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Significance of Nano N, P, K and $ZnSo_4$ fertilizers on soil fertility, nutrient uptake and yield of rice production

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Abstract
The field experiment was carried out in the farmer's field, Vittukkatti village, Thiruthuraipoondi taluk, Thiruvarur district, during June – October 2020 to evaluate the effect of Nano N, P, K and $ZnSO_4$ on rice production and its soil fertility. The experiment was laid out in Randomized Block Design (RBD) with nine treatments *viz*., T_1 - control,T_2 - 100% RDF (120: 40:40 N, P, K kg ha^{-1}), T_3 - 100% Nano N, P, K (25 kg ha^{-1}),T_4-75% RDF + 25% Nano N, P, K + $ZnSO_4$ @ 25 kg ha^{-1} (Soil application),T_5 - 75% RDF + 25% Nano N, P, K + $ZnSO_4$ @ 0.5% (foliar application),T_6 - 50% RDF + 50% Nano N, P, K + $ZnSO_4$ @ 25 kg ha^{-1}(soil application),T_7 - 50% RDF + 50% Nano N, P, K + $ZnSO_4$ @ 0.5% (foliar application),T_8 - 25% RDF + 75% Nano N, P, K + $ZnSO_4$ @ 25 kg ha^{-1}(Soil application),T_9 - 25% RDF + 75% Nano N, P, K + $ZnSO_4$ @ 0.5% (foliar application) replicated thrice. The experiment results proved that the combined application of conventional and Nano N, P, K along with different methods of $ZnSO_4$ application had a positive influence on most of the growth parameters which leads to enhanced nutrient uptake of rice. Among the treatments, application of 50% RDF + 50% Nano N, P, K + $ZnSO_4$ @ 25 kg ha^{-1}(T_6) showed its supremacy in enhancing the nutrient uptake of N, P, K (135.4, 24.1 and 126.0 kg ha^{-1}) and least available of 188.9, 15.12 and 187.0 kg ha^{-1} respectively. Experiment results revealed that 50% RDF + 50% Nano N, P, K and $ZnSO_4$soil application @ 25 kg ha^{-1}(T_6) has recorded the higher grain yield percentage of 10.1 and straw yield percentage of 8.2 than the other treatment next in order.

Keywords: nano n, p, k fertilizers, rice, $znso_4$

Introduction

The current agriculture system faces several challenges, the most important being the ability to feed the increasing world population and mitigate climate change. For over half of the population, rice (*Oryza sativa* L.) is considered as one the most important staple food crop on the planet (Dangwal *et al*., 2010) [5]. In India total area of rice cultivation with 43.78 m ha^{-1} and average productivity of 4.05 t ha^{-1} (USDA report 2020). In Tamil Nādu, rice is cultivated in an area of 18.04 lakhs hectare with a production of 63.08 lakh metric tonnes and productivity of 2.8 tonnes ha^{-1}. Improving the yield and quality of food, fertilizers play a vital part especially for those cultivars which are high-yielding and fertilizer responsive. Rice needs huge amounts of inorganic data sources for better growth and yield. Rice yield is influenced by soil conditions as well as the availability of nutrients such as Nitrogen, Phosphorous, Potassium, Sulfur, and Zinc (Ghasemi *et al*., 2017) [7]. However, fertilizer is the main input to increase agricultural production and productivity of the soil. The plants require a specific amount of some nutrients in a specific form to be added in time for their growth and development. The use of conventional fertilizers causes major environmental problems such as heavy metal accumulation in soil and plant systems (Abdel *et al*., 2017) [1]. Therefore modern ideas of nano fertilizers in the field of agronomy is to increase the crop yield efficiency and diminish losses of nutrients in the soil. Compared to conventional fertilizers their supplemental pattern of nutrients for plants needs minimizes leaching and improves fertilizer use efficiency (Subbaro *et al*., 2013). Further, Nano fertilizers provide the major nutrients to the crop as per the requirement in a phased manner as it contains nutrients and growth promoters encapsulated in Nanoscale polymers. It is designed to deliver nutrients use efficiency can be improved (Manikandan and Subramanian. 2016) [12].
Zinc is also considered the fourth major yield-limiting nutrient in India after nitrogen, phosphorus and potassium. Zinc is an essential micronutrient and plays a key role in chlorophyll formation, growth hormone stimulation, enzymatic activity and reproductive processes (Thenuva *et al*., 2014). However, zinc deficiency in soil is a major problem and thus, adequate supply is recommended to machinate (Ram *et al*., 2020) [16]. Foliar or Soil applications of fertilizers under field conditions have proved to be highly effective and can be a practical way to maximize the zinc accumulation and uptake in grains. Hence there is a need to have a new formulation of zinc or method and time of application with improved use efficiency for better crop performance with less input (Jangid *et al*., 2019) [10]. However, studies need to be carried out on crops like rice to know the nutrient use efficiency by using Nano fertilizers. Imbalanced and excess uses of conventional fertilizers need to be discouraged to reduce the input cost and also to enhance the nutrient use efficiency through proper methods of application. Hence, the present study was conducted, to assess the nutrient uptake, post-harvest soil fertility status

