International Journal of Plant & Soil Science

Volume 36, Issue 10, Page 393-399, 2024; Article no.IJPSS.124871
ISSN: 2320-7035

Yield and Economic Analysis of Rice (*Oryza sativa* L.) as Influenced by the Nano Forms of Nitrogen and Zinc

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Authors' contributions

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

Article Information

DOI: https://doi.org/10.9734/ijpss/2024/v36i105090

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/124871

Original Research Article

Received: 15/08/2024
Accepted: 16/10/2024
Published: 23/10/2024

ABSTRACT

A field experiment was conducted at College Farm of College of Agriculture located in Rajendranagar, Hyderabad, Telangana, conducted research during the *rabi* season of 2020-21, focusing on the effects of nano nitrogen and nano zinc in sandy loam soils. The experimental design employed was a randomized block design (RBD), comprising ten distinct treatments, each replicated three times. The treatments *viz.,* Control (T_1), 100% N through urea (T_2), T_2 + soil

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Cite as: *Lahari, Shagam, S. A Hussain, Y. S. Parameswari, and S. Harish Kumar Sharma. 2024. "Yield and Economic Analysis of Rice (Oryza Sativa L.) As Influenced by the Nano Forms of Nitrogen and Zinc". International Journal of Plant & Soil Science 36 (10):393-99. https://doi.org/10.9734/ijpss/2024/v36i105090.*

application of $ZnSO_4$ at transplanting (T_3), T_2 + foliar spray of 4 ml L^{-1} nano nitrogen at tillering and before panicle initiation stage (T_4), T_2 + foliar spray of 2 ml L^{-1} nano zinc at tillering and before panicle initiation stage (T_5), T_2 + foliar spray of 4 ml L^{-1} nano nitrogen at tillering and before panicle initiation stage + foliar spray of 2 ml L^{-1} nano zinc at tillering and before panicle initiation stage (T_6), 75% N through urea + foliar spray of 4 ml L^{-1} nano nitrogen before panicle initiation stage. (T_7), T_7 + foliar spray of 2 ml L^{-1} nano zinc at tillering and before panicle initiation stage (T_8), 50% N through urea + foliar spray of 4 ml L^{-1} nano nitrogen at tillering and before panicle initiation stage (T_9), T_9 + foliar spray of 2 ml L^{-1} nano zinc at tillering and before panicle initiation stage (T_{10}). The results indicated that the highest grain yield (6810 kg ha^{-1}) was registered with treatment T_{10} which is on par with T_9. The highest net returns (86649 Rs ha^{-1}) and B:C ratio (2.99) were noticed by the application of T_{10}.

Keywords: Foliar application; rice; nano nitrogen; nano zinc; yield; economics.

1. INTRODUCTION

Rice (*oryza sativa* L.) is the prominent staple food for a large part of the world, especially in Asia. India being the second largest producer of the world, rice accounting for 20% of all world rice production after china. Fertilizers are unavoidable in agricultural production system. Fertilizers application started in 1960’s which coincided with the arrival of fertilizer responsive varieties in Indian agriculture. Since fertilization with nitrogen reveals response in crops universally besides the urea’s low price due to subsidized rate, farmers started the irrational use of nitrogenous fertilizers mainly urea, which has led to the NPK ratio of 8.2: 3.2: 1, while optimal ratio is recommended as 4:2:1 in cereals. This is the very serious issue which is causing nitrate pollution in the ground water and eutrophication in aquatic system.

The nitrogen requirement for cereal crops is higher in comparison to other crops for its growth, development and grain production [1]. Most of the rice soils are deficient in N, Thus, nitrogen fertilizer application is important to meet the crop requirement. But, the efficiency of added fertilizer N in rice depends on the N sources, application method, rate of N as well as management practices [2]. Prilled urea (PU) is applied as N source for rice but the efficiency of added N from PU is very low, generally it is around 30-45%. This low N use efficiency in rice culture is attributed mainly due to denitrification, ammonia volatilization and leaching losses [3]. This necessitates the development slow release fertilizers for the regulation of nitrification processes, thereby N availability be achieved during the crop growth period.

