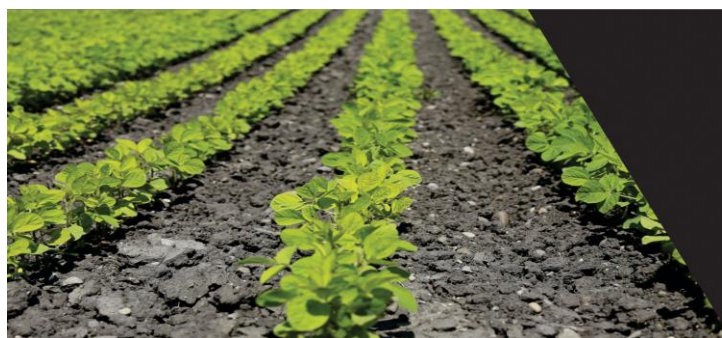




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Effect of different level Nano Zinc, organic manure and different level of fertilizers on growth and yield of rice (*Oryza sativa* L.)

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Abstract

A field experiment was conducted on Effect of different level Nano Zinc, Organic Manure and different level of Fertilizers on growth and yield of Rice (*Oryza sativa* L.) during *Kharif* season, 2023 and 2024 at the Crop Research Farm, Department of Agronomy with 25.40° N latitude, 81.85° E longitude, and 112.05 m above mean sea level at SHUATS, Prayagraj, U.P. The soil of the experimental plot was sandy loam soil having neutral pH (7.7), medium organic carbon (0.56%), available nitrogen (250 kg/ha), potassium (202 kg/ha), and low available phosphorus (21 kg/ha). The experiment was laid out in a split-plot design with 2 factors, each with 4 levels, viz., solid organic manures and Nano Zinc along with fertilizer levels which are replicated thrice. The results revealed that significantly higher growth attributes of Rice at 80 DAS based on the two years experimentations viz., Effect of organic manure and fertilizer levels was recorded significantly highest plant height (83.38 and 84.87 cm), number of tillers count (220.15 225.33 /m²), dry matter accumulation (937.20 and 9454.21gm/ m²), crop growth rate (7.83 and 7.90 g/m²/day) and relative growth rate (0.001 and 0.001(g/g/day) was recorded with application of 50% RDF + Poultry manure. Whereas, Effect of Nano-zinc foliar application was recorded significantly highest plant height (83.96 and 85.44 cm), number of tillers count (215.48 and 220.66/m²), dry matter accumulation (920.01 and 927.83 gm/ m²), crop growth rate (7.69 and 7.76 g/m²/day) and relative growth rate (0.002 and 0.002(g/g/day) was recorded with application of Nano zinc at 700 ppm.

Keywords: Growth, goat manure, FYM, poultry manure, vermicompost and nano zinc

Introduction

Rice (*Oryza sativa* L.) belongs to *Poaceae* family with chromosome number 2n = 24. With 75% starch, 6-7% protein in white rice, 7-9% protein in brown rice, and 2-2.5% fat, it is a high-calorie, C3 self-pollinated crop. It accounts for 15% of the world's population's protein needs and 21% of their calorie needs. Rice is grown in humid subtropical regions as well as rainy tropical climates. About 24% of India's gross cultivated land is made up of rice, the most important cereal food crop. It contributes 42% of total food grain production and 45% of overall cereal production in the country. With a long history of rice farming, India leads the world in both rice area and output, second only to China (Yadav *et al.* 2010). Although rice plants date back to 5000 BC, the cultivation of rice is thought to have started around 2000 BC in parts of southern and eastern Asia and China. Rice farming is estimated to have begun simultaneously in numerous countries about 6500 years ago. The majority of people think that rice originated in India around 3000 BC, when locals found the plant growing in the wild and started experimenting with it. Global food production will need to rise by more than 40% by 2030 and 70% by 2050, according to UN/FAO projections (FAO, 2009). To fulfil the demands of the growing population, rice output in India and a number of other Asian nations must double by 2025. For more than half of the world's population, it is one of the main basic foods [15, 18].

