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Batti Deepika

P.G. Research Scholar,
Department of Agronomy,
Agricultural College, Polasa,
Jagtial, Professor Jayashankar
Telangana Agricultural University,
Hyderabad, Telangana, India

Dr. D Sreelatha

Principal Scientist and
Coordinator, Department of
Agronomy, TRVK, Yadadri
Bhuvanagiri, Professor
Jayashankar Telangana
Agricultural University,
Hyderabad, Telangana, India

Dr. P Spandana Bhatt

Associate Professor, Department of
Agronomy, Agricultural College,
Polasa, Jagtial, Professor
Jayashankar Telangana
Agricultural University,
Hyderabad, Telangana, India

Dr. P Ravi

Scientist, Department of Soil
Science & Agricultural Chemistry,
AICRP on LTFE, RARS, Polasa,
Jagtial, Professor Jayashankar
Telangana Agricultural University,
Hyderabad, Telangana, India

Dr. B Srinivas

Scientist, Plant Breeding, Rice
Section, RARS, Polasa, Jagtial,
Professor Jayashankar Telangana
Agricultural University,
Hyderabad, Telangana, India

Corresponding Author:

Batti Deepika

P.G. Research Scholar,
Department of Agronomy,
Agricultural College, Polasa,
Jagtial, Professor Jayashankar
Telangana Agricultural University,
Hyderabad, Telangana, India

Effect of graded levels of nitrogen on yield and lodging of different rice (*Oryza sativa*. L) varieties

Batti Deepika, D Sreelatha, P Spandana Bhatt, P Ravi and B Srinivas

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Abstract

A field experiment was conducted during *rabi* 2025-2026 at the Regional Agricultural Research Station (RARS), Polasa, Jagtial, to evaluate effect of graded levels of nitrogen on yield and lodging of different rice (*Oryza sativa*. L) varieties. The experiment was laid out in a Split Plot Design with three varieties (JGL-24423, KNM-118 and JGL-21078) as main plots and four nitrogen levels (75% RDN, 100% RDN, 125% RDN and farmer's practice of 170:65:40 kg NPK ha⁻¹) as sub-plots, replicated thrice. Among the varieties, JGL-24423 (M₁) recorded significantly the highest grain yield (7438 kg ha⁻¹) and straw yield (9008 kg ha⁻¹), together with the lowest lodging percentage (9.73%), while JGL-21078 (M₃) recorded the lowest grain yield (5787 kg ha⁻¹) and straw yield (7469 kg ha⁻¹), along with the highest lodging percentage (23.02%). Harvest index did not vary significantly among varieties, though JGL-24423 recorded the numerically highest value (45.25%). Among the nitrogen levels, 100% RDN (S₂) and 125% RDN (S₃) were statistically comparable and produced the highest grain yield (7145 and 7081 kg ha⁻¹, respectively) and harvest index, whereas the farmer's practice, despite supplying the highest nitrogen dose, recorded the highest straw yield (8813 kg ha⁻¹), the lowest harvest index (40.83%) and the highest lodging percentage (20.21%). The interaction between variety and nitrogen level was significant for grain yield, with JGL-24423 receiving 125% RDN recording the highest grain yield (8240 kg ha⁻¹), statistically on par with JGL-24423 at 100% RDN (7890 kg ha⁻¹).

Keywords: Rice varieties, nitrogen levels, grain yield, straw yield, harvest index, lodging percentage, split plot design

Introduction

Rice (*Oryza sativa* L.) is one of the most important food crops of the world and serves as a major staple food for more than half of the global population. It occupies a prominent position in Indian agriculture and is cultivated extensively across diverse agro-climatic conditions. India is one of the leading rice-producing countries, with rice cultivated over 51.27 m ha, producing 150.18 m t with an average productivity of 2929 kg ha⁻¹. In Telangana, rice is one of the major food grain crops, occupying about 4.81 m ha with a production of 17.45 m t and productivity of 3627 kg ha⁻¹ (Indiastat, 2024-2025) [4]. The expansion of irrigation facilities, adoption of improved varieties and increased use of fertilizers have contributed considerably to enhancing rice productivity in the state (Peddi *et al.*, 2023) [11]. However, sustaining higher productivity requires efficient nutrient management along with the identification of varieties that can perform consistently under varying nutrient regimes.