and yield increase of rice by the application of Nano N, P, K and $ZnSO_4$ fertilizers.

Materials and method

A field experiment was carried out in 2020 at farmer's field Vittukatti village, Thiruthuraipoondi Taluk, Thiruvarur District, Tamil Nadu, to investigate the response of Nano N, P, K and $ZnSo_4$ application on rice production. The experiment field is geographically situated at 10º33′ North Latitude and 79º37′ East Longitude and an altitude of +6 m above mean sea level. The experiment farm is characterized by a tropical climate with a mean annual rainfall of 323.1 mm. The soils of the experiment field were clay loam in texture. The available nutrient status (N, P, K) of the soil was low, medium and high respectively. The experiment was conducted during the kuruvai season (July- Oct 2020), with a short duration rice variety CO-51 as the test crop. The experiment was laid out in Randomized Block Design (RBD) with three replications and 9 treatments combination and experimental plots were laid out with dimensions as Gross plot area (5.1 m × 4 m) and Net plot area (4.5 m × 3.6 m). The treatments *viz*., T_1 - control,T_2 - 100% RDF (120: 40:40 N, P, K kg ha^{-1}), T_3 - 100% Nano N, P, K (25 kg ha^{-1}),T_4-75% RDF + 25% Nano N, P, K + $ZnSO_4$ @ 25 kg ha^{-1} (Soil application),T_5 - 75% RDF + 25% Nano N, P, K + $ZnSO_4$ @ 0.5% (foliar application),T_6 - 50% RDF + 50% Nano N, P, K + $ZnSO_4$ @ 25 kg ha^{-1}(soil application),T_7 - 50% RDF + 50% Nano N, P, K + $ZnSO_4$ @ 0.5% (foliar application),T_8 - 25% RDF + 75% Nano N, P, K + $ZnSO_4$ @ 25 kg ha^{-1}(Soil application),T_9 - 25% RDF + 75% Nano N, P, K + $ZnSO_4$ @ 0.5% (foliar application). The recommended dose of nutrients 120:40:40 N, P_2O_5, K_2O kg ha^{-1} was applied through both conventional fertilizers (Urea, DAP, and MOP) and granular forms of Nano N, P, K fertilizers for the experiment under irrigated conditions. The appropriate amount of fertilizers (conventional and Nano fertilizers) can be calculated and applied as per the treatment schedule. The $ZnSO_4$ at the rate of 25 kg ha^{-1} was applied as soil broadcasting (basal) and 0.5% foliar sprays as per the treatment schedule. The experimental field soil texture is clay loam having pH of 6.69, EC 0.32 dSm^{-1}, low in available of N (210.4 kg ha^{-1}), medium in available P (18.8 kg ha^{-1}) and high in available K (293.8 kg ha^{-1}). The soil samples collected at 30 cm depth after harvest were analyzed to assess the available nutrients *viz*., N, P_2O_5, K_2O and $ZnSO_4$. The plant samples were analyzed for their nutrient contents (N, P, K and Zn SO_4) by following the standard procedures and the nutrient uptake was calculated. The mean values were used for statistical analysis as suggested by Panse and Sukhatme (1978) [14].

