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Effect of Nano nitrogen and Nano zinc application on nutrient content and their uptake by transplanted rice crop (*Oryza sativa* L.)

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Abstract
To evaluate the effect of nano nitrogen and nano zinc application on nutrient content and their uptake by transplanted rice (*Oryza sativa* L.) crop, a field experiment was carried out during the *kharif s*eason of 2023 at the Research Farm of the School of Agriculture, Abhilashi University, Mandi (H.P.). The experiment was laid out in randomized block design (RBD) with seven treatments and replicated thrice. The different treatment combination was T_1= Absolute control, T_2= 100% RDN by urea, T_3= T_2 + soil application of zinc, T_4= [T_2 + Nano nitrogen (4 ml L^{-1})], T_5= [T_2 + Nano zinc (2 ml L^{-1})] T_6= [80% RDN + Nano nitrogen (4 ml L^{-1})], T_7= [80% RDN + Nano zinc (2 ml L^{-1})]. The analysis of data revealed that there are no significant differences in nitrogen, phosphorus, potassium and zinc content in grains and straw of transplanted rice crop with the application of nitrogen and zinc. Interestingly, despite no significant changes in nutrient content, there was a noticeable significant differences were found in nutrient uptake under different treatment conditions. The application of treatment T_3= (T_2 +soil application of zinc) recorded significantly highest uptake of nitrogen, phosphorus, potassium and zinc by grains and straw of transplanted rice crop. Similarly, the total uptake of nitrogen, phosphorus, potassium and zinc was also found to be higher under treatment T_3. The treatments T_1 (Absolute control) were found to have minimum nitrogen, phosphorus, potassium and zinc content and uptake by grains and straw of transplanted rice crop. Strategic nutrient management, particularly zinc supplementation combined with 100% recommended dose of nitrogen and spraying of nano nitrogen significantly enhances nutrient uptake in transplanted rice crop, despite no significant changes in nutrient content. This underscores the importance of zinc and nitrogen application for improving nutrients uptake by transplanted rice crop.

Keywords: Transplanted rice, nano nitrogen, nano zinc, nutrient content and uptake

Introduction

Rice (*Oryza sativa* L.) is the staple cereal component that sustains two-thirds of the world's population. Rice is the primary source of foods for humans because of its abundance, nutritional richness and sovereignty (Burlando and Cornara., 2014) [1]. A small portion of rice grains are utilized as ingredients in the manufacturing of foods and non-foods, whereas the majority are eroded as cooked rice. Being a significant source of carbohydrates, it makes up a large portion of the world's calorie intake and offers vital nutrients such as dietary fiber, vitamins and minerals (Juliano., 2010) [2]. Over 2 billion people in Asia alone derive 80% of their energy needs from rice, which contains 80% carbohydrates, 7-8% protein, 3% fat and 3% fiber (Chaudhari *et al.*, 2018) [3]. Rice, with its nutritional and economic importance, has cultural and religious significance in various parts of the world. In India, the total production of rice during 2020–21 is 124.37 million tons, with an area of 45.77 million hectares and an average productivity of 2717 kg ha^{-1} (Anonymous, 2021) [4].

Nanotechnology has provided the feasibility of exploiting nanoscale or nanostructured materials as fertilizer carriers or controlled release of nutrients, so-called "smart fertilizer" as new facilities to enhance use efficiency and reduce costs of environmental protection (Veronica *et al.*, 2015) [5]. Foliar treatment has shown to be the most efficient method of addressing nutrient shortages and improving crop product quality and yield (Roemheld and El-Fouly., 1999) [6] and it also minimizes environmental pollution and improves nutrient utilization by reducing the amounts of fertilizer added to the soil (Abou-El-Nour., 2002) [7]. In the world of agriculture, foliar application of nano fertilizers has emerged as a promising technique that offers prospective solutions to improve crop yield, lower environmental impact and increase nutrient uptake efficiency. Rice plant require large amounts of mineral nutrients, including nitrogen for their growth, development and grain production (Ma., 2004) [8]. Nitrogen is a major nutrient for plant that primarily influences vegetative growth and crop yield (Gnaratnam *et al*., 2019) [9]. Nano nitrogen enhances plant uptake while simultaneously reducing environmental losses. For a steady and controlled release of nutrients into the soil, nano nitrogen is a suitable substitute for traditional fertilizers. Without sacrificing soil productivity, nano urea improves crop production, soil health and nutritional quality while reducing the requirement for conventional urea by half or more. (Quijano-Guerta *et al*., 2002) [10]. Zinc is an essential trace element required in small but critical amounts by both plants and animals (including humans). Many microorganisms exist in the range of hundreds of nanometers to tens of micrometers. ZnO-NPs have a higher specific surface area and better surface reactivity because of their smaller particle size, which contributes to their appealing antibacterial qualities (Seil., 2012) [11]. Zinc oxide (ZnO) is a biocompatible substance that exhibits photo-oxidizing and photo-catalytic effects on both biological and chemical species but the zinc sulphate is easily available to the farmers.