The Asia-Pacific region produces and consumes more than 90% of the world's rice. In 2022-2023, there were 165.70 million hectares (m/ha), 512.98 million metric tonnes (mmt), and 46.20 q/ha of rice produced worldwide. With 47.83 mha of land and 135.76 mmt of rice produced, India was rated first in terms of area and second in terms of production. However, compared to the global

average of 46.20 q/ha, 82.80 q/ha in the US, and 70.8 q/ha in China, this indicates low agricultural production of 42.60 q/ha (United States Department of Agriculture report, 2022-23). With an area of 407.34 lakh hectares, production of 1132.59.79 lakh tonnes, and productivity of 2780 kg/ha, India is a significant rice-growing nation in the globe (DES 2023-24). With an average productivity of 2768 kg/ha, Uttar Pradesh produces 158.65 lakh tonnes on 57.32 lakh hectares (DES 2023-24). The most important cereal food crop in India is rice, which makes up around 24% of the nation's gross cultivated area. It contributes 42% of total food grain production and 45% of overall cereal production in the country. In 2010, India produced 120.62 MT of rice on 44 M ha, while China produced 197.21 MT. In 2025-2026, Uttar Pradesh and India produced 5.73 million ha, 15.86 million tonnes, 2768 kg/ha, and 40.73 million 11.32 million tonnes, 2780 kg/ha, and hectares, respectively (DES 2023-24)^[2].

Applying organic manures to the soil greatly improves rice crop growth and development. Improved soil physico-chemical characteristics and efficient use of applied organic manures for increased seed yield and seed quality can be achieved by using organic manures either by itself or in conjunction with chemical fertilisers. In damp soil, FYM will break down to enhance soil structure and release its nutrients in a soluble form for crop growth. It contains 0.50% N, 0.25% P2O5, and 0.50% K2O. It enhances the soil's physical, chemical, and biological characteristics, increasing the number of tillers in rice. Vermicompost is a mixture of decomposing vegetable or food waste and bedding materials produced by the decomposition process using a variety of worm species, most often red wigglers, white worms, and earthworms. Macronutrients include N, P2O5, and K2O are abundant in vermicompost. Macronutrients such as N (0.5-1.5%), P2O5 (0.1-0.3%), and K2O (0.15-0.56%) are abundant in vermicompost. It improves a number of rice vegetative and reproductive growth characteristics by increasing the amount of phosphorus available in the soil. Goat dung is a great soil conditioner because of its high nitrogen content. Goat manure contains 3% N, 1% P2O5, and 2% K2O, which are the main nutrients present along with Ca, B, and Mg. It enhances the texture of the soil, makes effective use of water, and increases the amount of oxygen that reaches the roots, nodules, and plant growth inoculation. It revealed that there was more accessible phosphorus in the soil, which promoted improved root development and produced the advantageous effect of tillers, which is enhanced by PSB bacterial activity. An excellent source of nutrients for crops is poultry manure. Also known as chicken manure, it is a great soil supplement that, when applied carefully, enhances soil quality and supplies nutrients for growing crops due to its high organic matter content and accessible nutrients for plant growth. Which, in comparison to other large organic manures, have higher levels of phosphorus and nitrogen. The average nutritional content is 1.4% K2O, 2.63% P2O5, and 3.03% N. Zinc (Zn) is another critical micronutrient element that is crucial for the synthesis of auxin, the preferential accumulation of chlorophyll proteins, and the metabolism of starch. Zn deficiency in rice is known as Khaira disease, which manifests as dusty brown spots on upper leaves, limited growth, reduced tillering capacity, and sterility of spikelets. Applying zinc to rice improves its nutritional value and agricultural yield. Grain yield is increased by 20-50% when zinc is present. Zinc is necessary in trace amounts for the production of RNA, the utilisation of carbohydrates, the metabolism of phosphorus, and the evolution of carbon dioxide (Jyoti *et al.* 2013). According to DeRosa *et al.* (2010)^[16, 17], the properties of nano fertilisers or nanoencapsulated nutrients may include improved target action,

regulated release of chemical fertilisers that influence plant growth, and the ability to release nutrients on demand.

Material and methods

An experiment was conducted during the Kharif season of 2023 and 2024. It was conducted in alluvial soil at the Department of Agronomy. The experiments were carried out at Crop Research Farm, Department of Agronomy, NAI, SHUATS, Prayagraj, U.P. At a depth of 0-30 cm, a composite soil sample was taken. It underwent crushing, air drying, and physical and chemical testing. The soil of the experimental plot was sandy loam soil having neutral pH (7.7), medium organic carbon (0.56%), available nitrogen (250 kg/ha), potassium (202 kg/ha), and low available phosphorus (21 kg/ha. The experiment was laid out in a split-plot design with 2 factors, each with 4 levels, viz., solid organic manures and Nano Zinc along with fertilizer levels which are replicated thrice. The results revealed that significantly higher growth attributes of Rice at 80 DAS based on the two years experimentations. To apply nutrients as a spreading method, 4-5 cm deep furrows were dug along the seed rows using a hand hoeing. Ten days after sowing, the gaps were filled by transplanting nursery. In order to reduce crop density, weed competition, intercultural operations were carried out between 25- and 45-days intervals. At regular intervals from germination to harvest, plant growth parameters such as plant height (cm), number of tillers/hill, dry weight (g/plant), CGR and RGR were assessed at 80 DAS. Analysis of variance (ANOVA), as it relates to randomized block design, was used to statistically examine the observed data of ten treatments (Gomez and Gomez, 1984 and Mohan *et al.* 2024)^[5].

