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Response of nano fertilizer mediated approaches for nutrient management on rice (*Oryza sativa* L.) in Typic Ustochrepts Soil of Western U.P.

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Abstract

The increasing demand for sustainable agricultural practices has necessitated novel approaches for nutrient management, especially in major crops such as rice (*Oryza sativa* L.). This study studies the potential of integrating nano-fertilizers with conventional fertilizers to optimize nutrient use efficiency and enhance soil health attributes in rice cultivation. 13 treatments and three replicates in a randomized block design. The treatments included nano zinc spray, various combinations of inorganic fertilizers with bio-stimulant spray. The findings revealed significant variations in growth parameters (plant height, number of tillers, number of effective tillers, dry matter accumulation (g)) and yield characteristics among different treatments. The treatment containing 75% NPK + NPK consortia + NPK spray + Bio-stimulant spray + Nano zinc spray (T_{13}) consistently recorded significant improvement in the nutrient (nitrogen, phosphorus, potassium and zinc) content in rice grains as well as grain and straw yield. Additionally, T_{13} displayed the highest soil organic carbon and nutrient content, indicating increased residual soil fertility. Economically, the T_{13} treatment achieved the most favourable benefit-cost ratio as well as the highest gross and net returns, demonstrating its economic advantage over the standard 100% NPK treatment. Post transplantation use of inorganic fertilizers, consortia, bio-stimulant sprays and zinc sprays have emerged as the most effective and sustainable strategies for nutrient management in rice cultivation. This integrated approach not only optimizes fertilizer

Keywords: Nano fertilizer, consortia, yield and economic

Introduction

Rice (*Oryza sativa* L.) is the world's most important crop and the primary food source for half of the world's population. A total of 49% of calories consumed by the human population comes from rice, wheat and maize, where 23% is provided by rice, 17% by wheat and 9% by maize. Thus, almost one-fourth of the calories consumed by the entire world population comes from rice. Apart from this, rice also plays an important role both economically and in terms of food security. Rice is cultivated in an area of 43.42 million hectares, with a production of 105.25 million tonnes and an average productivity of 24.23 quintals per hectare. It accounts for about 40.92% of the total food grain production and 44.07% of the cereal production of the country. Farmers usually apply additional nitrogen in the form of granular urea and DAP to ensure higher grain yield. Furthermore, phosphorus absorption is a major constraint in tropical soils, interfering with plant uptake and polluting aquatic ecosystems through acidification, toxic algae blooms, and increased pollution of nearby rivers and wells. Continuous use of inorganic fertilizers in paddy fields leads to accumulation of heavy metals in plant tissues, affecting their nutritional quality. Therefore, we should adopt alternative types and techniques of fertilizer use to maintain adequate plant nutrition without polluting the ecosystem. Foliar application of nano fertilizers has proven to be the most effective way to overcome nutrient deficiencies and improve the quality and yield of crop produce and it also reduces environmental pollution and improves nutrient utilization by reducing the amount of fertilizer applied to the soil. In agriculture, foliar application of nanofertilizers has emerged as a promising technology that offers potential solutions for improving crop yield, reducing environmental impact and increasing nutrient absorption efficiency. Rice plants require large amounts of mineral nutrients including nitrogen for their growth, development and grain production. Nano fertilizer increases absorption by plants as well as reduces environmental harm. For a stable and controlled flow of nutrients into the soil, nano nitrogen is a suitable alternative to conventional fertilizers. Without compromising soil productivity, Nano Urea improves crop production, soil health and nutritional quality while reducing the requirement of conventional urea by half or more. Zinc is an essential trace element required by both plants and animals in small but significant quantities. Many microorganisms exist in the range of hundreds of nanometers to tens of micrometers. Zinc has high specific surface area and superior surface reactivity due to their small particle size, which contributes to their attractive antibacterial properties. Zinc oxide is a biocompatible substance.

Materials and Methods

The field experiment was conducted at Crop Research Centre, Chirodi of Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut (Uttar Pradesh). Meerut is located in the middle of western Uttar Pradesh and has a subtropical climate. The experimental field had flat topography and good drainage system. Soil samples were collected from each plot of the experiment from a depth of 0-15 cm before transplanting and a composite sample was taken to determine its physical and chemical properties. The soil of the experimental field was sandy loam, low in organic carbon and available nitrogen, medium in available phosphorus, medium in available potassium and almost neutral in response. The field experiment was conducted in a completely randomized block design with three replications and 13 treatments. (T_1) Control, (T_2) 100%RDF (NPK- 150:75:60), (T_3) 100%NPK + Nano Zinc spray (after transplanting), (T_4) 100%NPK + Bio-stimulant spray (after transplanting), (T_5) Seed treatment with 100%NPK + NPK consortia, (T_6) 75%NPK + NPK consortia @ 250 ml in 3 liter water at 60 kg-1, (T_7) 75%NPK + NPK spray @ 15 gm per liter (after transplanting), (T_8) 75%NPK + NPK consortia + Nano Urea spray (after transplanting), (T_9) 75%NPK + NPK consortia + NPK spray (after transplanting), (T_{10}) 75%NPK + NPK Consortia + Bio-stimulant (after planting), (T_{11}) 75%NPK + NPK Consortia + Nano Zinc spray (after planting), (T_{12}) 75%NPK + NPK Consortia + Nano Urea Spray + Nano Zinc spray (after planting) and (T_{13}) 75%NPK + NPK Consortia + NPK Spray + Bio-stimulant spray + Nano Zinc spray (after planting) were tested in a completely randomized block design with three replications.

