Plant Archives Vol. 26, Supplement 2, 2026 pp. 2118-2122 e-ISSN:2581-6063 (online), ISSN:0972-5210

Plant Archives

Journal homepage: http://www.plantarchives.org
DOI Url : https://doi.org/10.51470/PLANTARCHIVES.2026.v26.supplement-2.265

OPTIMIZING PRODUCTIVITY OF DIRECT-SEEDED RICE (*Oryza sativa* L.) THROUGH BROWN MANURING AND INORGANIC NITROGEN MANAGEMENT

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(Date of Receiving : 08-05-2026; Date of Revision : 26-06-2026; Date of Acceptance : 21-07-2026)

ABSTRACT

The productivity of direct-seeded rice is often limited by poor nitrogen-use efficiency and severe weed infestation, necessitating the development of efficient nutrient management strategies. A field experiment was conducted during the kharif seasons of 2024 and 2025 at the Agricultural College Farm, Bapatla, Andhra Pradesh, to evaluate the influence of brown manuring and graded nitrogen levels on the productivity of direct-seeded rice. The experiment was laid out in a randomized block design with seven treatments and three replications. The treatments consisted of 100% recommended dose of nitrogen (RDN) alone and its integration with brown manuring of sunnhemp terminated at 30 or 45 days after sowing (DAS) under 75, 100 and 125% RDN. The results revealed that 125% RDN + brown manuring of sunnhemp at 30 DAS recorded significantly higher grain and straw yields during both the years and in the pooled analysis, while 75% RDN + brown manuring of sunnhemp at 45 DAS produced the lowest yields. Harvest index remained statistically unaffected by the treatments, indicating that variations in nitrogen levels and brown manuring timings proportionately influenced grain and straw production without altering assimilate partitioning. The findings suggest that integrating early brown manuring with an adequate nitrogen supply is an effective strategy for enhancing the productivity of direct-seeded rice under the Krishna Delta conditions.

Keywords **:** Brown manuring; *Crotalaria juncea*; Direct-seeded rice; Grain yield; Nitrogen management; Nutrient-use efficiency; Straw yield.

Introduction

Rice (*Oryza sativa* L.) is the principal staple food crop for more than half of the global population and plays a vital role in ensuring food and nutritional security. In India, rice cultivation forms the backbone of the agricultural economy, particularly in irrigated ecosystems such as the Krishna Delta Zone of Andhra Pradesh. Traditionally, rice is grown under puddled transplanted conditions; however, increasing labour scarcity, delayed irrigation water availability, rising production costs, and concerns over diminishing water resources have accelerated the adoption of direct-seeded rice (DSR). Direct seeding reduces labour and water requirements, lowers cultivation costs, and enables timely crop establishment, although its productivity is often constrained by severe weed infestation and inefficient nutrient management (Yadav *et al*., 2021; Sandhu *et al*., 2021).

Nitrogen is the primary yield-limiting nutrient in rice because of its crucial role in chlorophyll synthesis, photosynthesis, tiller production, canopy development, and dry matter accumulation. Nevertheless, nitrogen-use efficiency in DSR is generally low due to considerable losses through volatilization, denitrification, leaching, and runoff, resulting in reduced fertilizer recovery and economic returns (Jat *et al*., 2019; Choudhary *et al*., 2022). Therefore, integrated nutrient management practices that improve nitrogen synchronization and enhance soil fertility

have become increasingly important for sustaining rice productivity.

Brown manuring has gained considerable attention as an eco-friendly agronomic practice for improving the productivity and sustainability of direct-seeded rice. The in-situ desiccation of a leguminous intercrop such as *sunnhemp* contributes biologically fixed nitrogen and organic matter, improves soil microbial activity, enhances nutrient cycling, and effectively suppresses weeds during the critical crop–weed competition period (Chaudhary *et al*., 2022). Furthermore, the timing of brown manuring influences residue quality, decomposition rate, and nutrient mineralization, thereby determining the extent to which nutrient release coincides with crop demand (Mohanty *et al*., 2022).

