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Effect of nano fertilizers mediated on nutrient uptake on rice crop and chemical properties of soil

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Abstract
The increasing demand for sustainable agricultural practices necessitates novel approaches to nutrient management, especially for major crops such as rice (*Oryza sativa* L.). The objective of this study is to evaluate the potential of integrating nano-fertilizers with conventional fertilizers to optimize nutrient use efficiency and enhance soil health in rice cultivation. A field experiment was conducted during 2022-23 at the Crop Research Station, Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut (UP), using thirteen treatments and three replications in a randomized block design. The treatments included nano zinc (Zn) spray, bio-stimulant spray and different combinations of 100% and 75% recommended dose of fertilizers (RDF) with NPK consortia. These treatments resulted in improved nutrient (nitrogen, phosphorus, potassium and zinc) content in rice grains as well as significant increase in grain and straw yields. Additionally, T_{13} displayed the highest soil organic carbon and nutrient content, indicating increased residual soil fertility, post transplantation application of 75% NPK + NPK consortia + NPK spray + bio-stimulant spray+nano zinc spray emerged as the most effective and sustainable form of nutrient management in rice cultivation. This integrated approach not only optimizes fertilizer use but also enhances soil health and economic benefits, thereby boosting rice production.

Keywords: Rice, *Oryza sativa*, nano-fertilizers, nutrient uptake, soil health

Introduction

Rice crops are among the oldest cereal crops, as they are the main source of food, and rice is the most important among these crops due to its strategic role in ensuring food security. About half of the world's population depends primarily on rice (*Oryza sativa* L.) for their food. About 20 species of the Oryza genus are recognized, but almost all cultivated rice (*Oryza sativa* L.) is cultivated in an area of more than 165.25 million hectares, with an estimated production of 503.27 million metric tons per year worldwide (USDA, 2022). Rice is the most important cereal crop providing more than 50 per cent of the world's staple diet and 27 per cent of the energy supply, however, improper use of fertilizers is leading to degradation of soil quality, which may be due to several reasons such as changes in physical and chemical properties of soil and reduction in microbial activity. Fertilizer leaching, irrigation with polluted water and crop rotation are the main causes. Soil application of fertilizers as base and top dressing is common in rice cultivation. Conventional granular urea is one of the most important nitrogenous fertilizers in the country, but the efficiency of nitrogen application is only 30-50 per cent due to rapid chemical changes, leaching and volatilization. Rice plants require a certain amount of nutrients in a specific form at a specific time for their growth and development. Nitrogen plays a vital role in rice cultivation. Nitrogen is an essential plant nutrient which is a constituent of amino acids, nucleic acids, nucleotides, chlorophyll, enzymes and hormones. Nitrogen promotes vigorous plant growth and improves grain yield and quality through greater tillering, leaf area development, grain formation, grain filling and protein synthesis. Nitrogen is highly mobile in plants and soils. Nitrogen is the most limiting element in almost all Indian soils. Therefore, proper use of nitrogen fertilizers is extremely important for improving crop growth and grain yield, especially in intensive farming systems. Nitrogen is mostly supplied by urea fertilizer, which is highly mobile in the soil and causes evaporation and surface runoff problems. Urea releases harmful pollutants into the air and soil water. It puts high concentrations of ammonia in the soil making it even more acidic, and thus slows down soil fertility. Thus the use of urea causes water and soil pollution and puts a financial burden on farmers. Soil waterlogging, which is common in rice production, causes zinc deficiency. Field studies have shown that seed treatments, foliar sprays or a combination of these can effectively enhance zinc uptake and accumulation in the grain.

Materials and Methods

The field experiment was carried out at Crop Research Station, Chirauri of Sardar Vallabhbhai University of Agriculture and Technology, Meerut (Uttar Pradesh) at 290 40' N latitude and 770 42' E longitude and at an altitude of 237 m above sea level. Meerut is located in the centre of western Uttar Pradesh and has a subtropical climate. The experimental area had a flat topography with good drainage system. Soil samples were collected from a depth of 0–15 cm from each plot of the experiment before transplanting and a composite sample was prepared to determine its physical and chemical properties. The soil of the experimental area was sandy loam in texture, low in organic carbon and available nitrogen, medium in available phosphorus and available potassium, and almost neutral in reaction. Field experiment was conducted in completely randomized block design (CRBD) with three replications and 13 treatments. (T_1) Control, (T_2) 100%RDF (NPK- 150:75:60), (T_3) 100%NPK + Nano Zn Spray, (T_4) 100%NPK + Bio-Stimulant Spray, (T_5) 100%NPK + Seed Treatment with NPK consortia, (T_6) 75%NPK + NPK Consortia @ 250 ml in 3 lit water 60 kg-^{1}, (T_7) 75% NPK + NPK spray @ 15gm per lit, (T_8) 75% NPK + NPK Consortia + Nano urea spray, (T_9) 75% NPK + NPK Consortia + NPK Spray, (T_{10}) 75%NPK + NPK Consortia + Bio-stimulant, (T_{11}) 75%NPK + NPK Consortia + Nano Zn spray, (T_{11}) 75% NPK + NPK Consortia + Nano urea spray + Nano Zn Spray and 75% NPK + NPK Consortia + NPK spray + Bio-stimulant Spray + Nano Zn Spray were tested in Randomized Block Design (RBD) with three replications.