Nitrogen plays a key role in agriculture by increasing the productivity of crops (Massignam *et al*., 2009) [12]. Nitrogen improve the food quality as well as the crop yield (Ullah *et al*., 2010) [13]. An ideal N rate boosts the formation of leaf area, duration of leaf area, photosynthetic activities and net assimilation rate in plants (Ahmad *et al*., 2009) [14]. Nitrogen is one of the primary nutrients critical for the survival of all living organisms. The human body needs nitrogen for healthy food digestion and growth. Phosphorus is a vital component in the process of plants converting the sun's energy into food, fiber and oil. Phosphorus plays a key role in photosynthesis, the metabolism of sugars, energy storage and transfer, cell division, cell enlargement and transfer of genetic information. Phosphorus can be found as a supplement as well as naturally occurring in a variety of meals. It has several functions within the body. It is essential to teeth, cell membranes and bones. Potassium is the most abundant cation in plants because it is required for a different function in plants (Leigh and Jones., 1984) [15]. Potassium plays a fundamental and intricate function in photosynthetic activity and plant growth through a variety of direct and indirect mechanisms (Sustr *et al*., 2019) [16]. Sufficient potassium availability promotes better nutritional absorption and photosynthetic assimilation. Potassium is a mineral that is essential for all of the body's functions. Potassium is necessary for the normal functioning of all cells. It regulates the heartbeat, ensures proper function of the muscles and nerves and is vital for synthesizing protein and metabolizing carbohydrates. Potassium is required for every cell to operate normally. It is essential for the synthesis of protein and the metabolism of carbohydrates, controls heart rate and guarantees that muscles and nerves operate normally. One of the most important micronutrients for plant is zinc (Zn), which is highly valued. Zinc plays a vital role in the biochemistry and metabolism of plant. It contributes to several physiological and cellular activities of plant and promotes plant growth, development and yield. In humans one of the most important micronutrient for immune system function and growth is zinc. It is a crucial component of enzymes and is involved in tissue development and cellular proliferation. Given that the human body lacks a long-term zinc storage mechanism, maintaining the exchangeable zinc pool and supporting these biological processes during childhood, puberty and pregnancy require regular food consumption (Gibson & Anderson., 2009) [17]. As we know the rice is staple food grain of most of the population, the uptake of these elements (*i.e*- N, P, K and Zn) by rice crop could be the good and significant source to provide these nutrients to human society.