Table 1: Treatment details

Treatments		Symbols Used
Integrated nutrient management (Main factor):		
T ₁	50% RDF + Poultry manure	N ₁
T ₂	50% RDF + FYM	N ₂
T ₃	50% RDF + Go at manure	N ₃
T ₄	50% RDF + Vermi compost	N ₄
Nano zinc levels (Sub - factor):		
T ₁	Nano Zn at 700 ppm	Z ₁
T ₂	Nano Zn at 800 ppm	Z ₂
T ₃	Nano Zn at 900 ppm	Z ₃
T ₄	Control (120-60-60 kg NPK/ha)	Z ₄

*Nano fertilizers sprayed at tillering stage and zinc sulphate monohydrate applied @ 25 kg/ha as basal in the entire plot except control.

Growth parameter
Plant Height (cm)

The results obtained during both years of experimentation (2023 and 2024) revealed that plant height increased gradually from transplanting up to 80 DAT, indicating continuous vegetative growth throughout the crop growth period. However, the rate of increase in plant height was comparatively slow up to 20 DAT, which may be attributed to the establishment phase of the transplanted seedlings. Thereafter, a rapid increase in plant height was observed due to enhanced vegetative growth supported by better nutrient uptake and favorable growing conditions. Among the different nutrient management treatments, the application of 50% recommended dose of fertilizers (RDF) combined with poultry manure in main plot recorded the maximum plant height (83.38 and 84.47 cm during 2023 and 2024, respectively). This treatment was followed closely by 50% RDF + goat manure, which produced plant heights of 81.02 and

82.55 cm during the respective years and remained statistically at par with the poultry manure treatment. Poultry manure also improves soil physical, chemical, and biological properties, enhances microbial activity, and increases nutrient-use efficiency, ultimately promoting vigorous vegetative growth and cell elongation. Similarly, goat manure, when integrated with inorganic fertilizers, provided a balanced and sustained nutrient supply throughout the crop growth period. The combined application of organic and inorganic nutrient sources ensured synchronized nutrient release, reduced nutrient losses, improved root development, and enhanced photosynthetic activity, which collectively contributed to increased plant height. The present findings are in agreement with those of Sangeetha and Baskar (2015), who reported significantly greater plant height in vegetable crops with integrated application of organic manures and inorganic fertilizers compared with the sole application of chemical fertilizers. Similar results were also reported by Meena *et al.* (2017), who observed enhanced vegetative growth due to the combined use of organic manures and recommended fertilizer doses. Furthermore, Yadav *et al.* (2019) reported that poultry manure significantly improved plant growth owing to its rich nutrient composition and beneficial effects on soil microbial activity. Comparable findings have also been documented by Kumar *et al.* (2021), who concluded that integrated nutrient management promotes better nutrient uptake, improved soil health, and enhanced vegetative growth in vegetable crops [7, 9, 12, 15].

Effect of different zinc levels, foliar application of Nano Zn at 900 ppm recorded the highest plant height (83.96 and 85.44 cm during 2023 and 2024, respectively). However, this treatment remained statistically at par with Nano Zn at 800 ppm, which produced plant heights of 83.01 and 84.48 cm during the respective years. The superior performance of Nano Zn at higher concentrations may be attributed to the enhanced availability and efficient utilization of zinc owing to the nano-sized particles, which possess a larger surface area and greater penetration into plant tissues. Zinc plays a vital role in several physiological and biochemical processes, including chlorophyll synthesis, auxin metabolism, enzyme activation, protein synthesis, carbohydrate metabolism, and photosynthesis. Adequate zinc availability promotes cell division, cell elongation, and internodal growth, resulting in increased plant height. The present findings are in close agreement with those of Raliya *et al.* (2018), who reported that nano-fertilizers significantly enhanced plant growth through improved nutrient absorption and higher nutrient-use efficiency. Similar observations were made by Dimkpa *et al.* (2020), who concluded that nano zinc fertilizers improve vegetative growth by increasing zinc bioavailability and physiological efficiency. Likewise, Subbaiah *et al.* (2021) observed significant improvement in plant height with foliar application of nano zinc owing to enhanced enzyme activity, chlorophyll synthesis, and photosynthetic performance [4, 10, 14].