Results and discussion

Growth and yield attributes

The growth and yield components *viz*., Plant height, LAI, number of tillers and DMP in various stages of rice growth and productive tillers m^{-2}, number of filled grains $panicles^{-1}$was enhanced due to combined application of conventional and Nano N, P, K fertilizers (Table 1). The maximum growth and yield attributes were recorded in 50% of RDF + 50 % of Nano N, P, K + soil application of $ZnSO_4$@ 25 kg ha^{-1} (T_6) *viz*., plant height of 51.3, 78.5 and 95.2 cm at tillering, flowering and harvest stage respectively, LAI of 5.96 at flowering stage, number of tillers $hills^{-1}$ of 25, DMP of 13893 kg ha^{-1} at harvest stage of the crop. Besides, the yield attributes like higher number of productive tillers m^{-2} (375) and filled grains $panicle^{-1}$ (127) at harvest, during the crop period. This fact indicates that the combined application of nano and conventional fertilizers encourages the plant to absorb and utilize the nutrients efficiently. It may create a continuous nutritional balance for the different growth stages of the rice plant especially nanomaterial which stimulates crop growth, improve the soil environment and promote crop growth metabolism. Especially, the increase in plant height by the application of nano fertilizer and its physiological role in stimulating porphyrin molecules and important metabolic compounds such as chlorophyll and cytochrome pigments necessary for photosynthesis and respiration as well as coenzymes that activate phosphorous which are essential for the function of many enzymes and the production of amino acids used in protein synthesis. Besides, zinc acts as an activator of enzymes in plants and is directly involved in the biosynthesis of auxin, when is applied as soil application compares to foliar spray, which produces more cells and dry matter that in turn will be stored in seeds as a sink. Similar results were obtained by Al-juthery and Saadoun (2019) [2], Rop *et al*. (2019) [17], Mahmoud and Swaefy (2020) [11].

Yield

The grain yield and straw yield as influenced by the integrated use of Nano and conventional fertilizers were presented in (Table 2). Among the treatments imposed, 50% RDF + 50% Nano N, P, K and $ZnSO_4$ 25 kg ha^{-1} recorded a significantly higher grain yield of 7635 kg ha^{-1} and straw yield of 8609 kg ha^{-1}. The higher grain yield and straw yield was obtained by the effective utilization of resources that increased the performance of the crop. These results conformed with the findings of Chowdhury *et al*., 2014

The influential role played by the Nano form of N, K and their longer duration availability to the crop especially in the later stages (reproductive stage) increased the yield. Further, the active role of Nanoparticles is integrated with other elements and act as a catalyst in increasing the enzymatic reactions due to their bulk surface area. In addition to that, the higher yield is associated with the combined use of Nano N, P, K and conventional fertilizers along with basal organic manures. This increased the availability and uptake of macro and micronutrients. Besides, the application of Zn and its positive interaction with other macronutrients induces biosynthesis of IAA, the activity of auxin and chlorophyll formation which may initiate the primordial for the reproductive part thus favouring the metabolic activities in a plant (EL-Ramady *et al*. 2018) [6]. Present results are concomitant with the findings of Zahedi *et al.* (2020) [22] and Al-Khuzai *et al*. (2020) [3].

Nutrient Uptake

The data about nutrient uptake at the harvest stage of rice were presented in (Table 2). The results revealed that the appreciable significant variation of nutrient uptake was observed due to the application of nano N, P, K and conventional fertilizer with soil application of $ZnSO_4$@ 120:40:40:25 kg ha^{-1}. Here 50% conventional fertilizer + 50% Nano N, P, K and $ZnSO_4$ 25 kg ha^{-1} (T_6) expressed the higher N, P, K uptake of 135.4, 24.1, 126.0 kg ha^{-1}respectively than the other treatments. The higher uptake of NPK due to the nano-based fertilizer formulations confirmed the nutrient availability for a longer period. Through increased specific surface area and number of particles per unit area of a fertilizer that provides more opportunity to contact nano-fertilizers which leads to more penetration and uptake of the nutrient. These results are in line with the findings of Sharmila Rahale (2011) [18], who reported that the longevity of nutrients released by nano and conventional fertilizers is more (> 1000 hrs) and (< 500 hrs) respectively. In addition to that, nano fertilizer appliance soil observed enhanced the obtainable P and K under nano fertilizer treatment than the 100% usual fertilizer due to soil application of zinc sulphate. Similar results were reported by (Rajonee *et al*., 2017) [15]. Since, the application of 50% RDF + 50% Nano N, P, K and $ZnSO_4$ @ 0.5% as a foliar application (T_7) were recorded the maximum total zinc uptake of 349.6 g ha^{-1}. Compared to soil application of micronutrients, the foliar application of $ZnSO_4$ at right time and stage resulted in better growth and development of rice. It also helps in increasing translocation of nutrients into the plant without any loss that contributes to better photosynthetic activity and thereby shows better uptake over other treatments. Moreover, the proper method of nutrient application could be an approach for better uptake and utilization of Zn in the present study. The control treatment (T_1) registered the least total uptake of zinc due to the unavailability of Zn as it is pure no fertilizers applied treatment.