Materials and Methods

The experiment entitled "Response of traditional and nano nitrogen and zinc on the growth and yield of rice (*Oryza sativa* L.)" was carried out at the research farm of the School of Agriculture, Abhilashi University, Mandi (H.P.) during the Kharif season of 2023. The experimental farm is situated at 30^0 32' N latitude and 74^0 53'E longitude, with an elevation of 1391 m above mean sea level. The soil of the experimental field was slightly acidic in reaction, medium in organic carbon, low in available nitrogen and medium in available phosphorus and potassium. The pH of the experimental soil was slightly acidic in reaction (5.6) with an electrical conductivity of 0.33 dS m^{-1}, medium in organic carbon (0.70%), low in available nitrogen (244.65 kg ha^{-1}), medium in available phosphorus (22.09 kg ha^{-1}), potassium (263.83 kg ha^{-1}) and low in available zinc (0.59 mg kg^{-1}). The net plot size was 2.5 $m^2 \times 1.5$ m^2 and the gross plot size was 3.0 m ×2.0 m. The spacing for the tested variety hybrid paddy super-120 was 20 × 10 cm row to row and plant to plant. The experiment was laid out in a randomized block design (RBD) with seven treatments and three replications. The treatments, *viz.*, T_1= Absolute control, T_2= 100% RDN by urea, T_3= T_2 + soil application of zinc, T_4= [T_2 + Nano nitrogen (4 ml L^{-1})], T_5= [T_2 + Nano zinc (2 ml L^{-1})], T_6= [80% RDN + Nano nitrogen (4 ml L^{-1})] and T_7= [80% RDN + Nano zinc (2 ml L^{-1})]. Nutrients were applied as per treatments. Recommended doses of N, P, K and Zn were applied through Urea, DAP, MOP and Zinc Sulphate. A foliar spray of nano nitrogen in the form of nano urea at 4 ml L^{-1} of water is applied and nano zinc at 2 ml L^{-1} of water is applied at the tillering and panicle initiation stages of the transplanted rice crop. Plant samples were collected from each treatment after harvest and they were cleaned and shade-dried. Later, the shade-dried samples were oven-dried at 60 ± 50 °C for 24 to 48 hours till their weight were constant and the samples than finely powdered using a mixer grinder. The finely grind plant samples were used for the analysis of N, P, K and Zn content and their uptake by transplanted rice crop. The estimation of nitrogen content in the plant sample was done by the modified Kjeldahl digestion and distillation method as described by (Jackson, 1973) [18]. The phosphorus content in the plant was determined by the venadomolybdate phosphoric yellow color method and the phosphorus content in the plant sample was estimated using a spectrophotometer as described by (Jackson, 1973) [18]. Potassium content in plants was estimated by using a flame photometer (Jackson, 1973) [18]. Zinc content in samples of rice was determined by the di acid method with estimation by the AAS (Lindsay and Norvell, 1978) [19]. The N, P, K and Zn (kg ha^{-1}) uptake by grains and straw of transplanted rice in each treatment was calculated by multiplying the N, P, K and Zn content (%) with yields of grains and straw (q ha^{-1}). The total uptake of different nutrients was calculated after summing their uptake by grain and straw of transplanted rice crop.

Results and Discussion

N content (%) and uptake (kg ha^{-1})

The N content and their uptake by grains and straw of transplanted rice is presented in Table- 1 and depicted in Fig.-1. The content of nitrogen in grains and straw of transplanted rice crop were didn't affected significantly by used treatments in the study. However, maximum N content in grains of rice crop were recorded under T_3= (T_2 + soil application of zinc) and minimum in treatment T_1 (Absolute control).

Table 1: Effect of nano nitrogen and nano zinc application on nitrogen content and their uptake by grain and straw of transplanted rice crop

Treatments		Nitrogen content (%)		Nitrogen uptake (kg ha^{-1})		
		Grain	Straw	Grain	Straw	Total
T_1	Absolute control	1.32	0.42	39.23	17.07	56.30
T_2	100% RDN by urea	1.38	0.43	59.86	21.22	81.08
T_3	T_2 + Soil application of zinc	1.41	0.45	70.75	24.92	95.67
T_4	T_2 + Nano nitrogen (4 ml L^{-1})	1.40	0.45	68.05	24.45	92.50
T_5	T_2 + Nano zinc (2 ml L^{-1})	1.40	0.44	62.92	22.29	85.21
T_6	80% RDN + Nano nitrogen (4 ml L^{-1})	1.36	0.43	57.01	20.64	77.65
T_7	80% RDN + Nano zinc (2 ml L^{-1})	1.35	0.42	54.59	19.72	74.31
	SE(m)±	0.04	0.01	1.78	0.63	2.38
	C.D.	NS	NS	5.54	1.95	7.42

The uptake of N by grains and straw as well as were significantly influenced by various N and Zn application treatments. The maximum N uptake was noted under treatment T_3= (T_2 + soil application of zinc) which was statistically at par with treatment T_4= [T_2 + Nano nitrogen (4 ml L^{-1})] during the study. However, minimum N uptake by grains were found in treatment T_1 (Absolute control). Like the N uptake by grains the N uptake by straw of transplanted rice crop was found highest in T_3= (T_2 + soil application of zinc) which was on par with treatment T_4= [T_2 + Nano nitrogen (4 ml L^{-1})] statistically, during the experiment. Whereas, the minimum N uptake by straw of transplanted rice crop was recorded in treatment T_1 (Absolute control). The total uptake of N was maximum under T_3= (T_2 + soil application of zinc) which was statistically at par with treatment T_4= [T_2 + Nano nitrogen (4 ml L^{-1})]. However, the minimum total N uptake by rice crop was found under treatment T_1 (Absolute control).

