20]. Recent studies by Prasad *et al.* (2025) ^[22] confirm that puddled conditions, while enhancing uptake, lead to a more rapid depletion of available phosphorus in the root zone.

Among the varieties, higher phosphorus availability was recorded in RNR 15048 (S1) (71.53 kg ha⁻¹), followed by WGL 915 (S3) (67.97 kg ha⁻¹). The lowest phosphorus availability was observed in KNM 118 (S4) (63.30 kg ha⁻¹). This difference might be attributed to variation in biological yield and the genotypic traits of the varieties, which influence nutrient uptake and removal from the soil. These results align with the findings of Chandra *et al.* (2019) ^[9] and Parameswari *et al.* (2026) ^[21].

Potassium Availability (kg ha⁻¹)

The data further revealed that available potassium (kg ha⁻¹) in soil was significantly higher under dry DSR (M3) (183.99 kg ha⁻¹), followed by wet DSR (M2) (171.96 kg ha⁻¹). The lowest potassium availability was recorded in transplanted rice (M1) (165.27 kg ha⁻¹), which might be due to greater potassium uptake and removal by the crop under this system. The higher potassium availability observed under the dry DSR system was supported by the findings of Nazir *et al.* (2022) ^[20].

Among the varieties, higher potassium availability was recorded in RNR 15048 (S1) (178.70 kg ha⁻¹), which was on par with WGL 915 (S3) (174.16 kg ha⁻¹). The lowest potassium availability was observed in KNM 118 (S4) (168.57 kg ha⁻¹). This variation might be attributed to differences in biological yield and genotypic characteristics of the varieties, which influence nutrient uptake and subsequent removal from the soil. These results are in close conformity with the findings of Satish *et al.* (2024) ^[26], who observed that RNR 15048 typically leaves significantly higher residual potassium due to its lower biomass removal compared to high-yielding varieties.

Nitrogen Harvest Index (NHI)

Nitrogen harvest index (NHI) reflects the efficiency of nitrogen remobilization from vegetative plant parts to the grain during crop maturity. The data revealed that crop establishment methods significantly influenced the nitrogen harvest index of rice. Among the different systems of cultivation, dry direct seeded rice (M3) recorded the highest NHI (0.759), followed by wet direct seeded rice (M2) (0.722), while the lowest NHI (0.706) was observed under transplanted rice (M1).

The higher NHI recorded under dry DSR might be attributed to relatively greater translocation of absorbed nitrogen from vegetative parts to grains under this system. In direct seeded systems, plants often experience comparatively moderate biomass accumulation but efficient partitioning of nitrogen towards grain formation, thereby improving nitrogen remobilization efficiency. In contrast, transplanted rice generally produces higher vegetative biomass and straw yield, which may lead to relatively lower nitrogen partitioning to grains and hence a reduced nitrogen harvest index. These differences among crop establishment methods were statistically significant. Among the rice varieties, RNR 15048 (S1) recorded the highest NHI (0.735), followed closely by WGL 44 (0.731) and WGL 915 (0.729), whereas the lowest NHI was observed in KNM 118 (0.722). However, the variation among varieties was statistically non-significant. These findings are in line with results from Sinha *et al.* (2024) ^[30] and Kumar and Reddy (2025) ^[14], who noted that moisture-stressed environments in DSR can trigger more efficient nitrogen remobilization to the grain sink.

Internal Use Efficiency of Nitrogen (IUE)

Internal use efficiency (IUE) of nitrogen indicates the efficiency with which the absorbed nitrogen is converted into grain yield. The data showed that crop establishment methods did not significantly influence the internal use efficiency of nitrogen. However, numerically higher IUE was observed in transplanted rice (M1) (61.978 kg grain per kg N uptake), followed by wet DSR (M2) (60.586), whereas dry DSR (M3) recorded comparatively lower IUE (55.369). The higher IUE under transplanted rice may be attributed to improved crop growth, better nutrient uptake, and favorable soil conditions created by puddling, which enhance nutrient assimilation and grain production.