Available Nutrient Status

The data on available nutrient status at the harvesting stage of rice was presented in Table 3. Among the Nano fertilizers added treatments, it was found that the 50% RDF + 50% Nano N, P, K and ZnSO4 @ 25 kg ha^{-1} (T_6) recorded the least available nutrients of 188.9, 15.12 and 187.0 kg ha^{-1} N, P and K respectively, in the soil during the crop period. This might be due to better utilization of released nutrients throughout its crop growth period which is evidenced with higher DMP and higher uptake of N, P and K. However, the available N, P, and K in soil were higher in other treatment combinations. Especially, the highest available nitrogen and phosphorus were found with the treatments RDF alone treatment (T_2) when compared to other treatments. This might be due to the low capturing capacity of nutrients during crop growth, which is evidenced in lesser growth attributes and low yield. The highest soil availability of f 1.398 ppm zinc was noticed in the treatment that received RDF and $ZnSO_4$ 25 kg ha^{-1} (T_4). When compared to the control and no Zinc fertilizers added treatments. These results were corroborated with the findings of He *et al.* (2013) and Gopi (2014) [8].

Conclusion

The utilization of nanotechnology in the field of agriculture is still in its growing stage. An outrageous nutrient insufficiency in agricultural soil has realized exceptional decreases in viability of yield and a huge economic crisis. From the results, the combined application of 50% RDF + 50% Nano N, P, K and $ZnSO_4$ @ 25 kg ha^{-1} (T_6) was found to be optimum in terms of growth and development, fertility status, nutrient uptake and yield of rice. In the nutshell, it can be concluded and recommended that the application of 50% RDF +50% Nano N, P, K with $ZnSO_4$ (soil application) could be a viable option for enhancing the low land rice productivity especially Cauvery deltaic regions of Tamil Nadu.

Table 1: Effects of Nano N, P, K and $ZnSO_4$ on growth and yield attributes of rice

Treatments	Plant height (cm)	No of tillers $hill^{-1}$	LAI	DMP (Kg ha^{-1})	Crop growth rate ($g^{-2}day^{-1}$)	Number of productive tillers m^{-2}	Number of filled grains $panicle^{-1}$	Test weight (g)
T_1	71.4	10	3.08	6314	2.01	176	98	16.41
T_2	77.5	14	3.40	8235	3.25	249	106	16.45
T_3	80.3	16	3.86	8672	3.71	268	109	16.48
T_4	89.6	20	5.43	10586	4.86	329	120	16.60
T_5	84.4	18	4.87	9426	4.18	298	115	16.51
T_6	95.2	25	5.96	13893	5.92	375	127	16.72
T_7	86.6	19	5.05	9719	4.41	312	117	16.58
T_8	92.5	23	5.73	12548	5.02	358	124	16.69
T_9	85.3	18	4.95	9617	4.72	309	116	16.53
SEm±	1.23	0.62	0.09	181.8	-	7.50	1.23	NS
CD(P=0.05)	2.62	1.33	0.20	385.4	-	15.91	2.62	NS

T1 – control
T2 - 100% RDF (120: 40:40 N, P, K kg ha-1)
T3 - 100% Nano N, P, K (25 kg ha-1)
T4 - 75% RDF + 25% Nano N, P, K + ZnSO4 @ 25 kg ha-1 (Soil application)
T5 - 75% RDF + 25% Nano N, P, K + ZnSO4 @ 0.5% (foliar application)
T6 - 50% RDF + 50% Nano N, P, K + ZnSO4 @ 25 kg ha-1(soil application)
T7 - 50% RDF + 50% Nano N, P, K + ZnSO4 @ 0.5% (foliar application)
T8 - 25% RDF + 75% Nano N, P, K + ZnSO4 @ 25 kg ha-1(Soil application)
T9 - 25% RDF + 75% Nano N, P, K + ZnSO4 @ 0.5% (foliar application)