The improved nutrient uptake might be associated with the combined application of soil-treated N and Zn. Zinc's role in enhancing root development and enzyme activity facilitates nutrient absorption by the transplanted rice crop. The foliar application of nano nitrogen, with its reduced particle size, might efficiently enhance nutrient uptake. Nano urea might enhance N nutrient uptake in rice by providing a controlled release of nitrogen, ensuring sustained availability to plants. Its nano-sized particles facilitate better absorption through roots, promoting efficient nutrient utilization. This result is in conformity with (Sahu *et al.*, 2022) [20].

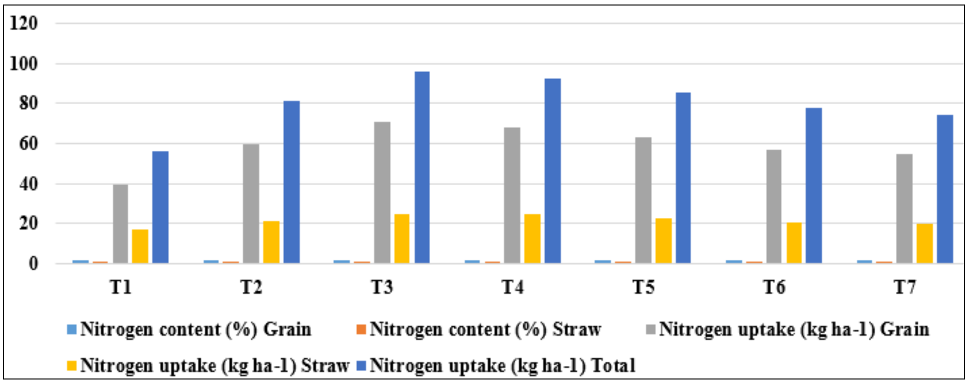

Fig 1: Effect of nano nitrogen and nano zinc application on nitrogen content and their uptake by grain and straw of transplanted rice crop.

P content (%) and uptake (kg ha^{-1})

The P content of the transplanted rice crop is shown in Table- 2 and displayed in Fig.- 2, along with their uptake by grains, straw and total uptake. The study found no significant differences in the content of P in the grains and straw of the transplanted rice crop between different treatments. Whereas, the highest P content was recorded under treatment T_3= (T_2 + soil application of zinc) and the lowest P content was found under treatment T_1 (Absolute control).

Different N and Zn application treatments had a substantial impact on the uptake of P by grains and straw. During the investigation, the highest P uptake was observed under treatment T_3= (T_2 +soil application of zinc), which was statistically comparable to treatment T_4= [T_2 + Nano nitrogen (4 ml L^{-1})]. However, treatment T_1 (Absolute control) found to be the lowest P uptake by grains of transplanted rice crop. Similarly, the P uptake by grains the P uptake by straw of transplanted rice crop was recorded maximum under treatment T_3= (T_2+ soil application of zinc) which was significantly comparable to treatment T_4= (T_2 + Nano nitrogen 4 ml L^{-1}). Although the minimum P uptake by straw of transplanted rice crop was observed in treatment T_1 (Absolute control). Treatment T_3= (T_2+ soil application of zinc) had the highest total uptake of P by grains and straw of transplanted rice crop which was comparable to treatment T_4= (T_2 + Nano nitrogen 4 ml L^{-1}). Whereas, the lowest total P uptake by grains and straw of transplanted rice crop were recorded under treatment T_1 (Absolute control).

Table 2: Effect of nano nitrogen and nano zinc application on phosphorus content and their uptake by grain and straw of transplanted rice crop

Treatments		Phosphorus content (%)		Phosphorus uptake (kg ha^{-1})		
		Grain	Straw	Grain	Straw	Total
T_1	Absolute control	0.23	0.101	6.84	4.11	10.95
T_2	100% RDN by urea	0.24	0.106	10.41	5.23	15.64
T_3	T_2 + Soil application of zinc	0.26	0.109	13.05	6.04	19.09
T_4	T_2 + Nano nitrogen (4 ml L^{-1})	0.25	0.107	12.15	5.81	17.96
T_5	T_2 + Nano zinc (2 ml L^{-1})	0.25	0.106	11.24	5.37	16.61
T_6	80% RDN + Nano nitrogen (4 ml L^{-1})	0.24	0.105	10.06	5.04	15.10
T_7	80% RDN + Nano zinc (2 ml L^{-1})	0.23	0.104	9.30	4.88	14.18
	SE(m)±	0.01	0.003	0.33	0.20	0.46
	C.D.	NS	NS	1.04	0.64	1.43

Nitrogen might enhance the efficacy of phosphorus-absorbing mechanisms and encourages root growth, which in turn helps in uptake of phosphorus by transplanted rice crop. By stimulating enzymes essential for phosphorus absorption and metabolism and enhancing root development, zinc might help rice crop to use phosphorus more efficiently. The increased specific surface area and dense distribution of reactive sites on the surfaces of nanoparticles cause them to be more reactive than other particle types. These properties might facilitate their uptake by plant at the nanoscale, improving uptake of phosphorus in transplanted rice crop. Some similar results were also found by (Bharti *et al.*, 2022) [21].