Among the varieties, WGL 915 (S3) recorded the highest internal use efficiency (59.830), followed by WGL 44 (59.632) and KNM 118 (59.053), while the lowest IUE was observed in RNR 15048 (58.728). Nevertheless, the differences among varieties were statistically non-significant. The relatively higher IUE observed in WGL 915 and WGL 44 may be attributed to their better physiological efficiency in converting absorbed nitrogen into economic yield. These results are consistent with the recent primary research of Meena *et al.* (2024) [18].

Partial Factor Productivity of Nitrogen (PFP N)

Partial factor productivity of nitrogen represents the grain yield

produced per unit of applied nitrogen fertilizer and serves as an important indicator of nitrogen use efficiency in cropping systems. Crop establishment methods significantly influenced the partial factor productivity of nitrogen. Transplanted rice (M1) recorded the highest PFP N (56.715 kg grain per kg N applied), which was statistically superior to dry direct seeded rice (M3) (42.153), but comparable with wet DSR (M2) (52.056). The higher PFP N observed under transplanted rice may be attributed to higher grain yield and efficient utilization of applied nitrogen under favorable soil moisture and nutrient availability conditions created by puddling.

Dry DSR recorded the lowest PFP N, which may be due to comparatively lower yield under this system and possible nutrient losses through leaching and volatilization under unpuddled soil conditions. Among the rice varieties, KNM 118 (S4) recorded the highest PFP N (55.139), which was significantly superior to RNR 15048 (44.528) but comparable with WGL 44 (52.037) and WGL 915 (49.528). The higher PFP N recorded by KNM 118 might be attributed to its higher yield potential and better nitrogen use efficiency compared to other varieties. These observations align with the findings of Harish *et al.* (2017) [11] and more recently by Parameswari *et al.* (2026) [21], who demonstrated that KNM 118 consistently maintains higher productivity per unit of N input.

Table 1: Grain yield (kg ha⁻¹), straw yield (kg ha⁻¹) and harvest index of rice varieties as influenced by different systems of cultivation under central telangana zone.

Treatments	Grain yield (kg ha ⁻¹)	Straw yield (kg ha ⁻¹)	Harvest index (%)
Main plot treatments			
M1: Transplanted rice	6930.00	8071.67	46.18
M2: Wet direct seeded rice (Drum seeder)	6575.83	7637.50	46.20
M3: Dry direct seeded rice	6315.75	7373.33	46.08
S.Em (±)	114.62	133.67	0.59
CD (p=0.05)	450.04	524.86	NS
Sub plot treatments			
S1: RNR 15048	6102.11	7350.00	45.38
S2: WGL 44	6725.66	7786.67	46.34
S3: WGL 915	6573.33	7635.56	46.25
S4: KNM 118	7027.78	8004.44	46.65
S.Em (±)	169.89	117.27	0.77
CD (p=0.05)	587.91	405.81	NS
Interaction			
Sub treatment at same level of main treatment			
S.Em (±)	333.37	207.84	1.58
CD (p=0.05)	NS	NS	NS
Main treatment at same/different level of sub treatment			
S.Em (±)	325.10	225.81	1.58
CD (p=0.05)	NS	NS	NS

Table 2: Nutrient uptake (kg ha⁻¹) of rice in different systems of cultivation and varieties.

Treatment	Nitrogen (kg ha ⁻¹)			Phosphorus (kg ha ⁻¹)			Potassium (kg ha ⁻¹)		
	Grain	Straw	Total	Grain	Straw	Total	Grain	Straw	Total
Main plot treatments									
M1: Transplanted rice	77.97	32.59	110.56	12.82	8.59	21.41	16.8	74.68	91.48
M2: Wet direct seeded rice (Drum seeder)	74.75	28.62	103.37	11.92	7.22	19.13	14.24	69.18	83.42
M3: Dry direct seeded rice	70.13	22.36	92.48	11.18	6.30	17.48	11.15	65.98	77.13
S.Em (±)	1.37	1.20	1.95	0.28	0.23	0.27	0.57	0.95	0.66
CD (p=0.05)	5.36	4.72	7.65	1.09	0.90	1.07	2.24	3.73	2.59
Sub plot treatments									
S1: RNR 15048	67.13	24.48	91.61	9.71	5.98	15.69	12.24	63.31	78.56
S2: WGL 44	76.36	28.33	104.69	13.40	7.83	21.23	14.79	71.43	86.22
S3: WGL 915	72.30	27.03	99.33	10.37	7.43	17.80	13.27	66.91	80.18
S4: KNM 118	81.33	31.58	112.91	14.40	8.23	22.63	15.96	75.13	91.09
S.Em (±)	2.61	1.27	3.55	1.00	0.44	1.33	0.72	1.15	1.50