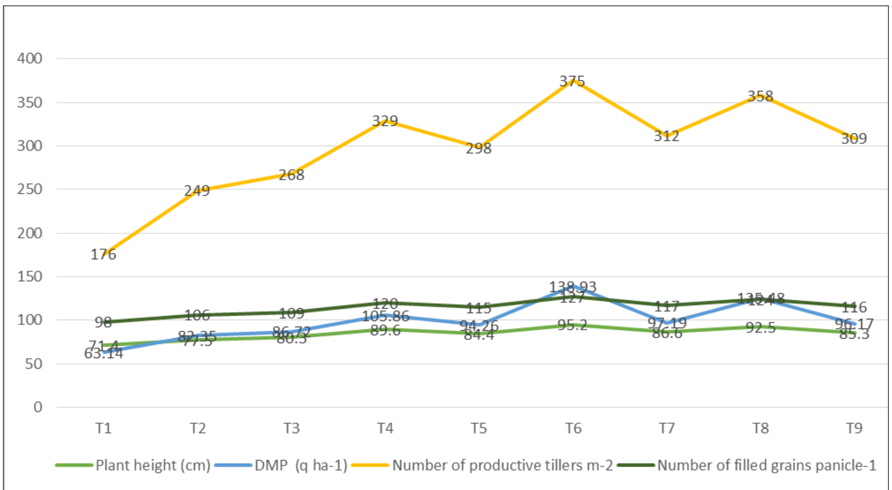

Fig 1: Effects of Nano N, P, K and ZnSO4 on growth and yield attributes of rice

Table 2: Effects of Nano N, P, K and $ZnSO_4$ on yield and nutrient uptake of rice

Treatments	Grain yield (Kg ha^{-1})	Straw yield (Kg ha^{-1})	Harvest index	Nitrogen uptake (Kg ha^{-1})	Phosphorus uptake (Kg ha^{-1})	Potassium Uptake (Kg ha^{-1})	Zinc uptake (g ha^{-1})
T_1	2743	4576	37.46	79.2	7.5	76.3	183.6
T_2	4425	6006	42.42	100.4	11.3	94.3	297.4
T_3	4841	6328	43.35	109.9	13.9	98.7	310.4
T_4	6273	7309	46.18	127.1	19.2	117.5	321.7
T_5	5634	6629	45.94	119.3	16.2	109.8	344.4
T_6	7635	8609	47.00	135.4	24.1	126.0	337.4
T_7	5827	6759	46.29	122.4	17.5	112.5	349.6
T_8	6935	7959	46.56	131.8	21.4	121.1	329.4
T_9	5717	6627	46.31	120.7	16.4	110.9	346.1
SEm±	103.1	113.8	-	1.67	0.70	1.34	2.81
CD(P=0.05)	218.5	241.4	-	3.56	1.50	2.86	5.97

T1 – control
T2 - 100% RDF (120: 40:40 N, P, K kg ha-1)
T3 - 100% Nano N, P, K (25 kg ha-1)
T4 - 75% RDF + 25% Nano N, P, K + ZnSO4 @ 25 kg ha-1 (Soil application)
T5 - 75% RDF + 25% Nano N, P, K + ZnSO4 @ 0.5% (foliar application)
T6 - 50% RDF + 50% Nano N, P, K + ZnSO4 @ 25 kg ha-1(soil application)
T7 - 50% RDF + 50% Nano N, P, K + ZnSO4 @ 0.5% (foliar application)
T8 - 25% RDF + 75% Nano N, P, K + ZnSO4 @ 25 kg ha-1(Soil application)
T9 - 25% RDF + 75% Nano N, P, K + ZnSO4 @ 0.5% (foliar application)

Table 3: Effects of Nano N, P, K and $ZnSO_4$ on Post-harvest soil status of rice

Treatments	Available nitrogen (Kg ha^{-1})	Available Phosphors (Kg ha^{-1})	Available Potassium (Kg ha^{-1})	Available Zinc (ppm)
T_1	180.1	11.53	177.5	0.424
T_2	229.2	22.03	221.6	0.528
T_3	218.9	20.42	217.5	0.574
T_4	180.6	17.47	197.4	1.398
T_5	205.9	19.37	208.5	0.725
T_6	188.9	15.12	187.0	0.938
T_7	203.6	18.55	206.8	0.635
T_8	193.4	16.44	192.0	1.255
T_9	204.1	19.07	207.0	0.680
SEm±	1.25	0.38	0.83	0.019
CD(P=0.05)	2.66	0.82	1.76	0.042

T1: control
T2: 100% RDF (120: 40:40 N, P, K kg ha-1)
T3: 100% Nano N, P, K (25 kg ha-1)
T4: 75% RDF + 25% Nano N, P, K + ZnSO4 @ 25 kg ha-1 (Soil application)
T5: 75% RDF + 25% Nano N, P, K + ZnSO4 @ 0.5% (foliar application)
T6: 50% RDF + 50% Nano N, P, K + ZnSO4 @ 25 kg ha-1(soil application)
T7: 50% RDF + 50% Nano N, P, K + ZnSO4 @ 0.5% (foliar application)
T8: 25% RDF + 75% Nano N, P, K + ZnSO4 @ 25 kg ha-1(Soil application)
T9: 25% RDF + 75% Nano N, P, K + ZnSO4 @ 0.5% (foliar application)

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