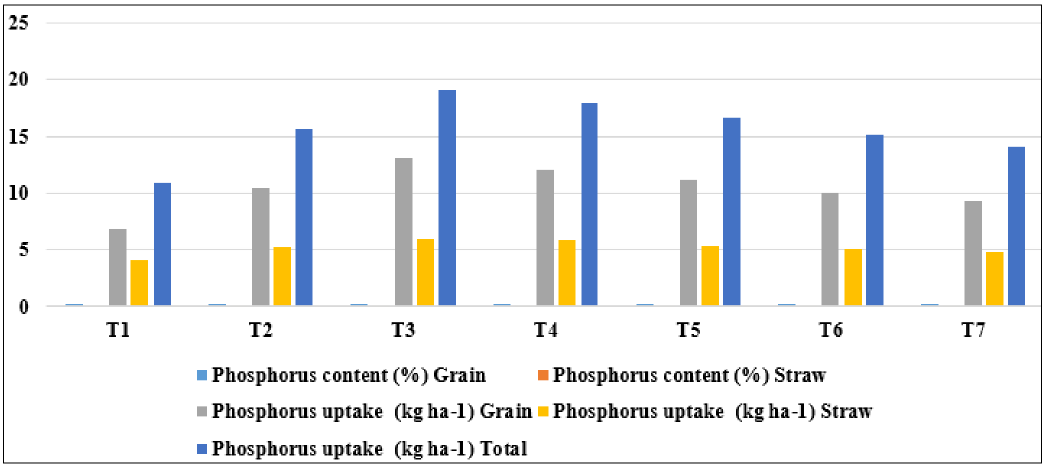

Fig 2: Effect of nano nitrogen and nano zinc application on phosphorus content and their uptake by grain and straw of transplanted rice crop

K content (%) and K uptake (kg ha^{-1})

Data concerning the K content and their uptake by grains and straw of the transplanted rice crop is presented in Table- 3 and illustrated in Fig.- 3. There wasn't any significant variation noticed in the K content of rice grains and straw. However, the maximum K content in grains and straw of the transplanted rice crop was recorded under treatment T_3= (T_2 + soil application of zinc) and the minimum in treatment T_1 (Absolute control).

The uptake of K by grains and straw of transplanted rice crop varied significantly among various N and Zn applied treatments. The maximum K uptake was recorded under treatment T_3= (T_2 + soil application of zinc), which was significantly at par with treatment T_4= [(T_2 + Nano nitrogen (4 ml L^{-1})] during the trial. However, minimum K uptake by grains was observed in treatment T_1 (Absolute control). Like the K uptake by grains and straw of the transplanted rice crop, it was found to be highest under treatment T_3= (T_2 + soil application of zinc), which was statistically at par with treatment T_4= [(T_2 + Nano nitrogen (4 ml L^{-1})]. Whereas, the minimum K uptake by straw of the transplanted rice crop was found under treatment T_1 (Absolute control). The total uptake of K was found to be higher under treatment T_3= (T_2 + soil application of zinc), which was statistically at par with treatment T_4= [(T_2 + Nano nitrogen (4 ml L^{-1})]. However, the minimum total K uptake by grains and straw of the rice crop was found in treatment T_1 (Absolute control).

Nitrogen promotes root growth and might enhances potassium uptake efficiency in rice crop by improving nutrient transport mechanisms. Zinc might aid in potassium absorption by stimulating root development and activating enzymes crucial for nutrient assimilation. Together, nitrogen and zinc optimize potassium uptake in transplanted rice crop. Nano nitrogen and nano zinc might facilitate potassium uptake in rice by improving root surface area and enhancing nutrient absorption efficiency. Their nano-scale properties enhance the effectiveness of nutrient uptake mechanisms, leading to increased potassium assimilation and utilization by rice crops, ultimately promoting overall uptake of potassium in transplanted rice crop. These results were in close agreement with the findings of (Sahu *et al.*, 2022) [20].