Results

Yield

Reported that the foliar application of Consortia + Nano urea spray significantly increased yield attributes except 1000 grain weight. Application of nano fertilizers had significant impact on grain (44.5 q ha^{-1}) and straw yield (52.8 q ha^{-1}). Data pertaining to yield is recorded and presented in table 1. Among the applied treatments, T_{12} (75% NPK + NPK Consortia + Nano urea spray + Nano Zn Spray) observed significantly higher grain yield 44.5 q ha^{-1} and straw yield 52.8 q ha^{-1}. Foliar application of nano urea fertilizer increase rice grain yield and straw yield because it increases rate of photosynthesis, higher dry matter produce, photosynthate accumulate and translocation to the economic part of the plant. A similar result was observed by Mehta.

Nutrient uptake

The data about nutrient uptake (kg ha^{-1}) at the harvest stage of rice were presented in Table 1, respectively. Significantly highest Total Uptake of Nitrogen (83.4 kg ha^{-1}), Phosphorus (23.1 kg ha^{-1}), Potassium (84.7 kg ha^{-1}) and Zinc (467.8 g ha^{-1}) was recorded in the treatment 75% NPK + NPK Consortia + NPK spray + Bio-stimulant Spray + Nano Zn Spray (After transplanting) followed by the treatment T_1- Control. The primary nutrient absorption affected by nitrogen amount and method of nanofertilizer nutrient application under different treatments is shown in Table 2. The total absorption of nitrogen by rice differed significantly among the different treatments. Application of 75% NPK + NPK Consortia + NPK Spray + Bio-stimulant Spray + Nano Zinc Spray (after transplanting) showed significant increase in total nitrogen absorption as compared to application of 00% NPK + Bio-stimulant Spray (after transplanting). Uptake of micronutrients in the crop varied significantly due to the treatment effects. Total uptake of zinc by the rice was found superior in the Application of 75% NPK + NPK Consortia + NPK spray + Bio-stimulant Spray + Nano Zn Spray (After transplanting). Zinc treatment through leaves would have increased zinc absorption by the leaf epidermis and reaccumulation into the rice grain via the phloem, due to multiple zinc-regulated transporter membranes that regulate this process. Improved nutrient absorption may also be a result of the long-term nutrient release pattern of nano fertilizers. Improved growth characteristics enable plants to absorb soil micronutrients more effectively. (*Subramanian*, 2015) [16].

Soil properties

Significant variation in soil fertility was observed under different micronutrient management, which was due to the removal and addition of different crops. Higher available nitrogen (212.4 kg ha^{-1}), phosphorus (17.9 kg ha^{-1}), potassium (214.7 kg ha^{-1}), zinc (0.98 mg ha^{-1}) and organic carbon (0.42%) after harvest of rice, and the lowest available nitrogen (201.4 kg ha^{-1}), phosphorus (15.0 kg ha^{-1}), potassium (196.6 kg ha^{-1}), zinc (0.42 mg ha^{-1}) and organic carbon (0.38%) after harvest of rice. Application of nano zinc alone or with 100% NPK significantly increased soil available nitrogen compared to 100% NPK, possibly leading to better root growth. Available soil nutrients (available N, P, K and Zinc) were significantly lower in unfertilized plots, while it was highest in plots receiving 75% NPK + NPK consortia + NPK spray + bio-stimulant spray + nano zinc spray, which was at par with 75% NPK + NPK consortia + nano urea spray + nano zinc spray, which was significantly better than 100% NPK. Positive nutrient balance in soil has been observed with the application of NPK by Meena *et al.* (2012) [11] and Sharma *et al.* (2020) [14].

Table 1: Effect of Nano fertilizer on yield and total nutrient uptake nitrogen, Phosphorus, potassium (kgha-1)and zinc (g ha-1) on rice crop at harvest

Treatments	Grains (q/ha)	Straw (q/ha)	Harvest Index (%)	Total Nitrogen uptake (kgha-1)	Total Phosphorus uptake (kgha-1)	Total potassium uptake (kgha-1)	Total Zinc uptake (gha-1)
T_1- Control	21.3	33.8	38.6				
T_2- 100%RDF (NPK- 150:75:60)	35.2	48.0	42.3	38.0	8.2	44.8	189.4
T_3- 100%NPK + Nano Zn Spray	43.4	52.0	45.5	65.2	15.5	71.4	293.6
T_4- 100%NPK + Bio-Stimulant Spray	41.3	50.8	44.8	81.1	21.2	82.4	451.7
T_5- 100%NPK + Seed Treatment with NPK consortia	36.2	48.3	42.8	77.3	19.8	79.6	424.9
T_6- 75%NPK + NPK Consortia @ 250 ml in 3 lit water 60 kg-1	30.6	46.4	39.7	66.6	16.2	72.9	306.0