Integrating brown manuring with inorganic nitrogen fertilization provides an opportunity to synchronize the rapid availability of fertilizer nitrogen with the gradual nutrient release from decomposing residues, thereby enhancing nitrogen-use efficiency, improving soil health, and sustaining crop productivity (Datta *et al*., 2020; Choudhary *et al*., 2018). However, information on the combined influence of brown manuring timing and nitrogen management under the agro-climatic conditions of the Krishna Delta Zone remains scarce. Therefore, identifying an efficient integration strategy is essential for enhancing the growth, yield, and sustainability of direct-seeded rice under irrigated ecosystems.

Material and Methods

A field experiment was conducted during the *kharif* seasons of 2024 and 2025 at the Agricultural College Farm, Bapatla, Andhra Pradesh, India. The experimental site is situated at 15°54′ N latitude and 80°25′ E longitude, at an altitude of 5.49 m above mean sea level, approximately 8 km from the Bay of Bengal, in the Krishna Agro-Climatic Zone of Andhra Pradesh. The region represents the upland coastal ecosystem of the Krishna Agro-Climatic Zone.

The experiment was laid out in a Randomized Block Design (RBD) with three replications comprising seven treatments:

M_1- 100% recommended dose of nitrogen (RDN)
M_2- 75% RDN + brown manuring with *sunnhemp* at 30 DAS
M_3- 100% RDN + brown manuring with *sunnhemp* at 30 DAS
M_4- 125% RDN + brown manuring with *sunnhemp* at 30 DAS
M_5- 75% RDN + brown manuring with *sunnhemp* at 45 DAS
M_6- 100% RDN + brown manuring with *sunnhemp* at 45 DAS and
M_7- 125% RDN + brown manuring with *sunnhemp* at 45 DAS.

The experimental soil was sandy clay loam in texture, neutral in reaction, non-saline, low in organic carbon and available nitrogen, and medium in available phosphorus and potassium. The rice variety BPT-5204 was used for the study. *Sunnhemp* (*Crotalaria juncea* L.) was grown as a co-crop with direct-seeded rice for brown manuring. Sunnhemp seeds were manually broadcast immediately after rice sowing in the designated treatment plots. The brown manure crop was terminated by spraying 2,4-D at 0.5 kg ha^{-1} using a spray volume of 500 L ha^{-1} at either 30 or 45 days after sowing, according to the treatment schedule.

The recommended fertilizer dose for rice was 120-60-40 kg N-P_2O_5-K_2O ha^{-1}. Nitrogen was applied according to the respective treatment levels, while phosphorus and potassium were applied uniformly to all treatments as per the recommended dose. Grain and straw yields were recorded from the net plot area (1 m^2) of each treatment and subsequently converted to kg ha^{-1} for statistical analysis.

Results and Discussion

Grain Yield (kg ha^{-1})

Significantly the highest grain yield (Table 1) was recorded with 125% RDN + brown manuring of *sunnhemp* at 30 DAS (M_4) during both the years of experimentation as well as in the pooled analysis, registering 5453, 5855 and 5654 kg ha^{-1}, respectively. This treatment proved to be significantly superior to all the other treatments. 100% RDN + brown manuring of *sunnhemp* at 30 DAS (M_3) and 125% RDN + brown manuring of *sunnhemp* at 45 DAS (M_7) were statistically comparable with each other and constituted the next best treatments, but were significantly inferior to M_4. The remaining treatments recorded comparatively lower grain yields, with 100% RDN (M_1), 100% RDN + brown manuring of *sunnhemp* at 45 DAS (M_6) and 75% RDN + brown manuring of *sunnhemp* at 30 DAS (M_2) exhibiting intermediate performance. The lowest grain yield was recorded with 75% RDN + brown manuring of *sunnhemp* at 45 DAS (M_5), registering 3015, 3265 and 3140 kg ha^{-1} during 2024, 2025 and in the pooled data, respectively.