Table 3: Effect of nano nitrogen and nano zinc application on potassium content and their uptake by grain and straw of transplanted rice crop

Treatments		Potassium content (%)		Potassium uptake (kg ha^{-1})		
		Grain	Straw	Grain	Straw	Total
T_1	Absolute control	0.28	1.31	8.32	53.25	61.57
T_2	100% RDN by urea	0.30	1.33	13.01	65.62	78.63
T_3	T_2 + Soil application of zinc	0.32	1.36	16.06	75.32	91.38
T_4	T_2 + Nano nitrogen (4 ml L^{-1})	0.32	1.35	15.56	73.36	88.92
T_5	T_2 + Nano zinc (2 ml L^{-1})	0.31	1.34	13.93	67.87	81.80
T_6	80% RDN + Nano nitrogen (4 ml L^{-1})	0.29	1.33	12.16	63.83	75.99
T_7	80% RDN + Nano zinc (2 ml L^{-1})	0.29	1.32	11.73	61.97	73.70
	SE(m)±	0.01	0.04	0.42	2.04	2.30
	C.D.	NS	NS	1.30	6.35	7.17

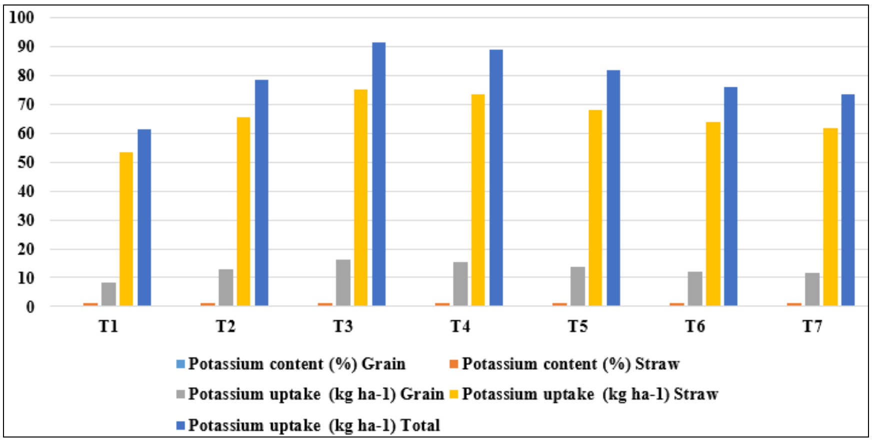

Fig 3: Effect of nano nitrogen and nano zinc application on potassium content and their uptake by grain and straw of transplanted rice crop

Zn content (mg kg^{-1}) and Zn uptake (g ha^{-1})

The Zn content and their uptake by grains and straws of transplanted rice crop are presented in Table- 4 and depicted in Fig.- 4. The content of Zn in the grains and straw of the transplanted rice crop wasn't affected significantly by the different treatments used in the study. However, maximum Zn content in grains of the rice crop was recorded under treatment T_3= (T_2 + soil application of zinc) and minimum in treatment T_1 (Absolute control).

The uptake of Zn by grains and straw was significantly influenced by various N and Zn application treatments. The maximum Zn uptake was noted under treatment T_3= (T_2 + soil application of zinc) which was statistically at par with treatment T_4= [T_2 + Nano nitrogen (4 ml L^{-1})] during the study. However, minimum Zn uptake by grains was found in treatment T_1 (Absolute control). Although the Zn uptake by grains the Zn uptake by straw of the transplanted rice crop was found maximum in treatment T_3= (T_2 + soil application of zinc), which was on par with treatment T_4= [T_2 + Nano nitrogen (4 ml L^{-1})] statistically during the experiment. Whereas, the minimum Zn uptake by straw of the transplanted rice crop was recorded in treatment T_1 (Absolute control). The total uptake of Zn was maximum under T_3= (T_2 + soil application of zinc) which was statistically at par with treatment T_4= [T_2 + Nano nitrogen (4 ml L^{-1})]. However, the minimum total Zn uptake by rice crop was found under treatment T_1 (Absolute control).

