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Effect of Rice Cultivation Practices and Nitrogen Management strategies on Growth and Yield Attributes in Rice under Rice-cowpea Cropping System

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

A field experiment was conducted during *kharif* 2022-23 and 2023-24 at College of Agriculture V.C, Farm, Mandya, India. The experiment consisted of three rice cultivation practices as vertical factors and five nitrogen management strategies as horizontal factors were laid out in strip plot design with three replications. Results revealed that among rice cultivation practices transplanted rice led to higher number of green leaves hill^{-1}(76.05), leaf area index (4.25), SPAD (Soil Plant Analysis Development) value (40.68), panicle length (19.96 cm), lower number of chaffy grains panicle^{-1} (19.29) and test weight (23.78g). However, among nitrogen management strategies, application of 100% RDN + foliar spray of 0.4% nano urea at tillering and PI stage were found significantly higher number of green leaves hill^{-1} (87.34), leaf area index (4.80), SPAD value (44.70), panicle length (20.73 cm), lower number of chaffy grains panicle^{-1}(15.28) and test weight (24.35 g). Among interactions, transplanted rice with application of 100% RDN + foliar spray of 0.4% nano urea at tillering and PI stage were found significantly superior for number of green leaves hill^{-1} (91.56), leaf area index (5.04), SPAD value (47.61), panicle length (21.82 cm) and lower number of chaffy grains panicle^{-1} (15.06). Transplanted rice combined with 100% RDN and foliar application of 0.4% nano urea at tillering and PI stages demonstrated superior growth and yield attributes, indicating its effectiveness in enhancing productivity.

Keywords: Direct seeded rice (DSR); Wet-DSR; nitrogen management; transplanted rice; nano urea: growth and yield attributes.

1. INTRODUCTION

The world's population is predicted to surpass 9.7 billion by 2050, necessitating a60 per cent increase in food production (Anon., 2013). The analysis revealed that billions of people rely on a small number of crops for the majority of their food and non-food needs, despite an increase in diversity of crops over the past 60 years. The most contributing food crops are maize, rice, and wheat, which together account for 19.5%, 16.5% and 15.0%, respectively of the world's total caloric consumption (Pariona, 2019). With 197 g per day and 71.9 kg per year, rice has the highest net availability per person of all the cereals in2020-21. (Anon., 2021). Rice is the most essential crop for millions of farmers who grow it on 164.19 million hectares worldwide, as well as for the countless landless people who work on these fields for a living. India is not just the world's second-biggest producer of rice, accounting for over 20% of global production; it is also one of the major users, with over half of the people relying on rice for survival. The United Nations General Assembly proclaimed 2004 as the International Year of Rice during its 57th session, highlighting the significance of raising awareness of role of rice in decreasing poverty and undernourishment and noting that one in three people on the earth are fed by this grain. Rice provides about 700 calories/day/person for about 3.0 billion people living mostly in developing countries (Sangeetha and Baskar, 2015).

The success of rice production in Asia will determine the future stability of the world's food supply. In addition to using between 24 and 30% of the world's freshwater, rice consumes between 34 and 43% of the world's irrigation water (Surendran et al., 2021). Puddling alone uses 30% of the crop's water requirement for wetland rice production (Chauhan and Opena, 2012). According to predictions, Asia's 17 to 22 million hectares of irrigated rice land would experience water scarcity by 2025 (Tuong and Bouman, 2002), prompting widespread use of water-saving techniques. While the total employment in agriculture dropped in India from 63.32% in 1991 to 42.6% in 2019 as a result of rapid economic growth in non-agricultural sectors and rising labour wages, manual rice transplanting requires 25 to 50 man-days ha^{-1} (Singh and Sharma, 2012; Zhang et al., 2011). Nearly 12% of anthropogenic methane and 55% of agriculturally produced greenhouse gas (GHG) emissions worldwide are caused by wetland rice farming (Anon., 2013). Transplanting machines and its maintenance are expensive, so poor farmers cannot afford them. Non-availability of herbicides, requirement of compulsory land leveling and more quantity of seeds (8 to 10 kg acre^{-1}) makes direct seeded rice disadvantageous over other methods. While, aerobic rice is not appropriate for higher rainfall areas where water can't be controlled and also requires relatively extra weed management.