In rice, among the different micronutrients known, zinc deficiency is mostly observed and zinc (Zn) deficiency had been found to be responsible for rice yield reduction, which was next to N, P and K deficiency. Zinc deficiency was first diagnosed in rice crop (*Oryza sativa L.*) on calcareous soils located in Northern India (Nene,1966). It was subsequently known to be a widespread phenomenon in Asiatic lowland rice areas. Zinc deficiency causes multiple symptoms which usually appear 2 to 3 weeks after transplanting of rice seedlings. In comparison to legumes, cereal crops are generally more susceptible to zinc deficiencies, which can lead to significant reductions in grain yield and nutritional quality. Moreover, the prevalence of zinc deficiency is particularly pronounced in rice compared to other crops, with more than 50% of the global rice crop affected by this nutritional inadequacy. Zinc can be administered through various methods, including soil application, foliar spraying, seed treatment, and fertigation. Evidence suggests that foliar or combined soil and foliar application of fertilizers under field conditions are more efficacious and represent a practical approach to enhance the accumulation and absorption of zinc in grains [4]. In light of the aforementioned considerations, the current investigation was undertaken to examine the effects of nano formulations of nitrogen and zinc on rice yield and associated economic factors.

2. MATERIALS AND METHODS

The research was conducted at the College Farm situated within the College of Agriculture, Rajendranagar, Hyderabad, Telangana, India during the *rabi* season of 2020-21. The type of soil in experiment field was sandy loamy and slightly alkaline (pH 7.85), with available nitrogen (230 kg ha^{-1}), phosphorous (36.5 kg ha^{-1}), potassium (358 kg ha^{-1}) and zinc content (0.3 mg kg^{-1}). Geographically the experiment field was located between 17 ^{0}19' 16.4" North latitude and

78^0 24' 43" East longitudes and at an altitude of 542.3 m above the mean sea level. The total rainfall of 32 mm in 5 rainy days was received during the crop growth period. The experimental layout was designed using a randomized block design comprising ten distinct treatments, each replicated thrice. The treatments consisted *viz.,* control (no fertilizer) (T_1), 100% N through urea (T_2), T_2 + soil application of $ZnSO_4$ at transplanting (T_3), T_2 + foliar spray of 4 ml L^{-1} nano nitrogen at tillering and before panicle initiation stage (T_4), T_2 + foliar spray of 2 ml L^{-1} nano zinc at tillering and before panicle initiation stage (T_5), T_2 + foliar spray of 4 ml L^{-1} nano nitrogen at tillering and before panicle initiation stage + foliar spray of 2 ml L^{-1} nano zinc at tillering and before panicle initiation stage (T_6), 75% N through urea + foliar spray of 4 ml L^{-1} nano nitrogen before panicle initiation stage. (T_7), T_7 + foliar spray of 2 ml L^{-1} nano zinc at tillering and before panicle initiation stage (T_8), 50% N through urea + foliar spray of 4 ml L^{-1} nano nitrogen at tillering and before panicle initiation stage (T_9), T_9 + foliar spray of 2 ml L^{-1} nano zinc at tillering and before panicle initiation stage (T_{10}). Each plot measures 22.68 m^{-2} (5.4 m X 4.2 m). Telangana Sona variety (RNR 15048) seedlings were transplanted on 21st December had a spacing of 15 cm X 15 cm. The recommended dose of fertilizers for the transplanted rice crop 120:60:40 kg N, P and K respectively. One third of the nitrogen, entire recommended dose of phosphorous and the potassium were added in the form urea, SSP and MOP as basal at the transplanting time to all the experiment plots except the control plot. 25 kg ha^{-1} of $ZnSO_4$ was applied as basal application as per the treatment specification. At the crop tillering stage, one third of nitrogen was applied as urea or nano nitrogen foliar spray according to the treatment specifications. On the third day after the application of nitrogen, foliar application of nano zinc was applied in accordance with the treatments. As per treatment stipulations another one third of nitrogen was applied at panicle initiation stage in the form of urea or foliar spray of nano nitrogen followed by the foliar spray of nano zinc on the third day after the application of nitrogen.

Both nano nitrogen and nano zinc were applied as foliar application in the present study. The liquid formulation of nano nitrogen contained 40000 ppm of N. The recommended amount of spray fluid for nano formulations is 313 L ha^{-1}. The recommended dosage of nano nitrogen is 4 ml L^{-1}. The liquid formulation of nano zinc formulation obtained contains 10000 ppm of zinc. The recommended dosage of nano zinc is 2 ml L^{-1}. Recommended measures of plant protection were taken up to protect the crop from pests and diseases. Harvesting and threshing operations were done with the brush cutter and thresher to adopt mechanization in cultivation. Growth and yield components were recorded periodically. After harvest yield from both grain and straw recorded.