Number of tillers (m⁻²)

Different amounts of nano zinc and integrated nutrient management had a substantial impact on the number of tillers (m⁻²) during different rice crop growth sub-periods. Among the various integrated nutrient management strategies, 50% RDF + Poultry manure had the highest mean number of tillers (220.15, 225.33, m⁻²), which was comparable to 50% RDF + Goat manure (218.53 and 223.57 m⁻²) at different growth intervals in both 2022-2023 and 2023-2024, respectively. Throughout the two years of the experiment, 50% RDF + FYM produced noticeably less tillers at different stages of rice growth. The number of tillers

varied between 215.48 and 220.66 m⁻² at 80 DAT in both years. Nano Zn at 900 ppm treatment produced more tillers m⁻² at 20, 40, 60, 80, 100 D AT, and harvest stage in both years than the other treatments, with the exception of Nano Zn at 800 ppm and Nano Zn at 700 ppm at 80 D AT, respectively.

Foliar application of nano zinc significantly increased the number of tillers compared with the control treatment. Nano Zn @ 900 ppm produced the maximum number of tillers at all growth stages and remained statistically at par with Nano Zn @ 800 ppm and Nano Zn @ 700 ppm at 80 DAT. The beneficial effect of nano zinc may be attributed to its higher bioavailability, greater absorption efficiency, and improved translocation within plant tissues. Zinc plays a crucial role in chlorophyll synthesis, enzyme activation, auxin metabolism, protein synthesis, and photosynthesis, thereby promoting cell division and tiller formation. Similar findings were reported by Alloway (2008), Fageria *et al.* (2002), and Dimkpa and Bindraban (2018), who concluded that adequate zinc nutrition enhances vegetative growth, tillering, and biomass production through improved physiological and biochemical processes. Recent studies by Kumar *et al.* (2022) and Singh *et al.* (2023) also reported that foliar application of nano zinc significantly improved tiller number and growth attributes of rice owing to enhanced nutrient use efficiency and better zinc availability [1, 3, 8, 13].

Dry Matter Accumulation (g/m²)

Among the different integrated nutrient management (INM) treatments, the application of 50% RDF + poultry manure resulted in significantly greater dry matter accumulation (g m⁻²) than 50% RDF + FYM throughout the study. At 20, 40, 60, 80, and 100 DAT, as well as at harvest, plants receiving 50% RDF + poultry manure consistently recorded higher dry matter accumulation than those treated with 50% RDF + FYM during both years of experimentation. In contrast, the lowest dry matter accumulation at all growth stages was observed under the 50% RDF + FYM treatment.

Among the nano zinc treatments, foliar application of Nano Zn at 900 ppm produced the highest dry matter accumulation, recording 920.01 and 927.83 g m⁻² at 80 DAT during the first and second years, respectively. These values were statistically at par with Nano Zn at 800 ppm, which recorded 914.60 and 922.35 g m⁻² at 80 DAT, respectively. A similar response was observed at subsequent growth stages, where Nano Zn at 800 ppm recorded 984.46 and 992.82 g m⁻² at 100 DAT and 1333.98 and 1343.70 g m⁻² at harvest during the first and second years, respectively. Both Nano Zn at 900 ppm and Nano Zn at 800 ppm consistently produced significantly higher dry matter accumulation than the remaining nano zinc treatments in both years of the experiment, while remaining statistically comparable with each other. The control treatment recorded the lowest dry matter accumulation at 80 DAT, and a similar trend was observed across all other crop growth stages during both years of the study.

The lowest dry matter accumulation was observed in the control treatment at 80 DAT during both years, and a similar trend was evident at all crop growth stages. This reduction may be associated with inadequate zinc availability, leading to impaired metabolic activities, restricted photosynthesis, and reduced plant growth. The consistent superiority of Nano Zn @ 900 ppm and Nano Zn 800 ppm throughout the experimental period suggests that nano zinc application effectively improved nutrient utilization and biomass accumulation in rice. Overall, the findings indicate that the integration of 50% RDF with poultry manure, coupled with foliar application of Nano Zn 900 ppm or 800 ppm, provides a synergistic effect on crop growth by improving

nutrient availability, enhancing physiological activities, and increasing dry matter accumulation. These results demonstrate the potential of integrated nutrient management and nano zinc fertilization as sustainable strategies for improving rice productivity.