Crop establishment procedures can be changed to provide solutions to all of the aforementioned issues (Alam et al., 2016; Chakraborty et al., 2017; Biradar et al., 2020). Sustainable technologies are highly essential to enhance rice yield, which may include cost minimization by saving resources and adoption of low cost or non-monetary inputs. Hence, crop husbandry practices such as establishment methods and judicious application of fertilizer are of prime importance in rice production (Haque et al., 2016; Bell et al., 2017; Patidar et al., 2023). Usually, rice is cultivated as a traditional transplanting, wet and dry-direct seeded crop all over the world. Dry direct-seeded rice is a crop establishment method wherein seeds are sown directly into the soil aside from supporting farmers to address the higher cost of rice production and reduced water requirement for no rice seedling is being transplanted into standing water. It is usually followed in rain fed uplands. In wet-seeding, the pre-germinated seeds are broadcasting into recently water removed, well-puddled seedbed or into pre-stagnation of water in the fields. It is very commonly followed in irrigated areas (Kumar and Ladha, 2011; Rao et al*.,* 2007; Sannagoudar et al., 2023).

Among the advancement in science, nanotechnology is emerging out as the greatest imperative tools in recent agriculture and predictable to become a driving economic force in the near future (Lal, 2008; Roco, 2011; Sannagoudar et al., 2020). Nanotechnology is the art and science of operating matter at nano scale (1×10^{-9} m) to create new and exclusive materials and products. Nanotechnology has the ability to release nutrients according to crop demand, the ability to manage the release of chemical fertilizers and the ability to govern plant growth and increase yield targets that promotes productivity of the crop while ensuring environmental safety. Nano fertilizers are appropriate alternatives to conventional fertilizers for gradual and controlled supply of nutrients in the soil (Kottegoda et al., 2011; Shang et al., 2019; Rajanna et al., 2024). Nano particles possess special properties like smaller size, higher specific surface area, surface energy and solubility. Owing to the unique properties, nano particles have capability to enhance the uptake of water and nutrients. These unique properties can be exploited beneficially for improving nutrient use efficiency (Naderi and Danesh-Sharaki, 2013; Rajanna et al., 2023).

Nano urea fertilizers are alternative to conventional fertilizers and can be used as a foliar spray to supplement soil nitrogen. This nano urea usage can reduce the requirement of nitrogen and thereby conventional urea in rice production. Industries are claiming efficacy of 500ml of nano urea is equivalent to one bag of urea (45kg). This is an ecofriendly, can minimize soil & water quality deterioration also helps in addressing the concerns of global warming and may be in future it is cheaper than conventional urea, So use of nano urea can reduce input cost to farmers, leads to increase income. Further it improves crop productivity, soil health and nutritional quality of produce as due to direct beneficial effect. This investigation aims to assess the effects of various rice cultivation practices and nitrogen management strategies on growth and yield attributes of rice. The study seeks to contribute valuable insights into improving rice productivity and ensuring food security in India for sustainable rice ecosystem.