Grain yield is the principal economic output of rice and is the cumulative expression of several growth and yield-contributing attributes. Nitrogen is one of the most important nutrients influencing rice growth and productivity, as it plays a vital role in chlorophyll formation, photosynthesis, tiller production, dry matter accumulation and grain development. Adequate nitrogen supply promotes productive tillering and biomass production and supports grain formation and filling. However, the response of rice to nitrogen is not always linear, as application beyond the optimum requirement can result in excessive vegetative growth, increased plant height and canopy weight and inefficient partitioning of assimilates towards grain production (Nayak *et al.*, 2022; Cherupelly *et al.*, 2024) [7, 2]. Therefore, judicious management of nitrogen is essential for achieving a favourable balance between vegetative growth and economic yield.

Excessive nitrogen availability is also associated with an increased risk of lodging, which is one of the major constraints affecting the productivity and harvestability of high-yielding rice. Lodging refers to the bending or displacement of culms from their normal upright position and is influenced by excessive nitrogen, plant height, canopy weight, internodal characteristics, stem thickness and culm strength (Singh *et al.*, 2020) ^[15]. Lodged plants may experience reduced canopy photosynthesis, impaired assimilate translocation during grain filling and difficulties in harvesting, ultimately resulting in yield losses (Setter *et al.*, 1997) ^[14]. The problem becomes particularly important under high nitrogen regimes, where enhanced vegetative growth and increased canopy weight may adversely affect crop standability. Straw yield is another important component of total biomass production and is influenced by the amount of vegetative growth and dry matter accumulation. Although increased nitrogen availability can enhance biomass and straw production, excessive nitrogen may promote vegetative growth disproportionately to grain production. The efficiency of biomass partitioning towards grain is reflected by harvest index, which provides an indication of the proportion of total above-ground biomass converted into economic yield (Padhan *et al.*, 2023) ^[9]. Therefore, simultaneous assessment of grain yield, straw yield and harvest index, along with lodging percentage, provides a more comprehensive understanding of the productivity and standability of rice varieties under different nitrogen regimes.

Under the prevailing rice-based production systems of Telangana, where fertilizer use and productivity enhancement are important components of intensive rice cultivation, identification of suitable variety-nitrogen combinations is essential for achieving higher productivity without compromising crop standability. Evaluation of the interaction between varieties and nitrogen levels is particularly important because varieties may differ in their growth, biomass accumulation, yield formation and lodging response to increased nitrogen supply. Such information can help in identifying nitrogen levels that optimize grain production while maintaining favourable straw yield, harvest index and lodging resistance.

Materials and Methods

The field experiment was conducted during *rabi* 2025-2026 at the I6A block of the Regional Agricultural Research Station (RARS), Polasa, Jagtial, situated at an altitude of 282 m above mean sea level (18°50'40.53" N latitude and 78°57'16.06" E longitude) under the Northern Telangana Zone of Telangana State. The soil of the experimental site was sandy clay loam in texture, slightly alkaline in reaction (pH 7.78), with low available nitrogen (180.70 kg ha⁻¹), high available phosphorus (42.60 kg ha⁻¹) and high available potassium (315.66 kg ha⁻¹).

The experiment was laid out in a Split Plot Design (SPD) with three rice varieties, viz., JGL-24423 (M₁), KNM-118 (M₂) and JGL-21078 (M₃), allotted to the main plots and four nitrogen levels, viz., 75% RDN or 90 kg N ha⁻¹ (S₁), 100% RDN or 120 kg N ha⁻¹ (S₂), 125% RDN or 150 kg N ha⁻¹ (S₃) and farmer's practice of 170:65:40 kg NPK ha⁻¹ (S₄), allotted to the sub-plots, replicated thrice, giving twelve treatment combinations. 27 days old seedlings were transplanted at a spacing of 15 cm × 15 cm with 2-3 seedlings hill⁻¹. Fertilizers were applied as per the recommended dose of Phosphorus and Potassium @ 60 & 40 kg ha⁻¹ in the form of SSP and MOP for S₁, S₂, S₃ and for S₄,

phosphorus and potassium @ 65 & 40 kg ha⁻¹ is applied, while nitrogen was applied as per the treatment schedule in three equal splits at transplanting, tillering and panicle initiation stages. At maturity, grain yield and straw yield were recorded plot-wise and expressed on a kg ha⁻¹ basis at 14% grain moisture, harvest index was computed as the ratio of grain yield to total biological yield expressed in percentage and the percentage of lodged plants was recorded at maturity and expressed as lodging percentage (Lodging percentage (%) = (Number of lodged plants ÷ Total number of plants) × 100). The data were statistically analysed as per the procedure for a split plot design suggested by Panse and Sukhatme (1978) ^[10] and OPSTAT software. The significance of differences among treatment means for the various parameters was assessed based on the critical difference (CD) at the 5% probability level (p = 0.05).