Crop Growth Rate (g/m²/day): During both study years, there was no discernible difference in crop growth rate (g/m²/day) between 20-40, 40-60, and 60-80 across various integrated nutrient management. Due to different integrated nutrition management treatments, the crop growth rate (g/m²/day) of rice assessed at 20-day intervals varied considerably. In 2022-2023 and 2023-2024, the rice crop growth rate varied between 7.30 and 7.83, 7.36 and 7.90 g/m²/day at 60-80, depending on the quantity of nano zinc. Nano Zn at 900 ppm was shown to have a greater crop growth rate (g/m²/day) at 60 to 80 D AT in the control treatment and at 100 D AT to harvest in Nano Zn at 900 ppm compared to the other treatments in both study years. The much reduced crop growth rate was noted in control circumstances in both years of experimental study.

The improved crop growth rate under Nano Zn treatment may be attributed to the enhanced availability and uptake of zinc, which plays a vital role in chlorophyll synthesis, enzyme activation, protein synthesis, and auxin production. These physiological functions promote greater photosynthetic efficiency and dry matter accumulation, resulting in a higher crop growth rate. In contrast, the control treatment recorded the lowest crop growth rate in both years, which may be due to inadequate zinc availability, leading to reduced metabolic activity and biomass production. These findings suggest that foliar application of Nano Zn at 900 ppm effectively improves crop growth by enhancing nutrient use efficiency and supporting better physiological performance throughout the crop growth period.

Relative Growth Rate (g/g/day)

During both study years, there was no discernible variation in the relative growth rate of rice under various integrated nutrition management at 60-80. The RGR registered substantial difference at all the phases of crop growth among integrated nutrient management techniques during both the years of research. The relative growth rate of rice showed a zigzag pattern among various nano zinc levels, ranging from 0.001 to 0.002, 0.004 to 0.005, and 0.004 to 0.005 g/g/day at 60-80, 80-100 D AT, and 100 DAT-harvest in 2022-23 and 2023-24, respectively. These findings suggest that foliar application of Nano Zn at 900 ppm effectively improves crop growth by enhancing nutrient use efficiency and supporting better physiological performance throughout the growth period.

Conclusion

The application of 50% RDF along with Poultry manure was found to be highly growth and production. However, in terms of growth parameters application of Nano Zn 900 ppm was found more remunerative for Rice crop cultivation. Therefore, based on the two years experimentation, it is concluded that application of Poultry manure followed by Nano Zn 900 ppm can be profitable for cultivating Rice in the eastern Uttar Pradesh.

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Table 2: Effect of different level of nano zinc and organic manure on growth parameter of Rice.

Treatments	Growth Parameters									
	Plant Height (cm) at 80 DAT		Number of tillers (m ⁻²) 80 DAT		Dry Matter Accumulation (g/m ²)		Crop growth rate (g/g ⁻¹ /day ⁻¹) 60 - 80 DAT		Relative growth rate (g/g ⁻¹ /day ⁻¹) 60 - 80 DAT	
	2022-23	2022-23	2022-23	2023-24	2022-23	2023-24	2022-23	2023-24	2022-23	2023-24
(A) Integrated Nutrient Management										
50% RDF + Poultry manure	83.38	84.47	220.15	225.33	937.20	945.21	5.93	5.83	0.001	0.001
50% RDF + FYM	78.22	80.26	187.20	191.50	873.31	880.64	4.53	4.43	0.002	0.002
50% RDF + Go at manure	81.02	82.55	218.53	223.57	913.09	919.84	5.97	5.88	0.001	0.001
50% RDF + Vermi compost	74.87	82.40	197.93	202.66	906.67	914.36	5.01	4.90	0.001	0.001
SE(m)±	1.36	1.70	1.03	1.04	1.52	1.54	0.42	0.42	0.0001	0.0001
C.D. (P=0.05)	4.69	4.96	3.55	3.60	5.24	5.37	NS	NS	NS	NS
(B) Nano Zinc levels										
Nano Zn at 700 ppm	80.56	80.63	201.85	206.56	904.25	911.91	5.54	5.33	0.002	0.002
Nano Zn at 800 ppm	83.01	84.48	210.36	215.08	914.60	922.35	5.10	5.10	0.001	0.001
Nano Zn at 900 ppm	83.96	85.44	215.48	220.66	920.01	927.83	5.09	4.98	0.001	0.001
Control	73.14	75.99	196.12	200.75	892.25	899.79	5.71	5.62	0.001	0.001
SE(m)±	1.68	1.76	2.37	2.42	1.89	1.91	0.49	0.41	0.0001	0.0001
C.D. (P=0.05)	4.91	5.13	6.94	7.08	5.53	5.58	NS	NS	NS	NS

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