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Efficiency of Rock Phosphate and Zinc Oxide Nano Particles on the Yield of Rice in Inceptisols

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Abstract A field experiment was conducted on sandy loam acid inceptisols, OUAT Research Farm, Bhubaneswar to assess the efficiency of Nano Zinc and Nano rock phosphate (NRP) on the yield of hybrid rice var Rajalaxmi, grown in *kharif* season 2013. The results indicated that the yield of rice was significantly increased by 24% with the application of NPK+Nano Zn whereas 21% increased in rice yield by the application of NPK+Zinc sulfate ($ZnSO_4$) over control. Considering the treatments, NPK + Nano Zn increased the rice yield by 7% and 4.8% with the application of NPK + $ZnSO_4$ over nitrogen, phosphorus and potash (NPK), respectively. However, there was no significant yield difference between Nano Zinc and $ZnSO_4$. Comparing between NRP and diammonium phosphate (DAP), DAP was performed better than NRP, to the tune of yield increase by 8.5%. Highest biomass yield of rice was obtained by the application $ZnSO_4$ @ 5 kg/ha. Highest zinc use efficiency (ZnUE), zinc harvest index (ZnHI) and uptake efficiency index (UEI) was obtained with the application of Nano Zinc. It is concluded that Nano Zinc had marginal effect on the yield of rice.

Keywords Nano Zinc, Nano rock phosphate, Hybrid rice, ZnUE, ZnHI.

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Introduction

Agriculture provides food for humans. Increasing current global population, it is necessary to use the modern technology like bio and nano technology in agricultural science. Nano particles which are used to improve fertilizer formulation for increasing uptake in plant cells and by minimizing nutrient loss (Solanki et al. 2015). Solubility and dispersion for mineral micronutrient cause controlled released formulation (Waden and Danesh-Shahraki 2013). Nano sized formulation of mineral micronutrients may improve solubility and dispersion of insoluble nutrients in soil, reduce soil absorption and fixation and increase the bio-availability leads to increased nutrient uptake efficiency. Veronica et al. (2015) showed that nano fertilizer will combine nano devices in order to synchronize the release of fertilizer-N and – P with their uptake by crops, so preventing undesirable nutrient losses to soil, water and air via direct internalization by crops and avoiding the interaction of nutrients with soil, microorganisms, water and air. Nano structure fertilizers due to high surface areas, reactivity with the soil colloids and its mobility, have strong potential to adsorbe on to soil and sediment particles, increase the nutrient use efficiency by slow or controlled release as per biological demands (Kuzma and Verhage 2006). Usually zinc sulfate is used as micronutrient fertilizer. The micropores, which are very small pores that occur within the soil structure, contain a network of humic materials and soil mineral colloids (Kretzschmar and Sachafer 2005). Nano-particles are small enough to fit into these micropores and sequestration in the micropores can be expected to affect nano particles mobility. Because of high surface area,

Table 1. Effect of Nano Zn and Nano rock phosphate on yield (t/ha) (straw+ grain) of rice.

Treatments	Yield (t/ha) Grain	Straw	Total yield (t/ha)	YEI
T_1 – Control	3.55	4.20	7.75	–
T_2 – 100% NK	3.73	5.08	8.81	–
T_3 – 100% NPK (P through DAP)	4.10	5.60	9.70	0.80
T_4 – T_3 + Nano Zn @ 1.5 kg/ha	4.40	4.33	8.73	0.89
T_5 – T_3+Zn @ 5 kg/ha as $ZnSO_4$	4.30	4.95	9.25	0.84
T_6 – T_2+Nano rock phosphate @ 60 kg/ha	3.78	5.80	9.58	0.81
T_7 – T_6+Nano Zn @ 1.5 kg /ha	4.10	4.38	4.48	0.71
T_8 – T_6+Zn @ 5 kg / ha through $ZnSO_4$	4.23	6.05	10.28	0.75
CD (0.05)	0.54	0.76	–	–

nano particles have strong potential to adsorb on to soil and sediment particles (Oberdorster et al. 2005). Soil microbes play a very important role in bio-weathering and bio-degradation of nano particles. As the particle size of rock phosphate decreases, the microbes mediated solubilization of rock phosphate increases in soil. Higher yield response was obtained to nano-rock phosphate in all soils. Fertilizer particle can be coated with nano membranes that facilitate in slow and steady release of nutrients thereby reducing loss of nutrients and enhancing its use efficiency of crops. Nano clay composites have been developed in order to supply with the range of nutrients in desirable proportions (Datta 2011, Wu et al. 2008). Adhikari et al. (2015) studies the zinc oxide nano particles with their effect on growth of maize (*Zea mays* L.). Nano fertilizer can supply essential nutrients for plant growth, have higher nutrient use efficiency and can be delivered in a timely manner to a rhizosphere target or by foliar spray. Nano particle can adsorb on to the clay lattice thereby preventing fixation while releasing in to soil solution. They can be utilized by plant. The process improves soil health and nutrient use efficiency by crops. The nano structured formulation might permit fertilizer to control the released speed of nutrients to match the uptake pattern of crop. Application of Zn nano particle (< 100 nm) at lower level (0.28 ppm) enhanced the growth of maize plant as compare to normal $ZnSO_4$ (0.5 ppm) (Adhikari 2011). Adhikari et al. (2010) found that plant height, root length and volume, dry matter weight of maize were improved due to application of zinc oxide. Tarafdar et al. (2015) showed that the application of 160 mg nano zinc / ha increased the average Zn use efficiency by four crops to 78.6% against 3.5% with mega zinc particles. Keeping in these views, a study was conducted with the collaboration of IISS, Bhopal to know the efficiency of rock phosphate and zinc as nano particles on rice based cropping system in acidic lateritic soils of Odisha.