Data recorded from different parameters during the study were statistically analyzed using analysis of variance (ANOVA) which was given by Gomez and Gomez [5]. The significance level used in the "F" test was given at 5 per cent. The input prices mentioned in local market during the experiment were considered to work out the incurred cost of cultivation (COC). The gross returns are calculated with the rice yield and the produce market price at the time of marketing. The net returns (ha^{-1}) are calculated after deducting the COC per hectare from the incurred gross returns per hectare.

Net monetary returns = Gross monetary returns **-** Total cost of cultivation

B: C ratio was worked out by using the formula for each treatment

Benefit cost ratio = Gross returns (Rs ha^{-1})**/** Cost of cultivation (Rs ha^{-1})

3. RESULTS AND DISCUSSION

3.1 Seed Yield

Foliar application of nano nitrogen and nano zinc significantly influenced the seed yield of rice (Table 1). The application of 50% N through urea + foliar spray of 4 ml L^{-1} nano nitrogen at tillering and P.I stage + foliar spray of 2 ml L^{-1} nano Zn at tillering and P.I stage (T_{10}) had the highest seed yield (6810 kg ha^{-1}) which was comparable with application of 50% N through urea + foliar spray of 4 ml L^{-1} nano nitrogen at tillering and P.I stage (T_9) (6653 kg ha^{-1}). Lowest seed yield (3136 kg ha^{-1}) was obtained with the no fertilizer (control) (T_1). There was an increase of seed yield by 8% in comparison to RDF (T_2), 58.95 % over the control (T_1).

Table 1. Seed yield and straw yield (kg ha^{-1}) of rice as influenced by the foliar application of nano nitrogen and nano zinc

Treatment	Yield (kg ha^{-1})	
	Seed	**Straw**
T_1-No fertilizer (control)	3136	4329
T_2-100% N through urea	6265	7386
T_3-T_2 + soil application of 25 kg ha^{-1} $ZnSO_4$ at transplanting.	6390	7403
T_4-T_2+ foliar spray of 4 ml L^{-1} nano nitrogen at tillering and before panicle initiation stage	6002	7712
T_5-T_2 + foliar spray of 2 ml L^{-1} nano zinc at tillering and before panicle initiation stage	6456	7532
T_6-T_2 + foliar spray of 4 ml L^{-1} nano nitrogen at tillering and before panicle initiation stage + foliar spray of 2 ml L^{-1} Nano zinc at tillering and before panicle initiation stage	6095	7891
T_7-75% N through urea + foliar spray of 4 ml L^{-1} Nano Nitrogen before panicle initiation stage.	5890	7063
T_8-T_7 + foliar spray of 2 ml L^{-1} nano zinc at tillering and before panicle initiation stage	5986	7156
T_9-50% N through urea + foliar spray of 4 ml L^{-1} nano nitrogen at tillering and before panicle initiation stage.	6653	7662
T_{10}-T_9 + foliar spray of 2 ml L^{-1} nano zinc at tillering and before panicle initiation stage	6810	7702
SE(m)±	123	125
CD (P = 0.05)	352	357

Increment in the grain yield might be achieved due to increased nutrient uptake of the plant resulting in the superlative plant parts growth and improved metabolic processes such as photosynthesis resulting in improved accumulation and translocation of photosynthates to the economic parts of the plant, hence ensuing in higher yield that might be achieved due to increased source (leaves) and sink (economic part) strength. These findings were in accordance with the findings of Liu and Lal [6], Harsini et al. [7], Subramani et al. [8], Khan et al. [9] and Benzon et al. [10].

3.2 Straw Yield

Straw yield was influenced significantly by the foliar spray of nano nutrients (Table 1). Treatment T_6 (100 % N through urea + foliar spray of 4 ml L^{-1} nano nitrogen at tillering and P.I stage + foliar spray of 2 ml L^{-1} nano Zn at tillering and P.I stage) resulted in higher straw yield (7891 kg ha^{-1}) which was comparable T_4 (100% N through urea + foliar spray of 4 ml L^{-1} nano nitrogen at tillering and P.I stage) (7712 kg ha^{-1}), T_{10} (50% N through urea + foliar spray of 4 ml L^{-1} nano nitrogen at tillering and P.I stage + foliar spray of 2 ml L^{-1} nano Zn at tillering and P.I stage) (7702 kg ha^{-1}), T_9 (50% N through urea + foliar spray of 4 ml L^{-1} nano nitrogen at tillering and P.I stage) (7662 kg ha^{-1}) and was statistically higher when compared to that of other treatments. The lowest straw yield (4329 kg ha^{-1}) was observed with no fertilizer treatment. Enhancement in the straw yield with the foliar application of nano nitrogen and nano zinc fertilizers might be attributed for the quick absorption of nutrients in the nano form by the plant and translocated at a faster rate influenced the root and shoot growth that aided in higher rate of photosynthesis and increased dry matter accumulation which resulted in higher straw yield. These findings were in corroboration with the reports of Hafeez et al. [11], Kumar et al. [12] and Abdel et al. [13].