2. MATERIALS AND METHODS

The experiment was conducted at college of Agriculture V.C, Farm, Madya, India, during the *kharif* season of 2022-23 and 2023-24 to assess "Effect of rice cultivation practices and nitrogen management strategies on growth and yield attributes in rice under rice-cowpea cropping system". The soil of the experimental plot was sandy clay loam in texture, medium in fertility status of organic carbon (0.51%) and nitrogen (308.41 kg available N ha^{-1}), phosphorous (33.54 kg available P_2O_5 ha^{-1}) and potassium (204.95 kg available K_2O ha^{-1}) and neutral to slightly alkaline condition in nature (pH = 7.89).The experiment consisted of three rice cultivation practices in vertical factors i.e., M_1 (Transplanted rice) ,M_2 (Wet-Direct seeded rice (Drum seeding)) and M_3 (Dry-Direct seeded rice (Seed drill)) and five nitrogen management strategies in horizontal factors i.e., N_1: Control (Without nitrogen),N_2: 75% RDN, N_3: 100% RDN, N_4:75% RDN + foliar spray of 0.4% nano urea at tillering and PI stage , N_5: 100% RDN + foliar spray of 0.4% nano urea at tillering and PI stage, laid out in strip plot design with three replications with plot size was 4.8 m × 4.8 m (23.04 m^2).The rice variety 'MTU 1001' was taken in the present experiment. A uniform recommended dose of50 kg P_2O_5 and 50 kg K_2O ha^{-1} was applied for rice crop through single super phosphate (SSP) and murate of potash (MOP), respectively. The nitrogen applied as per the treatments mentioned in the study through urea and nano urea. Half dose of nitrogen along with the full dose of phosphorus and potash was applied as basal at the time of sowing, rest half dose of N was top dressed in two equal splits, with one part added at the tillering stage and the other at the panicle initiation stage of rice. After harvesting of rice, cowpea was sown with recommended dose of fertilizers (NPK) as residual crop. The experimental data were analysed using analysis of variance (ANOVA) to evaluate various parameters. Treatment effects were assessed with the 'F' test (variance ratio), and critical differences (C.D.) at the 5% significance level were calculated to compare treatment means.

3. RESULTS AND DISCUSSION

3.1 Effect on Growth Parameters of Rice

Growth attributes *viz.*, number of green leaves hill^{-1}, leaf area index and SPAD value of rice recorded at 90 days after sowing (DAS) differed significantly due to rice cultivation practices and nitrogen management strategies (Table 1).

Among the rice cultivation practices, transplanted rice (M_1) recorded significantly higher number of green leaves hill^{-1}, leaf area index and SPAD values at 90 DAS (76.05, 4.25 and 40.68, respectively) was compared to wet-DSR (M_2) (73.22, 4.04 and 38.65, respectively) and dry-DSR (M_3) of rice cultivation (69.47, 3.87 and 37.28, respectively). It is due to the reason that plant to plant and row distance were maintained leading to less competition. Among the plants, deep penetration of roots causing higher nutrient uptake and plant growth resulted in higher plant height, photosynthetic active leaves, with pronounced effect on leaf area index and SPAD values (Sannagoudar and Kalyana Murthy, 2018). Similar results were also reported by Mahajan et al. (2004), Stoop and Kassam (2005), Hardev et al. (2014) and Kumhar et al*.* (2016).

Among nitrogen management strategies, application of 100% RDN + foliar spray of 0.4% nano urea at tillering and PI stage (N_5) resulted significantly higher number of green leaves hill^{-1}, leaf area index and SPAD values of rice was recorded at 90 DAS (87.34, 4.80 and 44.70, respectively) over other treatments. Lower number of green leaves hill^{-1}, leaf area index and SPAD values was recorded in control (without-N) (N_1) (53.07, 3.01 and 30.09, respectively). This might be due to increased seedling vigor by application of nano urea with conventional nitrogen fertilizers accelerated the activity of many enzymes and chlorophyll content there by increased auxin metabolism in the plant system leads to greater cell division and cell elongation, which resulted in production of active green leaves for effective photosynthesis (Kumar et al., 2015 and Nithya et al., 2018). Higher LAI to minimizing particle size increased fertilizer's specific surface area and particle count per unit area, which led to significant increase in leaf area index Benzon et al. (2015).