The significantly higher grain yield recorded with 125% RDN + brown manuring of *sunnhemp* at 30 DAS (M_4) could be attributed to the complementary effect of adequate nitrogen availability and timely brown manuring, which ensured synchronized nutrient release during the critical stages of crop growth. Early

desiccation of *sunnhemp* reduced crop–legume competition and promoted rapid decomposition of the succulent biomass, resulting in improved nutrient availability, enhanced photosynthetic efficiency, and better partitioning of assimilates towards grain formation. Similar findings were reported by Sarangi *et al*. (2016), who observed increased grain yield in direct-seeded rice through the integration of brown manuring with nitrogen fertilization, and Sachin Singh *et al*. (2023), who reported superior productivity of direct-seeded rice under brown manuring integrated with appropriate nitrogen management and effective weed control. Recent review Anjali Chaudhary *et al*. (2023) also highlighted that brown manuring improves nutrient availability, suppresses weeds, enhances soil biological activity, and ultimately increases grain yield in direct-seeded rice systems.

Table 1 : Grain yield (kg ha^{-1}) of direct seeded rice as influenced by time of brown manuring and varied nitrogen levels during *kharif* 2024, 2025 and pooled data

Treatments	Grain yield		
	2024	2025	Pooled data
M_1 - 100% RDN	3311	3660	3486
M_2 - 75% RDN + Brown manuring with *sunnhemp* at 30 DAS	3167	3471	3319
M_3 - 100% RDN + Brown manuring with *sunnhemp* at 30 DAS	4756	5140	4948
M_4 - 125% RDN + Brown manuring with *sunnhemp* at 30 DAS	5453	5855	5654
M_5 - 75% RDN + Brown manuring with *sunnhemp* at 45 DAS	3015	3265	3140
M_6 - 100% RDN + Brown manuring with *sunnhemp* at 45 DAS	3978	4371	3983
M_7 - 125% RDN + Brown manuring with *sunnhemp* at 45 DAS	4650	5084	4867
S.Em±	215.1	229.5	220.2
CD (p=0.05)	663	707	679
CV (%)	9.2	9.0	9.1

The lower grain yield recorded with 75% RDN + brown manuring of *sunnhemp* at 45 DAS (M_5) might be due to insufficient nitrogen availability during the peak vegetative phase and delayed nutrient release from relatively mature *sunnhemp* residues. The prolonged coexistence of rice and *sunnhemp* before desiccation likely intensified competition for light, moisture, and nutrients, while the slower decomposition of older residues delayed nutrient mineralization and reduced nutrient availability during the period of maximum crop demand. Similar observations were reported by Sarangi *et al*. (2016), who emphasized that inefficient nitrogen management limits the productivity of direct-seeded rice, and Das and Rao (2023), who concluded that delayed nutrient release from brown manuring reduces its effectiveness in enhancing crop productivity when compared with timely termination.

Straw yield

The effect of brown manuring and nitrogen levels on straw yield (Table 2) followed a trend similar to that observed for grain yield during both the years of experimentation as well as in the pooled analysis. Among the different treatments, 125% RDN + brown manuring of *sunnhemp* at 30 DAS (M_4) produced the highest straw yield(6580, 7480 and 7030 kg ha^{-1} during 2024, 2025 and in pooled data respectively) and were significantly superior to all the other treatments. The treatments 100% RDN + brown manuring of *sunnhemp* at 30 DAS (M_3) and 125% RDN + brown manuring of *sunnhemp* at 45 DAS (M_7) recorded the next highest straw yields and were statistically at par with each other, but significantly inferior to M_4. The remaining treatments registered comparatively lower straw yields, with 100% RDN (M_1), 100% RDN + brown manuring of *sunnhemp* at 45 DAS (M_6) and 75% RDN + brown manuring of *sunnhemp* at 30 DAS (M_2) exhibiting intermediate performance. Significantly the lowest straw yield was obtained with 75% RDN + brown manuring of *sunnhemp* at 45 DAS (M_5) during 2024, 2025 and in the pooled analysis, indicating the least productive treatment with respect to biomass accumulation.