3.3 Economic Analysis

Returns from the rice crop was significantly influenced by the foliar application of nano nitrogen and nano zinc (Table 2). 50% N through urea + foliar spray of 4 ml L^{-1} nano nitrogen at tillering and P.I stage + foliar spray of 2 ml L^{-1} nano Zn at tillering and P.I stage (T_{10}) application fetched highest gross returns (130281 Rs. ha^{-1}) The next best treatment was T_9 (50% N through urea + foliar spray of 4 ml L^{-1} nano nitrogen at tillering and P.I stage) which resulted in gross returns of 127416 Rs. ha^{-1}. The minimal gross returns were recorded in the control (no fertilizer) (60777 Rs. ha^{-1}).

Higher net returns were noted with T_{10} (50% N through urea + foliar spray of 4 ml L^{-1} nano nitrogen at tillering and P.I stage + foliar spray of 2 ml L^{-1} nano Zn at tillering and P.I stage) *fb* T_9 (50% N through urea + foliar spray of 4 ml L^{-1} nano nitrogen at tillering and P.I stage) which gained a net returns of 86649 and 84385 Rs. ha^{-1}, respectively. The lowest net returns were noticed in the treatment where no fertilizers were applied T_1 (24397 Rs. ha $^{-1}$). The highest B:C ratio 2.99 was recorded from treatment T_{10} (50% N through urea + foliar spray of 4 ml L^{-1} nano nitrogen at tillering and P.I stage + foliar spray of 2 ml L^{-1} nano Zn at tillering and P.I stage) *fb* T_9 (50% N through urea + foliar spray of 4 ml L^{-1} nano nitrogen at tillering and P.I stage which fetched B: C ratio of 2.96. Lowest B: C ratio of 1.67 was registered in the treatment T_1 (no fertilizer).

Table 2. Economics of rice as influenced by foliar application of nano nitrogen and nano zinc

Treatments	Cost of cultivation (Rs/ ha)	Gross returns (Rs/ ha)	Net returns (Rs/ ha)	B-C Ratio
T_1	36380	60777	24397	1.67
T_2	44058	120152	75894	2.71
T_3	44733	122423	77690	2.74
T_4	44658	115748	71090	2.59
T_5	43458	123740	80282	2.85
T_6	45120	117601	72481	2.60
T_7	43756	113082	69326	2.58
T_8	43541	114904	71363	2.64
T_9	43031	127416	84385	2.96
T_{10}	43631	130281	86649	2.99

Market rates of paddy seed @ Rs. 18/-per kg; paddy straw @ Rs. 1/- per kg

High gross returns, net returns and B:C ratio were obtained due to less cost of cultivation from the reduced level of urea application and effective utilization of foliar nano fertilizers which resulted in higher yield of grain and straw which led to higher returns. These findings were coinciding with Kumar et al. [12] and Apoorva et al. [14].

4. CONCLUSION

The yields of both seed and straw exhibited significant variation as a result of the foliar application of nano nitrogen and nano zinc. The treatment consisting of 50% conventional nitrogen fertilizer combined with a foliar spray of 4 ml L^{-1} nano nitrogen at the tillering stage and prior to panicle initiation, along with a foliar spray of 2 ml L^{-1} nano zinc at the same stages, produced optimal outcomes in terms of seed yield and straw yield, which proved to be comparable to the treatment involving 50% conventional nitrogen fertilizer plus the aforementioned foliar spray of 4 ml L^{-1} nano nitrogen at the tillering and pre-panicle initiation stages. Consequently, the application of nano nutrients resulted in yield enhancements, which subsequently led to increased gross returns, net returns and an elevated benefit-to-cost ratio (B:C ratio).

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

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

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/124871