Among the interactions, transplanted rice with application of 100% RDN + foliar spray of 0.4% nano urea at tillering and PI stage (M_1N_5) recorded significantly superior umber of green leaves hill^{-1}, leaf area index and SPAD values of rice was recorded90 DAS (91.56, 5.04 and 47.61, respectively) on par with wet-DSR with application of 100% RDN + foliar spray of 0.4% nano urea at tillering and PI stage (M_2N_5) for number of green leaves hill^{-1}(87.73) and found superior over other treatments. This might have happened due to fact that foliar application of nano urea enhanced absorption and transport of nitrogen which led to significant improvement in number of leaves hill^{-1} in transplanted rice. Algym et al*.* (2020) reported adequate supply of nitrogen through nano urea boosted the production of chlorophyll, which augment the rate of photosynthesis and caused the plant to expand which, resulted in greater production of leaves. The development of leaves along with functional roots is a prerequisite for rice seeds to shift from heterotrophic to autotrophic status. The establishment of rice seedlings and their subsequent growth depends on above-ground morphological characteristics that define seedling vigour along with growth of new roots (Hoshikawa and Ishi, 1974; Biradar et al., 2023; Halli et al., 2021) and the amount of irreparable damage incurred by the roots during transplanting (Ros et al*.,* 2003; Sachin et al., 2023). These above and below-ground characteristics of rice plants, before and after transplanting, vary with seedling age (Himeda, 1994; Sannagoudar et al., 2021a), growing environment (Kordon, 1974) and seeding rate (Sasaki, 2004). Seedling vigour is an important contributor to be associated with plant viability, height, thickness of stems and uniformity (Matsuo and Hoshikawa, 1993).

3.2 Effect on Yield Attributes of Rice

The data pertaining to yield attributes *viz*., panicle length, number of chaffy grains panicl^{-}

[1]and test weight as influenced by rice cultivation practices and nitrogen management strategies is depicted in Table 2. Transplanted rice resulted in significantly superior panicle length (19.96 cm), test weight (23.78g) and lower number of chaffy grains panicle^{-1} (19.29) compared to wet-DSR and dry-DSR. The results are in line with Kumhar et al. (2016). Among the different nitrogen management strategies, application of 100% RDN + foliar spray of 0.4% nano urea at tillering and PI stage (N_5) resulted in significantly higher panicle length (20.73 cm), test weight (24.35g) and lower number of chaffy seeds panicl^{-1}(15.28) compared to other treatments. While, lower panicle length (17.17 cm), test weight (21.69g) and higher number of chaffy grains panicl^{-1} (31.64) was observed in control (without-N) (N_1). The availability of nitrogen in transplanted rice by synthesis of amino acid and chlorophyll and better carbohydrates transformation resulted in increased panicle length (Sannagoudar et al., 2021b). Similar results were reported by Eleyan et al. (2018).

Table 1. Effect of rice cultivation practices and nitrogen management strategies on growth attributes at 90 DAS in rice under rice-cowpea cropping system