Results and Discussion

Grain yield (kg ha⁻¹)

Grain yield was significantly influenced by both varieties and nitrogen levels as presented in table.1. Among the varieties, JGL-24423 recorded significantly the highest grain yield (7438 kg ha⁻¹), followed by KNM-118 (6485 kg ha⁻¹), while JGL-21078 recorded the significantly lowest grain yield (5787 kg ha⁻¹). The superior yield of JGL-24423 could be attributed to its higher yield potential, efficient nutrient utilization and better assimilate translocation towards reproductive; its dwarf stature, thicker culm and stronger stem also reduced lodging under higher nitrogen levels, thereby maintaining uninterrupted grain filling. The present findings corroborate the observations reported by (Swathi *et al.*, 2023; Revathi *et al.*, 2023) ^[17, 13]. The comparatively lower yield of JGL-21078 was associated with fewer productive tillers, a higher chaffy grain percentage and greater susceptibility to lodging, which disrupted photosynthesis and assimilate translocation during the reproductive phase, resulting in lower grain yield.

Among the nitrogen levels, 100% RDN (120 N kg ha⁻¹) recorded significantly the highest grain yield (7145 kg ha⁻¹), statistically on par with 125% RDN (150 N kg ha⁻¹) (7081 kg ha⁻¹), while the lowest grain yield was recorded under 75% RDN (90 N kg ha⁻¹) (5805 kg ha⁻¹). Interestingly, the farmer's practice (170 N kg ha⁻¹), despite receiving the highest nitrogen dose, produced only an intermediate grain yield (6249 kg ha⁻¹); its excessive nitrogen supply favoured vegetative growth and greater straw production, and the accompanying increase in lodging impaired grain filling and lowered the harvest index. These observations are in accordance with the findings of Hossain *et al.*, 2006 ^[3]. This indicates that a balanced nitrogen supply at 100% RDN was more effective than nitrogen application beyond the recommended level for maximising grain yield.

The interaction between varieties and nitrogen levels was significant for grain yield (Table 2 and fig.1). JGL-24423 with 125% RDN recorded the highest grain yield (8240 kg ha⁻¹), statistically on par with JGL-24423 at 100% RDN (7890 kg ha⁻¹), indicating that JGL-24423 could economise on nitrogen input by responding equally well at the recommended dose without a significant yield penalty. In contrast, JGL-21078 recorded comparatively lower grain yield at all nitrogen levels, with the lowest yield under farmer's practice (5299 kg ha⁻¹), reflecting its greater susceptibility to lodging and reduced grain-filling efficiency at higher nitrogen doses.

Table 1: Effect of varieties and nitrogen levels on yield (kg ha⁻¹), harvest index (%) and lodging percentage (%)

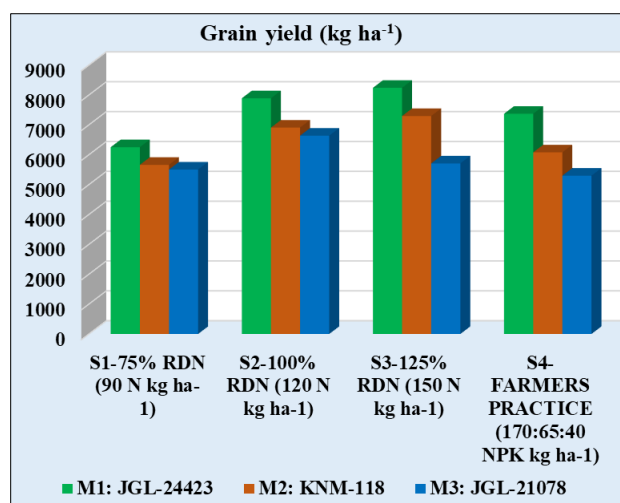
	Treatment	Grain yield (kg ha ⁻¹)	Straw yield (kg ha ⁻¹)	Harvest index (%)	Lodging percentage (%)
Varieties					
M ₁	JGL-24423	7438	9008	45.25	9.73
M ₂	KNM-118	6485	8313	43.77	13.44
M ₃	JGL-21078	5787	7469	43.20	23.02
	S.E(m)±	171	171	0.94	0.48
	CD (p=0.05)	672	670	NS	1.90
Nitrogen levels					
S ₁	75% RDN (90 kg N ha ⁻¹)	5805	7468	43.78	11.61
S ₂	100% RDN (120 kg N ha ⁻¹)	7145	8255	46.41	13.10
S ₃	125% RDN (150 kg N ha ⁻¹)	7081	8517	45.25	16.68
S ₄	Farmer's practice (170:65:40 NPK kg ha ⁻¹)	6249	8813	40.83	20.21
	S.E(m)±	152	191	0.90	0.51
	CD (p=0.05)	456	567	2.70	1.53
Interaction					
Sub plots at same main plots					
	SE(m)±	262.11	330.38	1.58	0.89
	CD (p=0.05)	787.01	NS	NS	NS
Main plots at same or different level of sub plots					
	SE(m)±	286.36	434.92	1.66	0.91
	CD (p=0.05)	948.49	NS	NS	NS

The critical differences (CD) at 5% probability level.