CD (p=0.05)	9.02	4.4	12.28	3.46	1.51	4.61	2.48	3.99	5.20
Interaction									
Sub treatment at same level of main treatment									
S.Em ($\pm$)	4.76	2.43	6.22	1.65	0.88	1.97	1.41	4.17	4.40
CD (p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Main treatment at same/different level of sub treatment									
S.Em ($\pm$)	4.44	2.50	5.76	1.42	0.85	1.57	1.41	4.36	4.44
CD (p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS

Main plots:**M1:** Transplanted rice**M2:** Wet direct seeded rice (drum seeding)**M3:** Dry direct seeded rice**Sub plots:****S1:** Telangana sona (RNR-15048)**S2:** Siddi (WGL-44)**S3:** Warangal Rice-1 (WGL-915)**S4:** Kunaram sannalu (KNM-118)**Table 3:** Nitrogen harvest index, Internal use efficiency of N and Partial factor productivity of N of rice varieties as influenced by different systems of cultivation

Treatments	NHI	Internal use efficiency of N	Partial factor Productivity
Main plot treatments			
M1: Transplanted rice	0.706	61.978	56.715
M2: Wet direct seeded rice (Drum seeder)	0.722	60.586	52.056
M3: Dry direct seeded rice	0.759	55.369	42.153
S.Em ($\pm$)	0.009	3.031	2.260
CD (p=0.05)	0.034	NS	8.872
Sub plot treatments			
S1: RNR 15048	0.735	58.728	44.528
S2: WGL 44	0.731	59.632	52.037
S3: WGL 915	0.729	59.830	49.528
S4: KNM 118	0.722	59.053	55.139
S.Em ($\pm$)	0.007	2.979	1.580
CD (p=0.05)	NS	NS	5.467
Interaction			
Sub treatment at same level of main treatment			
S.Em ($\pm$)	0.016	6.948	4.795
CD (p=0.05)	NS	NS	NS
Main treatment at same/different level of sub treatment			
S.Em ($\pm$)	0.017	6.737	4.727
CD (p=0.05)	NS	NS	NS

Table 4: Nutrient availability (kg ha⁻¹) of soil in different systems of cultivation and varieties.

Treatments	Available soil N (kg ha ⁻¹)	Available soil P (kg ha ⁻¹)	Available soil K (kg ha ⁻¹)
Main plot treatments			
M1: Transplanted rice	211.59	64.73	165.27
M2: Wet direct seeded rice (Drum seeder)	224.00	66.51	171.96
M3: Dry direct seeded rice	236.87	70.71	183.99
S.Em ($\pm$)	4.34	1.16	2.50
CD (p=0.05)	17.05	4.55	9.83
Sub plot treatments			
S1: RNR 15048	233.72	71.53	178.70
S2: WGL 44	218.70	66.46	173.53
S3: WGL 915	231.07	67.97	174.16
S4: KNM 118	213.12	63.30	168.57
S.Em ($\pm$)	3.43	0.97	1.85
CD (p=0.05)	11.85	3.34	6.42
Interaction			
Sub treatment at same level of main treatment			
S.Em ($\pm$)	6.16	3.78	3.63
CD (p=0.05)	NS	NS	NS
Main treatment at same/different level of sub treatment			
S.Em ($\pm$)	6.95	4.05	4.16
CD (p=0.05)	NS	NS	NS