Treatment	Number of green leaves hill^{-1}			LAI			SPAD value		
Rice cultivation practices (M)									
	2022	**2023**	**Pooled**	**2022**	**2023**	**Pooled**	**2022**	**2023**	**Pooled**
M_1	73.85	78.25	76.05	4.09	4.41	4.25	37.08	44.28	40.68
M_2	70.92	75.52	73.22	3.86	4.22	4.04	35.45	41.85	38.65
M_3	67.17	71.77	69.47	3.69	4.05	3.87	34.58	39.98	37.28
S.Em.±	0.58	0.61	0.60	0.03	0.03	0.03	0.28	0.33	0.31
CD(p=0.05)	2.26	2.40	2.33	0.12	0.13	0.13	1.09	1.30	1.20
Nitrogen management strategies (N)									
N_1	50.57	55.57	53.07	2.88	3.14	3.01	27.75	32.42	30.09
N_2	66.02	69.68	67.85	3.42	3.72	3.57	35.39	40.06	37.73
N_3	72.03	77.03	74.53	4.12	4.52	4.32	36.98	42.98	39.98
N_4	79.28	84.28	81.78	4.39	4.76	4.58	38.34	45.34	41.84
N_5	85.34	89.34	87.34	4.60	5.00	4.80	40.03	49.37	44.70
S.Em.±	0.50	0.55	0.53	0.03	0.03	0.03	0.26	0.30	0.28
CD(p=0.05)	1.64	1.78	1.71	0.10	0.11	0.11	0.84	0.97	0.91
Interactions (MXN)									
M_1N_1	52.25	58.25	55.25	2.97	3.27	3.12	27.25	33.25	30.25
M_1N_2	67.33	71.33	69.33	3.68	3.98	3.83	37.33	42.33	39.83
M_1N_3	75.88	79.88	77.88	4.28	4.68	4.48	38.49	45.49	41.99
M_1N_4	84.21	88.21	86.21	4.65	4.95	4.80	40.21	47.21	43.71
M_1N_5	89.56	93.56	91.56	4.89	5.19	5.04	42.11	53.11	47.61
M_2N_1	51.12	56.12	53.62	2.83	3.13	2.98	27.89	32.89	30.39
M_2N_2	65.38	68.38	66.88	3.44	3.74	3.59	34.89	39.89	37.39
M_2N_3	71.49	77.49	74.49	4.15	4.55	4.35	37.10	42.10	39.60
M_2N_4	80.39	86.39	83.39	4.35	4.75	4.55	37.95	44.95	41.45
M_2N_5	86.23	89.23	87.73	4.52	4.92	4.72	39.40	49.40	44.40
M_3N_1	48.34	52.34	50.34	2.83	3.03	2.93	28.12	31.12	29.62
M_3N_2	65.34	69.34	67.34	3.14	3.44	3.29	33.96	37.96	35.96
M_3N_3	68.73	73.73	71.23	3.92	4.32	4.12	35.35	41.35	38.35
M_3N_4	73.23	78.23	75.73	4.17	4.57	4.37	36.87	43.87	40.37
M_3N_5	80.23	85.23	82.73	4.38	4.88	4.63	38.59	45.59	42.09
S.Em.±	1.38	1.46	1.42	0.07	0.08	0.08	0.70	0.82	0.76
CD(p=0.05)	4.15	4.38	4.27	0.22	0.24	0.23	2.09	2.46	2.28

***Vertical factors:** Rice cultivation practices (M)*
***M_1:** Transplanted rice*
***M_2:** Wet-Direct seeded rice (Drum seeding)*
***M_3:** Dry-Direct seeded rice (Seed drill)*

***Horizontal factors:** Nitrogen management strategies (N)*
***N_1:** Control (Without nitrogen)*
***N_2:** 75% RDN*
***N_3:** 100% RDN*
***N_4:** 75% RDN + foliar spray of 0.4% nano urea at tillering and PI stage*
***N_5:** 100% RDN+ foliar spray of 0.4% nano urea at tillering and PI stage*

Table 2. Effect of rice cultivation practices and nitrogen management strategies on yield attributes at harvest in rice under rice-cowpea cropping system