T_7- 75% NPK + NPK spray @ 15gm per lit	33.5	47.8	41.2	56.5	12.9	65.8	265.2
T_8- 75% NPK + NPK Consortia + Nano urea spray	32.2	46.7	40.8	62.1	14.6	69.8	283.9
T_9- 75% NPK + NPK Consortia + NPK Spray	39.2	49.4	44.2	59.7	13.7	67.6	274.4
T_{10}- 75%NPK + NPK Consortia + Bio stimulant	40.1	50.1	44.4	72.6	18.1	76.2	381.9
T_{11}- 75%NPK + NPK Consortia + Nano Zn spray	37.2	49.1	43.1	75.0	18.9	77.4	400.2
T_{12}- 75% NPK + NPK Consortia + Nano urea spray + Nano Zn Spray	44.5	52.8	45.7	69.8	17.1	74.3	351.7
T_{13}- 75% NPK + NPK Consortia + NPK spray + Bio-stimulant Spray + Nano Zn Spray	45.7	53.4	46.1	83.4	23.1	84.7	467.8
S.Em (±)	1.5	1.8	1.6	85.8	25.0	86.9	480.4
C.D. (P=0.05)	4.2	5.2	4.6	2.7	0.7	2.8	14.4
				7.7	2.0	8.1	41.2

Table 2: Effect of Nano fertilizer on bulk density(Mgm^{-3}), EC(dSm^{-1}), soil pH, Organic carbon (%), N, P, K (kg ha-1) and Zinc (mg kg-1) in soil on rice crop

Treatments	Bulk density (Mg m-3)	Soil pH	EC (dSm-1)	Organic carbon (%)	Available Nitrogen (kg ha-1)	Available Phosphorus (kg ha-1)	Available Potassium (kg ha-1)	Available zinc (mg kg-1)
T_1- Control	1.55	7.83	0.20	0.38	201.4	15.0	196.6	0.42
T_2- 100%RDF (NPK- 150:75:60)	1.49	7.75	0.22	0.43	206.9	15.6	208.7	0.70
T_3- 100%NPK + Nano Zn Spray	1.42	7.71	0.24	0.46	210.6	17.5	212.7	0.95
T_4- 100%NPK + Bio-Stimulant Spray	1.42	7.71	0.24	0.46	209.5	17.1	212.2	0.93
T_5- 100%NPK + Seed Treatment with NPK consortia	1.48	7.74	0.22	0.43	207.4	15.8	209.2	0.76
T_6- 75%NPK + NPK Consortia @ 250 ml in 3 lit water 60 kg-1	1.52	7.81	0.21	0.41	205.1	15.0	199.4	0.57
T_7- 75% NPK + NPK spray @ 15gm per lit	1.50	7.79	0.22	0.42	206.1	15.4	206.4	0.67
T_8- 75% NPK + NPK Consortia + Nano urea spray	1.51	7.80	0.22	0.42	205.7	15.1	204.5	0.62
T_9- 75% NPK + NPK Consortia + NPK Spray	1.44	7.73	0.23	0.44	208.1	16.3	210.4	0.89
T_{10}- 75%NPK + NPK Consortia + Bio stimulant	1.43	7.72	0.23	0.45	208.6	16.5	211.6	0.91
T_{11}- 75%NPK + NPK Consortia + Nano Zn spray	1.44	7.73	0.23	0.44	207.8	16.1	209.7	0.80
T_{12}- 75% NPK + NPK Consortia + Nano urea spray + Nano Zn Spray	1.41	7.70	0.24	0.47	211.5	17.7	213.8	0.96
T_{13}- 75% NPK + NPK Consortia + NPK spray + Bio-stimulant Spray + Nano Zn Spray	1.41	7.70	0.25	0.48	212.4	17.9	214.7	0.98
S.Em (±)	0.05	0.28	0.01	0.02	7.5	0.7	7.6	0.03
C.D. (P=0.05)	N.S	N.S	N.S	0.05	22.4	2.1	22.7	0.09

Conclusion

On the basis of the foregoing facts it remains no more obscure that different nutrient management practices had significant effect on yield attributes, yield, nutrient uptake by crop and soil properties. Rice crop fertilized with 75% NPK + NPK Consortia + NPK Spray + Bio-stimulant Spray + Nano Zinc Spray achieved optimum higher yield and monetary benefit than 100% NPK. Nutrient content in plant tissues and absorption were also highest with the treatments. Moreover, residual soil fertility also indicated a positive trend. Alternatively, the crop can be fertilized with 75% NPK + NPK Consortia + NPK Spray + Bio-stimulant Spray + Nano Zinc Spray to be equivalent to the best treatment.

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