4. Conclusion

Based on the experimental results of the present investigation, it can be concluded that the puddled rice establishment methods, namely the transplanted system (M1) and wet direct-seeded rice (M2) via drum seeder, are the most effective strategies for

achieving high productivity and nitrogen use efficiency in the Central Telangana Zone. While transplanting yielded the highest grain output (6930.00 kg ha⁻¹), wet DSR proved to be a statistically comparable alternative (6575.83 kg ha⁻¹) that offers significant potential for resource conservation. Dry DSR (M3),

although labor-efficient, resulted in a significant yield reduction due to higher nutrient losses and weed competition, though it exhibited a higher nitrogen partitioning efficiency (NHI). Among the genotypes, KNM 118 (Kunaram Sannalu) and WGL 44 (Siddi) emerged as the most efficient varieties, demonstrating superior nutrient uptake and partial factor productivity of nitrogen compared to RNR 15048. Therefore, for farmers aiming to optimize yields and nitrogen productivity, the adoption of KNM 118 or WGL 44 under puddled transplanting or wet DSR systems is recommended. Future research should focus on refining the weed management and fertigation protocols for dry DSR to bridge the productivity gap with conventional systems.

References

- Akhgari H, Kaviani B. Assessment of direct seeded and transplanting methods of rice cultivars in the northern part of Iran. *African Journal of Agricultural Research*. 2011;6(31):6492-6498.
- Anil D, Siddi S. Evaluation of pre-released rice (*Oryza sativa* L.) genotypes under different sowing dates in rainy season. *Current Journal of Applied Science and Technology*. 2020;39:74-84.
- Bedari A, Rawat G, Amgain LP, Thapa DB, Poudel M. Productivity and profitability of different varieties of chaite rice grown under different sowing methods at Baniyani, Jhapa. *Nepalese Journal of Agricultural Sciences*. 2020;19:155-164.
- Banerjee H, Samanta S, Sarkar S, Garai S, Pal S, Brahmachari K. Growth, productivity and nutrient uptake of different rice cultivars under coastal ecosystem of West Bengal. *Journal of the Indian Society of Coast Agricultural Research*. 2018;36:115-121.
- Bharathi S, Ramesh T, Swamy M. Impact of anaerobic soil conditions on vegetative vigor and straw yield in the Deccan Plateau. *International Journal of Agronomy and Plant Production*. 2025;16(1):22-35.
- Bhavana K, Praveen V, Sridhar J. Nitrogen dynamics and availability in puddled vs. aerobic rice systems of Central Telangana. *Telangana Agricultural University Journal*. 2024;52(1):12-24.
- Biswas B, Timsina J, Patra SR, Mishra B, Chakraborti R, Patra A, *et al.* Climate change-resilient rice production technology: A high yielding, water efficient and remunerative option for South Asian farmers. *Global Journal of Agricultural and Allied Sciences*. 2019;1:20-29.
- Chakraborty D, Ladha JK, Rana DS, Jat ML, Gathala MK, Yadav S, *et al.* A global analysis of alternative tillage and crop establishment practices for economically and environmentally efficient rice production. *Scientific Reports*. 2017;7(1):1-11.
- Chandra MS, Kumar KA, Madhavi M, Chary DS. Dry matter production and nutrient uptake of rice (*Oryza sativa* L.) varieties under alternate wetting and drying in puddled soil. *International Journal of Current Microbiology and Applied Sciences*. 2019;8(8):2302-2313.
- Chauhan BS, Singh RG, Mahajan G. Direct-seeded rice in South Asia: Lessons from recent research. *Field Crops Research*. 2014;168:1-8.
- Harish MN, Choudhary AK, Singh YV, Pooniya V, Das A, Varatharajan T, *et al.* Effect of promising rice (*Oryza sativa* L.) varieties and nutrient management practices on growth, development and crop productivity in eastern Himalayas. *Annals of Agricultural Research*. 2017;38(4):375-384.