Results and Discussion

Growth parameter

In growth parameters maximum plant height (60.9 cm), number of tillers (65.3), leaf area index (6.88), dry matter accumulation (946.3 g m^{-2}), panicle length (26.7 cm) and test weight (20.6 g) were recorded in 75% NPK + NPK consortia + NPK spray + bio-stimulant spray + nano Zn spray treatment and minimum data was recorded in control treatment, plant height (90.7 cm), number of tillers (226.3 m^{-2}), leaf area index (3.18), dry matter accumulation (919.8 g m^{-2}), panicle length (20.9 cm) and test weight (19.7 g). Combined use of $N_{100}P_{30}K_{40}$ + root dipping with 2% DAP + foliar application of 2% Nano DAP at MT and PI stage significantly increased the yield characteristics as compared to T2 and T3 at maturity stage. Foliar application of $N_{100}P_{30}K_{40}$ + root dipping + 2% Nano DAP with 2% DAP at MT and PI stage significantly increased the number of tillers m^{-2} at all stages of crop growth as compared to T_2 and T_3. Higher crop growth rate and 50% relative to flowering and maturity were recorded under foliar application of $N_{100}P_{30}K_{40}$ + root dipping + 2% Nano DAP with 2% DAP at MT and PI stage. Increased vegetative growth with more nitrogen supply to the plant may be the primary reason for the increase in plant height with increased fertilizer treatment. Higher nitrogen availability to the plant during active tillering stage may lead to better tillers due to the effect of nano urea application by Yomso and Menon 2021. Nanofertilizer can control the nutrient exudation *a*nd provide the right amount of nutrients required by the crops in proper proportion and boost productivity while ensuring environmental safety.

Yield Parameter

The highest grain yield (45.7 quintals per hectare) was recorded in 75% NPK + NPK Consortia + NPK Spray + Bio-stimulant Spray + Nano Zinc Spray (after transplanting) treatment, which was at par with 75% NPK + NPK Consortia + Nano Urea Spray + Nano Zinc Spray (after transplanting) recorded higher grain yield over control treatment. The crop index was significantly affected by different treatments related to nutrient management. Among different nutrient management treatments, the lowest crop index (38.6%) was found in control treatment, while the highest crop index (46.1%) was recorded in 75% NPK, Consortia. The use of nano fertilizers has increased the yield. The overall study followed the same trend which showed that 75% NPK + NPK Consortia + NPK Spray + Bio-stimulant Spray + Nano Zinc Spray is the best treatment followed by 75% NPK + NPK Consortia + NPK Spray + Bio-stimulant Spray + Nano Zinc Spray.

In the data shown, the cost of cultivation for the crop grown without application of nutrient is Rs.25482/ha whereas the maximum cost recorded was Rs.35360/ha. 75% NPK + NPK Consortia + NPK Spray + Bio-stimulant Spray + Nano Zinc Spray is due to use of different sources of nutrients. Gross profit per hectare for the crop grown without nutrient application was Rs. 61075 and maximum gross profit per hectare of Rs. 127215 was recorded under the treatment of 75% NPK + NPK Consortia + NPK Spray + Bio Stimulant Spray + Nano Zinc Spray. Highest net profit was Rs. 91855 per hectare, which was same as 75% NPK + NPK Consortia + Nano Urea Spray + Nano Zinc Spray and 100% NPK + Nano Zinc Spray. Lowest net profit was recorded in treatment Control. B:C ratio was highest (2.62) in the crop grown with 75% NPK + NPK Consortia + NPK Spray + Bio Stimulant Spray + Nano Zn Spray treatment and lowest (1.40) in the control.

Table 1: Effect of nutrient management on plant height (cm), Number of tillers, leaf area index, dry matter accumulation (g), Panicle length (cm) and Filled grains panicle^{-1} at harvest under rice crop.