Table 2: Interaction effect of varieties and nitrogen levels on grain yield (kg ha⁻¹)

Nitrogen level	M ₁ : JGL-24423	M ₂ : KNM-118	M ₃ : JGL-21078
S ₁ : 75% RDN (90 kg N ha ⁻¹)	6252	5662	5504
S ₂ : 100% RDN (120 kg N ha ⁻¹)	7890	6908	6638
S ₃ : 125% RDN (150 kg N ha ⁻¹)	8240	7296	5709
S ₄ : Farmer's practice (170: 65: 40 NPK kg ha ⁻¹)	7372	6079	5299
	Sub plots at same main plots (S×M)		Main plots at same or different level of sub plots (M×S)
	S.E(m)±	262	286
	CD (p=0.05)	787	948

The critical differences (CD) at 5% probability level.

**Fig 1:** Interaction effect of varieties and nitrogen levels on grain yield (kg ha⁻¹)

Straw yield (kg ha⁻¹)

Straw yield, being a reflection of the vegetative growth and source capacity of the crop, was significantly influenced by varietal differences as well as nitrogen levels (Table 1). Among the varieties, JGL-24423 recorded significantly the highest straw yield (9008 kg ha⁻¹), followed by KNM-118 (8313 kg ha⁻¹), while JGL-21078 recorded the significantly lowest straw yield (7469 kg ha⁻¹). The higher straw yield of JGL-24423 could be attributed to its better vegetative growth and greater accumulation of structural

biomass, supported by its dwarf stature, thicker culm and reduced lodging, which maintained the crop canopy and sustained photosynthesis. The lower straw yield of JGL-21078, despite its greater lodging susceptibility, reflected comparatively lower overall biomass production, as lodging during grain filling adversely affected assimilate translocation and biomass accumulation. Similar results were obtained by Li *et al.*, 2024 ^[6]. Among the nitrogen levels, straw yield increased progressively with nitrogen supply, being significantly the highest under farmer's practice (8813 kg ha⁻¹), which was statistically on par with 125% RDN (8517 kg ha⁻¹) and 100% RDN (8255 kg ha⁻¹), while the significantly lowest straw yield was recorded under 75% RDN (7468 kg ha⁻¹). This contrasting trend, wherein grain yield peaked at 100-125% RDN while straw yield continued to increase up to the farmer's practice level, indicates that nitrogen supply beyond the optimum promoted excessive vegetative growth without a corresponding improvement in grain filling, with the additional nitrogen being channelled into vegetative biomass rather than the reproductive sink (Khan *et al.*, 2020) ^[5]. The interaction effect of varieties and nitrogen levels on straw yield was non-significant, indicating that the relative response of the varieties to increasing nitrogen was similar for straw production.

Harvest index (%)

Harvest index reflects how efficiently a crop partitions its dry matter into economically useful grain rather than vegetative biomass. Varieties did not differ significantly in harvest index (Table 1), although JGL-24423 recorded the numerically highest

value (45.25%), followed by KNM-118 (43.77%) and JGL-21078 (43.20%). The relatively higher harvest index of JGL-24423 could be associated with its better assimilate partitioning towards grains, aided by its dwarf stature, greater culm strength and reduced lodging, whereas the marginally lower harvest index of JGL-21078, despite its higher vegetative biomass, reflected comparatively less efficient partitioning under greater lodging. Nitrogen levels, on the other hand, significantly influenced harvest index. The highest harvest index was recorded under 100% RDN (46.41%), statistically on par with 125% RDN (45.25%) and 75% RDN (43.78%), while the significantly lowest harvest index was recorded under farmer's practice (40.83%). The higher harvest index under 100% RDN reflected a favourable balance between vegetative growth and reproductive development, with efficient partitioning of assimilates towards grain, whereas the comparable value under 125% RDN indicated no added advantage from nitrogen beyond the recommended level. The lowest harvest index under farmer's practice could be attributed to excessive nitrogen-induced vegetative growth and greater lodging, which impaired assimilate translocation to the grain and favoured retention of biomass in vegetative parts (Ohnishi *et al.*, 1999) [8]. The interaction between varieties and nitrogen levels was non-significant for harvest index, indicating a similar pattern of dry matter partitioning across varieties at all nitrogen levels.