Treatment	Panicle length (cm)			Total number of chaffy grains panicle^{-1}			Test weight (g)		
Rice cultivation practices (M)									
	2022	**2023**	**Pooled**	**2022**	**2023**	**Pooled**	**2022**	**2023**	**Pooled**
M_1	19.33	20.58	19.96	21.19	17.39	19.29	23.57	23.98	23.78
M_2	18.32	19.49	18.91	25.21	20.81	23.01	23.36	23.66	23.51
M_3	17.90	19.23	18.57	27.91	20.46	24.19	23.04	23.40	23.22
S.Em.±	0.14	0.14	0.14	0.21	0.18	0.20	0.18	0.18	0.18
CD(p=0.05)	0.54	0.57	0.56	0.82	0.72	0.77	NS	NS	NS
Nitrogen management strategies (N)									
N_1	16.52	17.81	17.17	35.01	28.26	31.64	21.52	21.86	21.69
N_2	17.72	18.45	18.09	27.12	23.03	25.08	23.15	23.39	23.27
N_3	19.26	19.95	19.61	23.81	18.73	21.27	23.83	24.15	23.99
N_4	19.29	20.95	20.12	20.08	15.00	17.54	24.00	24.43	24.22
N_5	19.79	21.67	20.73	17.82	12.74	15.28	24.12	24.57	24.35
S.Em.±	0.13	0.15	0.14	0.22	0.19	0.21	0.17	0.17	0.17
CD(p=0.05)	0.43	0.47	0.45	0.72	0.61	0.67	0.56	0.56	0.56
Interactions (MXN)									
M_1N_1	16.44	17.75	17.095	31.92	26.92	29.42	21.89	22.29	22.09
M_1N_2	18.26	19.00	18.63	22.93	20.93	21.93	23.26	23.38	23.32
M_1N_3	20.68	21.25	20.97	18.29	16.29	17.29	24.10	24.39	24.25
M_1N_4	20.39	22.15	21.27	17.56	12.56	15.06	24.28	24.88	24.58
M_1N_5	20.89	22.75	21.82	15.23	10.23	12.73	24.34	24.94	24.64
M_2N_1	16.48	18.00	17.24	34.27	28.27	31.27	21.48	21.68	21.58
M_2N_2	17.62	18.00	17.81	29.23	25.23	27.23	23.17	23.47	23.32
M_2N_3	18.97	19.70	19.34	26.23	21.23	23.73	23.91	24.19	24.05
M_2N_4	19.00	20.23	19.62	19.10	16.10	17.60	24.08	24.38	24.23
M_2N_5	19.51	21.51	20.51	17.23	13.23	15.23	24.16	24.59	24.38
M_3N_1	16.63	17.69	17.16	38.84	29.59	34.22	21.18	21.60	21.39
M_3N_2	17.28	18.36	17.82	29.19	22.94	26.07	23.01	23.31	23.16
M_3N_3	18.14	18.89	18.52	26.92	18.67	22.80	23.48	23.88	23.68
M_3N_4	18.48	20.46	19.47	23.59	16.34	19.97	23.65	24.04	23.85
M_3N_5	18.96	20.74	19.85	21.01	14.76	17.89	23.86	24.19	24.03
S.Em.±	0.35	0.38	0.37	0.41	0.34	0.38	0.44	0.44	0.44
CD(p=0.05)	1.04	1.13	1.09	1.22	1.01	1.12	NS	NS	NS

Vertical factors: *Rice cultivation practices (M)*
M_1: *Transplanted rice*
M_2: *Wet-Direct seeded rice (Drum seeding)*
M_3: *Dry-Direct seeded rice (Seed drill)*

Horizontal factors: *Nitrogen management strategies (N)*
N_1: *Control (Without nitrogen)*
N_2: *75% RDN*
N_3: *100% RDN*
N_4: *75% RDN + foliar spray of 0.4% nano urea at tillering and PI stage*
N_5: *100% RDN+ foliar spray of 0.4% nano urea at tillering and PI stage*

Among interactions effect, transplanted rice with application of 100% RDN + foliar spray of 0.4% nano urea at tillering and PI stage (M_1N_5) found significantly panicle length (19.96 cm) and lower number of chaffy grains panicl^{-1}(12.73) compared to other treatments. However, it was on par with wet-DSR with application of 100% RDN + foliar spray of 0.4% nano urea at tillering and PI stage (M_2N_5) and transplanted rice with application of 75% RDN + foliar spray of 0.4% nano urea at tillering and PI stage (M_1N_4). Significantly lower per cent chaffyness was found in conventional fertilizers with foliar application of nano urea in transplanted rice. This is mainly due to the better development of source in form of dry matter accumulation and enhanced uptake, translocation of sugars and higher carbohydrate accumulation in sink (grain), which might have contributed to less chaffy grains, higher panicle length and test weight (Abdoli et al., 2014 and Kumar et al., 2015).

4. CONCLUSION

The study demonstrated that the transplanted rice with application of 100% recommended dose of nitrogen + 2 foliar spray of 0.4% nano urea at tillering and panicle initiation stage is recommended for maximizing the growth attributes *viz.*, number of green leaves hill^{-1}, leaf area index, SPAD values and yield attributes *viz.,*panicle length, test weight and lower no. of chaffy grains panicle^{-1}. Therefore, 100%

recommended dose of nitrogen + 2 foliar spray of 0.4% nano urea at tillering and panicle initiation stage in transplanted rice presents a viable option for enhancing rice growth and yield contributing to more efficient and sustainable agricultural practices in present changing climate.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declares that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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