Treatments	Plant height (cm)	Number of tillers	Leaf area index	Dry matter accumulation (g)	Panicle length (cm)	Filled grains panicle$_{-1}$
T_1- Control	78.6	42.0	4.40	631.3	20.9	82.9
T_2- 100%RDF (NPK- 150:75:60)	98.4	48.5	5.46	771.8	22.9	100.6
T_3- 100%NPK + Nano Zn Spray (After transplanting)	110.7	63.2	6.32	872.1	24.9	110.9
T_4- 100%NPK + Bio-Stimulant Spray (After transplanting)	108.6	62.5	6.25	867.3	24.8	110.2
T_5- 100%NPK + Seed Treatment with NPK consortia	98.4	58.3	5.22	775.4	23.0	100.8

T_{6}- 75%NPK + NPK Consortia @ 250 ml in 3 lit water 60 kg^{-1}	97.1	51.4	5.07	756.3	22.1	97.8
T_{7}- 75% NPK + NPK spray @ 15gm per lit (After transplanting)	97.9	48.3	5.11	763.6	22.8	100.0
T_{8}- 75% NPK + NPK Consortia + Nano urea spray (After transplanting)	97.8	51.6	5.24	760.3	22.3	98.3
T_{9}- 75% NPK + NPK Consortia + NPK Spray (After transplanting)	104.8	58.5	6.19	859.0	24.3	107.5
T_{10}- 75%NPK + NPK Consortia + Bio stimulant (After transplanting)	105.5	58.7	6.23	860.2	24.7	109.8
T_{11}- 75%NPK + NPK Consortia + Nano Zn spray (After transplanting)	104.1	50.2	5.85	857.7	24.3	105.5
T_{12}- 75% NPK + NPK Consortia + Nano urea spray + Nano Zn Spray (After transplanting)	111.4	64.7	6.67	934.4	25.4	112.6
T_{13}- 75% NPK + NPK Consortia + NPK spray + Bio-stimulant Spray + Nano Zn Spray (After transplanting)	113.3	65.3	6.88	946.3	26.7	115.8
S.Em (±)	3.8	2.1	0.22	31.2	0.9	3.9
C.D. (P=0.05)	11.0	6.1	0.63	89.2	2.5	11.2

Table 2: Effect of nutrient management on yield attributes characters and economics of rice

Treatments	**Test weight (g)**	**Grains**	**Straw**	**Harvest index (%)**	**Cost of cultivation (₹ha-1)**	**Gross returns (₹ha-1)**	**Net returns (₹ha-1)**
T_{1}- Control	19.7	21.3	33.8	38.6	25482	61075	35593
T_{2}- 100%RDF (NPK- 150:75:60)	19.9	35.2	48.0	42.3	31096	99360	68264
T_{3}- 100%NPK + Nano Zn Spray (After transplanting)	20.3	43.4	52.0	45.5	33963	121070	87107
T_{4}- 100%NPK + Bio-Stimulant Spray (After transplanting)	20.2	41.3	50.8	44.8	33723	115475	81752
T_{5}- 100%NPK + Seed Treatment with NPK consortia	19.9	36.2	48.3	42.8	31475	101970	70495
T_{6}- 75%NPK + NPK Consortia @ 250 ml in 3 lit water 60 kg^{-1}	19.8	30.6	46.4	39.7	30280	87310	57030
T_{7}- 75% NPK + NPK spray @ 15gm per lit (After transplanting)	19.9	33.5	47.8	41.2	30758	94985	64227
T_{8}- 75% NPK + NPK Consortia + Nano urea spray (After transplanting)	19.8	32.2	46.7	40.8	30558	91450	60892
T_{9}- 75% NPK + NPK Consortia + NPK Spray (After transplanting)	20.1	39.2	49.4	44.2	32526	109840	77314
T_{10}- 75%NPK + NPK Consortia + Bio stimulant (After transplanting)	20.2	40.1	50.1	44.4	32780	112275	79495
T_{11}- 75%NPK + NPK Consortia + Nano Zn spray (After transplanting)	20.1	37.2	49.1	43.1	31723	104680	72957
T_{12}- 75% NPK + NPK Consortia + Nano urea spray + Nano Zn Spray (After transplanting)	20.3	44.5	52.8	45.7	34443	124035	89592
T_{13}- 75% NPK + NPK Consortia + NPK spray + Bio-stimulant Spray + Nano Zn Spray (After transplanting)	20.6	45.7	53.4	46.1	35360	127215	91855
S.Em (±)	0.7	1.5	1.8	1.6	-	4056	2864
C.D. (P=0.05)	NS	4.2	5.2	4.6	-	11612	8200

Conclusion

It is further evident that different nutrition management practices based on the given nutrients provide significant growth development, grain yield and economic benefits. Rice crop fertilized with ***75%*** NPK, consortium, NPK spray, bio-stimulant spray and nano zinc spray showed favorable growth and gave higher yield and positive profit as compared to ***100%*** NPK. The results of this research will also be beneficial for other studies related to the combination of inorganic, organic and nano fertilizers in agriculture field.

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