The significantly higher straw yield recorded with 125% RDN + brown manuring of *sunnhemp* at 30 DAS (M_4) could be attributed to the synergistic effect of adequate nitrogen availability and timely brown manuring, which enhanced vegetative growth, leaf area development, and dry matter production throughout the crop growth period. Early desiccation of *sunnhemp* facilitated rapid decomposition of succulent residues, resulting in synchronized nutrient release, improved nutrient uptake, and greater biomass accumulation, thereby increasing straw yield. Similar findings were reported by Sarangi *et al*. (2016), who observed enhanced biomass and straw yield in direct-seeded rice

through brown manuring integrated with nitrogen fertilization. Singh *et al.* (2023) also reported that integrated nitrogen management coupled with brown manuring significantly improved vegetative growth and straw yield. Comparable results were documented by Chaudhary *et al*. (2022), who attributed increased straw production to the combined effect of brown manuring and optimum nitrogen nutrition.

Table 2 : Straw yield (kg ha^{-1}) and harvest index of direct seeded rice as influenced by time of brown manuring and varied nitrogen levels during *kharif* 2024, 2025 and pooled data

Treatments	Straw yield			Harvest index		
	2024	2025	Pooled data	2024	2025	Pooled data
M_1 - 100% RDN	4267	4584	4426	0.44	0.44	0.44
M_2 - 75% RDN + Brown manuring with *sunnhemp* at 30 DAS	4105	4305	4205	0.44	0.45	0.44
M_3 - 100% RDN + Brown manuring with *sunnhemp* at 30 DAS	5805	6535	6170	0.45	0.44	0.45
M_4 - 125% RDN + Brown manuring with *sunnhemp* at 30 DAS	6580	7480	7030	0.45	0.44	0.44
M_5 - 75% RDN + Brown manuring with *sunnhemp* at 45 DAS	4088	4154	4121	0.42	0.44	0.43
M_6 - 100% RDN + Brown manuring with *sunnhemp* at 45 DAS	5026	5526	5435	0.44	0.44	0.42
M_7 - 125% RDN + Brown manuring with *sunnhemp* at 45 DAS	5802	6479	6140	0.44	0.44	0.44
S.Em±	243.2	298	208.3	0.02	0.02	0.02
CD (p=0.05)	749	918	642	NS	NS	NS
CV (%)	8.3	9.2	6.7	8.4	9.1	7.9

The significantly lower straw yield recorded under 75% RDN + brown manuring of *sunnhemp* at 45 DAS (M_5) might be due to inadequate nitrogen supply during the active vegetative stage and delayed nutrient release from relatively mature sunnhemp residues. The prolonged coexistence of rice and *sunnhemp* before desiccation could have intensified competition for light, moisture, and nutrients, while the slower decomposition of older residues delayed nutrient mineralization, thereby restricting vegetative growth and biomass accumulation. Similar observations were reported by Sarangi *et al.* (2016) and Das and Rao (2023), who emphasized that delayed brown manuring and inadequate nitrogen availability reduced biomass production and straw yield in direct-seeded rice.

Harvest Index

Harvest index, expressed as the ratio of grain yield to total biological yield, was not significantly influenced by different brown manuring timings in combination with graded nitrogen levels during 2024, 2025, or in the pooled analysis. The absence of significant variation in harvest index indicates that the treatments brought about a proportionate increase or decrease in both grain and straw yields, thereby maintaining a relatively stable partitioning of assimilates between the economic and vegetative components of the crop. This suggests that while variations in nitrogen levels and brown manuring timings considerably influenced overall crop growth, biomass accumulation, and yield, they did not affect the intrinsic efficiency of the crop in allocating the accumulated dry matter towards grain production. Consequently, the improvements in grain yield observed under certain treatments were primarily associated with enhanced biological yield rather than any marked alteration in assimilate partitioning. The corresponding data on harvest index are presented in Table 2.

Conclusion

The study revealed that integrating 125% RDN with brown manuring of sunnhemp at 30 DAS significantly enhanced grain and straw yields of direct-seeded rice, while 75% RDN with brown manuring at 45 DAS recorded the lowest yields. However, harvest index remained unaffected, indicating that the treatments proportionately influenced both grain and straw production without altering assimilate partitioning. Therefore, early brown manuring integrated with an adequate nitrogen supply can be considered a promising strategy for improving the productivity of direct-seeded rice under the Krishna Delta conditions.

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