Application of N and Zn might enhance root development and enzyme activity, facilitating zinc absorption by transplanted rice crop. Better nitrogen and zinc transporters, more efficient control of the transport systems and improved absorption and storage can all lead to increased zinc uptake capacity. Similarly, the foliar application of nano nitrogen with its reduced particle size, might efficiently promote zinc uptake by plant roots, collectively contributing to increased zinc absorption in the transplanted rice crop. Nano fertilizers might enhance zinc uptake in plants by improving the efficiency of nutrient delivery and absorption mechanisms. The nano-scale properties of these fertilizers, such as increased surface area and reactivity, facilitate better interaction with plant roots. Additionally, nano formulations can protect Zn from soil interactions that may reduce its availability, ensuring a higher uptake by transplanted rice crop. The results are in submission with (Apoorva *et al.*, 2017) [22].

Table 4: Effect of nano nitrogen and nano zinc application on zinc content and their uptake by grain and straw of transplanted rice crop

Treatments		Zinc content (mg kg^{-1})		Zinc uptake (g ha^{-1})		
		Grain	Straw	Grain	Straw	Total
T_1	Absolute control	16.81	22.78	49.96	92.60	142.56
T_2	100% RDN by urea	18.74	25.69	81.29	126.75	208.04
T_3	T_2 + Soil application of zinc	19.96	26.98	100.16	149.42	249.58
T_4	T_2 + Nano nitrogen (4 ml L^{-1})	19.57	26.72	95.13	145.20	240.33
T_5	T_2 + Nano zinc (2 ml L^{-1})	18.85	26.23	84.71	132.85	217.56
T_6	80% RDN + Nano nitrogen (4 ml L^{-1})	18.59	25.34	77.93	121.61	199.54
T_7	80% RDN + Nano zinc (2 ml L^{-1})	17.91	24.61	72.43	115.54	187.97
	SE(m)±	0.76	0.86	2.46	3.93	6.14
	C.D.	NS	NS	7.68	12.24	19.14

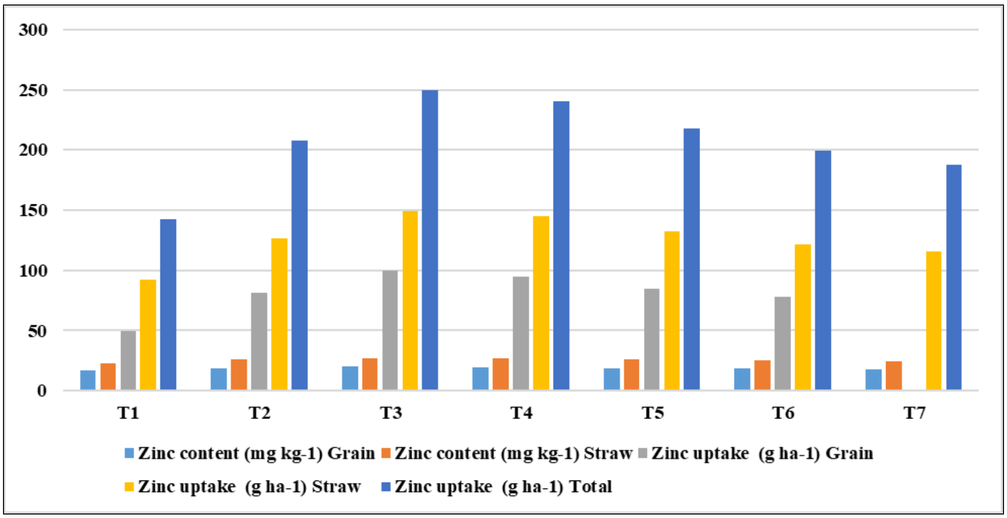

Fig 4: Effect of nano nitrogen and nano zinc application on zinc content and their uptake by grain and straw of transplanted rice crop

Conclusion

In conclusion, the nutrient (N, P, K and Zn) content in the grains and straw of the transplanted rice crop did not vary significantly among the various treatments. However, the uptake of nutrients by grains and straw as well as total uptake varied significantly. The maximum nutrient (N, P, K and Zn) uptake by grains and straw of rice crop was found under treatment T_3= (T_2 + soil application of zinc) which was significantly at par with treatment T_4= [T_2 + Nano nitrogen (4 ml L^{-1})]. Similarly, the total nutrient uptake (N, P, K and Zn) was also found highest in treatment T_3, which was on par with treatment T_4. Both the application of N and Zn as well as the foliar application of nano nitrogen and nano zinc highlight its promising role in promoting enhanced nutrient utilization by the transplanted rice crop. These findings provide valuable insights for future research and agricultural strategies, emphasizing the importance of considering nanoscale interventions for nutrient content and their uptake by transplanted rice crop.