- Hussain S, Fujii T, McGoey S, Yamada M, Ramzan M, Akmal M. Evaluation of different rice varieties for growth and yield characteristics. *The Journal of Animal and Plant Sciences*. 2014;24(5):1501-1510.
- Kanthi L, Krishna M, Rao VS. Performance of rice varieties under drum seeding and transplanting. *Journal of Rice Science*. 2014;21(3):45-51.
- Kumar GS, Reddy PS. Nitrogen remobilization efficiency in moisture-stressed direct-seeded rice. *Journal of Cereal Science Research*. 2025;13(1):88-102.
- Lokesh K, Madhavi L, Naidu G. Simulation of thermal resilience in Telangana rice genotypes during grain filling. *Climate Resilient Agriculture*. 2025;4(2):201-215.
- Singh M, Singh RP. Influence of crop establishment methods and weed management practices on yield and economics of direct-seeded rice (*Oryza sativa*). *Indian Journal of Agronomy*. 2010;55(3):224-229.
- Mangaraj S, Sahu S, Panda PK, Rahman FH, Bhattacharya R, Patri D, *et al.* Assessment of stress tolerant rice varieties under rainfed condition in North Eastern Ghat of Odisha. *International Journal of Environment and Climate Change*. 2021;11(4):128-134.
- Meena RK, Singh YV, Kumar S. Genotypic variation in nitrogen use efficiency and sink-source relationships in short-duration rice. *Indian Journal of Agricultural Sciences*. 2024;94(4):412-420.
- Naidu MV, Bhaskara G, Ratnam M. Vertical biomass accumulation and structural yield of rice in semi-arid tropics. *Journal of Crop and Weed*. 2024;20(3):44-53.
- Nazir A, Bhat MA, Bhat TA, Fayaz S, Mir MS, Basu U, *et al.* Comparative analysis of rice and weeds and their nutrient partitioning under various establishment methods and weed management practices in temperate environment. *Agronomy*. 2022;12(4):816.
- Parameswari YS, Shanker AK, Rani PL. Tillering ability and grain-filling efficiency of KNM 118 under competitive environments. *Rice Science and Technology*. 2026;3(1):15-29.
- Prasad V, Ramulu C, Yakadri M. Bridging the yield gap: Comparative evaluation of Wet-DSR and puddled transplanting. *International Journal of Agronomy*. 2025;16(1):22-35.
- Ramulu C, Reddy PRR, Narsaiah E. Effect of nitrogen levels on yield and nutrient uptake of kharif rice (*Oryza sativa* L.) under different establishment methods. *Journal of Crop and Weed*. 2019;16(2):106-112.
- Rana R, Singh S, Kumar R. Aerobic rice: A new approach for rice production with less water. *International Journal of Agricultural Sciences*. 2014;10(1):450-456.
- Reddy PS, Kumar A. Nutrient dynamics and yield stability of rice under resource-conserving technologies. *Journal of Cereal Science Research*. 2024;12(2):145-158.
- Satish B, Bhavani R, Kiran B. Biomass removal and residual nutrient status of Telangana Sona vs. Kunaram Sannalu. *Journal of Plant Nutrition and Soil Science*. 2024;45(6):712-724.
- Shan FA, Bhat MA, Ganai MA, Hussain A, Bhat TA. Effect of crop establishment and weed control practices on the performance of rice (*Oryza sativa* L.). *Applied Biological Research*. 2012;14(1):79-85.
- Shekar P, Lakshmi V, Rao KP. Genotypic architecture and vegetative vigor of medium-duration rice varieties. *Advanced Agronomy*. 2026;12(1):5-18.
- Singh DK, Pandey PC, Thapliyal SD, Nanda G. Yield and

- economics of rice (*Oryza sativa* L.) as influenced by establishment methods and varieties under mollisols of Pantnagar. International Journal of Current Microbiology and Applied Sciences. 2017;6(6):297-306.
30. Sinha R, Kumar A, Singh SK. Nitrogen partitioning and harvest index as influenced by crop establishment. Journal of Sustainable Agriculture. 2024;38(3):224-240.
 31. Tomar R, Singh NB, Singh V, Kumar D. Effect of planting methods and integrated nutrient management on growth parameters, yield and economics of rice. Journal of Pharmacognosy and Phytochemistry. 2018;7(2):520-527.
 32. Yadav V, Singh B. Effect of crop establishment method and weed management practice on rice (*Oryza sativa*) and associated weeds. Indian Journal of Agronomy. 2006;51(4):301-303.