Lodging percentage (%)

Rice varieties differed significantly in lodging percentage (Table 1 and fig. 2). JGL-24423 recorded the significantly lowest lodging

percentage (9.73%), followed by KNM-118 (13.44%), while JGL-21078 recorded the significantly highest lodging percentage (23.02%). The lower lodging in JGL-24423 could be attributed to its dwarf plant type, shorter internodes and greater culm strength, which provided better mechanical stability under wind and panicle load (Sreeja *et al.*, 2014) [16], whereas the higher lodging in JGL-21078 was associated with its longer internodes and comparatively weaker culm strength, which increased the bending moment on the lower culm despite its larger stem diameter.

Nitrogen levels also significantly influenced lodging percentage, which increased progressively with increasing nitrogen supply. The lowest lodging percentage was recorded under 75% RDN (11.61%), statistically comparable with 100% RDN (13.10%), while lodging increased significantly to 16.68% under 125% RDN and reached the highest value of 20.21% under farmer's practice. The progressive increase in lodging with higher nitrogen doses could be attributed to excessive vegetative growth, greater plant height, canopy weight and mechanical stress on the culm at higher nitrogen levels. The findings are in accordance with the observations made by Rani *et al.*, 2012 [12] and Chen *et al.*, 2022 [1]. The interaction between varieties and nitrogen levels for lodging percentage was non-significant, indicating that the varieties responded similarly to increasing nitrogen with respect to lodging behaviour. These results emphasise that a balanced nitrogen supply, together with the choice of a lodging-resistant, high-yielding variety such as JGL-24423, is important for maintaining crop standability while realising higher grain yield.

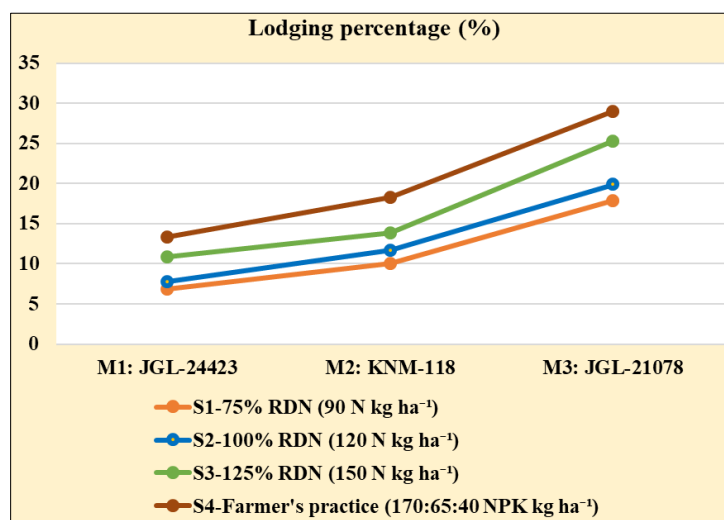


Fig 2: Effect of varieties and nitrogen levels on lodging percentage (%)

Conclusion

Based on the results of the present investigation, it can be concluded that among the rice varieties tested, JGL-24423 was superior with respect to yield and standability, recording the highest grain yield (7438 kg ha⁻¹) and straw yield (9008 kg ha⁻¹) together with the lowest lodging percentage (9.73%), while JGL-21078 recorded the lowest grain and straw yield due to the highest lodging percentage (23.02%). Among the nitrogen levels, 100% RDN (120 kg N ha⁻¹) and 125% RDN (150 kg N ha⁻¹) were statistically at par and produced significantly higher grain yield and harvest index than the farmer's practice of 170:65:40 kg NPK ha⁻¹, which, despite the highest nitrogen dose, recorded the highest straw yield, the lowest harvest index and the highest lodging percentage. The interaction of JGL-24423 with 125% RDN recorded the highest grain yield (8240 kg ha⁻¹), statistically

on par with JGL-24423 receiving 100% RDN. This indicates that growing JGL-24423 with 100-125% of the recommended nitrogen dose can achieve near-maximum grain yield with better lodging resistance and a more favourable harvest index, offering a nitrogen-use-efficient and lodging-resistant alternative to the prevailing farmer's practice across Northern Telangana climate conditions.

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