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Reference

1. Burlando, Cornara. Therapeutic properties of rice constituents and derivatives (*Oryza sativa* L.). Trends in Food Science and Technology. 2014;40(1):82-98.
2. Juliano B. Rice in human nutrition. International Rice Research Institute and Food and Agriculture Organization; c2010.
3. Chaudhari PR, Tamrakar N, Singh L, Tandon A, Sharma D. Rice nutritional and medicinal properties: A review article. Journal of Pharmacognosy and Phytochemistry. 2018;7(2):150-156.
4. Anonymous, 4th Advance Estimates, Agricultural statistics at a glance, Department of Agriculture & Farmers Welfare Economics & Statistics Division. Government of India Ministry of Agriculture & Farmers Welfare; c2021.
5. Veronica N, Guru T, Thatikunta R, Reddy NS. Role of nano fertilizer in agricultural farming. International Journal of Environmental Science and Technology. 2015;1(1):1-3.
6. Roemheld V, El-Fouly MM. Foliar nutrient application challenge and limits in crop production. Proceedings of the 2nd International Workshop on Foliar Fertilization, Bangkok, Thailand; c1999. p. 4-10.
7. Abou-El-nour EAA. Can supplemented potassium foliar feeding reduce the recommended soil potassium. Pakistan Journal of Biological Science. 2002;5:259-262.
8. Ma JF. Role of silicone in enhancing the resistance of plants to biotic and abiotic stresses. Soil science and plant nutrition. 2004;50:11-18.
9. Gnaratnam A, Mccurdy M, Grafton M, Kumar JP, Bishop P, Davies C. Assessment of nitrogen fertilizers under controlled environmental - *A* Lysimeter Design; Massey University: Palmerston North, New Zealand; c2019.
10. Quijano-Guerta C, Kirk GJD, Portugal AM, Bartolome VI, Mclaren GC. Tolerance of rice germplasm to zinc deficiency. Field Crop Research. 2002;76:123-30.
11. Seil JT. Webster, Antimicrobial applications of nanotechnology: Methods and literature. Int. J Nanomed. 2012;7:2767-2781.
12. Massignam AM, Chapman SC, Hammer GL, Fukai S. Physiological determinants of maize and sunflower achene yield as affected by nitrogen supply. Field Crops Research. 2009;113:256-267.
13. Ullah MA, Anwar M, Rana AS. Effect of nitrogen fertilization and harvesting intervals on the yield and forage quality of elephant grass (*Pennisetum purpureum* L.) under mesic climate of Pothowar plateau. Pak. J. Agri. Science. 2010;47:231-234.
14. Ahmad SR, Ahmad MY, Ashraf M, Ashraf, Waraich EA. Sunflower (*Helianthus annuus* L.) response to drought stress at germination and seedling growth stages. Pak. J. Botany. 2009;41(2):647-654.
15. Leigh RR, Jones RG. A hypothesis relating critical potassium concentrations for growth to the distribution and functions of this ion in plant cell. New Phytol. 1984;97:1–

13.
16. Sustr M, Soukup A, Tylova E. Potassium in root growth and development. Plants. 2019;8:435.
17. Gibson RS, Anderson VP. A review of interventions based on dietary diversification or modification strategies with the potential to enhance intakes of total and absorbable zinc. Food and Nutrition Bulletin, 2009;30(1):108–143.
18. Jackson ML. Soil chemical analysis, Prentice hall of India, Pvt. Ltd., New Delhi; c1973.
19. Lindsay WL, Norvell WA. Development of a DTPA soil test for zinc, iron, manganese and copper. Soil, Sci, Soc Am, J. 1978;42(3):421-428.
20. Sahu KT, Kumar M, Kumar N, Chandrakar T, Singh DP. Effect of nano urea application on growth and productivity of rice (*Oryza sativa* L.) under midland situation of Bastar region. The Pharma Innovation Journal. 2022;11(6):185-187.
21. Bharti KS, Sharma G, Pandey D, Keshry PK, Chaure NK. Effect of nitrogen management through nano fertilizer in rice (*Oryza sativa* L.). International Journal of Chemical Research and development. 2022;4(1):25-27.
22. Apoorva MR, Chandrasekhar PR, Padmaja G. Effect of zinc with special references to nano zinc carrier on yield, nutrient content and uptake by rice (*Oryza sativa* L.). International Journal of Current Microbiology and Applied Sciences. 2017;6(8):1057-1063.