Materials and Methods

A field experiment was conducted during *kharif* 2013 at Central Research Farm of OUAT, Bhubaneswar. The soil was inceptisols, having pH 4.98, electrical conductivity 0.008 dSm^{-1}, organic carbon 0.56%, available P 18–22 kg/ha and DTPA extractable Zn content was 0.87 mg/kg. The experiment was laid out in a randomized block design with eight treatments comprising different combinations of $ZnSO_4$, DAP, Nano Zn (<100 nm) and Nano RP (<160 nm), replicated four times. The treatments were : T_1– Control, T_2–100% NK through chemical fertilizer, T_3–100% NPK (P through DAP), T_4–T_3+Nano Zn @ 1.5 kg (ZnO), T_5–T_3+Zn @ 5 kg through $ZnSO_4$, T_6–T_2 + Nano rock phosphate @ 60 kg P_2O_5 (Udaipur), T_7–T_6+ Nano Zn @ 1.5 kg/ha (ZnO), T_8–T_6 + Zn @ 5 kg / ha through $ZnSO_4$. The nano materials were mixed with finely ground and sieved dry farm yard manures powder and applied just before transplanting of rice. Special precautions like hand gloves, specks and masks were used to prevent inhalation, skin and eye irritation. Hybrid rice (var Rajalaxmi) was transplanted during first week of July. The plant samples were collected at harvest, oven dried at 70°C, processed and analyzed for P and Zn. The grain and straw yield of rice were recorded. The soil and plant samples were collected from each plot after harvest of rice and analyzed for P and DTPA

Table 2. Effect of Nano Zn and Nano rock phosphate on the concentration (ppm) of zinc in rice root, shoot and grain (mean value).

Treatments	Root	Shoot	Grain	Ratio
T_1 – Control	50.0	40.4	17.6	2.8 : 2.3 : 1
T_2 – 100% NK	70.0	44.0	20.0	3.5 : 2.2 : 1
T_3 – 100% NPK (P through DAP)	75.0	58.1	20.3	3.7 : 2.9 : 1
T_4 – T_3 + Nano Zn @ 1.5 kg / ha	83.6	55.8	21.6	3.9 : 2.6 : 1
T_5 – T_3+Zn @ 5 kg/ha as $ZnSO_4$	77.7	66.9	21.1	3.7 : 3.2 : 1
T_6 – T_2 + Nano rock phosphate @ 60 kg/ha	68.0	44.8	17.9	3.8 : 2.5 : 1
T_7 – T_6 + Nano Zn @ 1.5 kg/ha	80.8	51.8	20.6	3.9 : 2.5 : 1
T_8 – T_6 + Zn @ 5 kg/ha through $ZnSO_4$	60.0	38.7	19.3	3.1 : 2.0 : 1

extractable Zinc using AAS as described by Lindsay and Norvell (1978).

Results and Discussion

The grain yield (4.4 t ha^{-1}) of rice was significantly higher in the treatment receiving NPK + Nano Zn compared to rest of the treatments (Table 1). The results indicated that the yield of rice was significantly increased by 24% with the application of NPK +Nano Zn whereas 21% increased in rice yield by the application of NPK + $ZnSO_4$ over control. Considering the treatments, application of NPK + Nano Zn was increased in rice yield by 7.1% and 4.8%. In the treatment receiving NPK + $ZnSO_4$ over NPK treatment. It indicated that the Nano Zn had an effect on grain yield of rice because of its high surface areas and the reactivities with soil colloids which resulted to reduce the nutrient loss, hence increase the use efficiency, thereby increased the plant uptake. However, statistically the difference in yield of rice were at par with the Nano Zn and $ZnSO_4$ application. Similar observation was also made by Datta (2011), Wu et al. (2008), Adhikari et al. (2015), Tarafdar et al. (2015) on maize. In another treatment, the rice grain yield (3.8 t ha^{-1}) was recorded when 100% NK + Nano rock phosphate @ 60 kg ha^{-1} was applied. The increase was 0.1 t ha^{-1} over 100% NK. When Nano Zn was added to the above treatment the grain yield of rice was enhanced by 0.3 t ha^{-1} whereas yield (0.45 t ha^{-1}) of rice was increased by the application of $ZnSO_4$. Comparison between the nano RP and DAP as P source, DAP performed better than nano RP. The increase in yield was 0.32 t/ha i.e. 8.5% yield increase over nano RP. Comparison between interactive effect of P source with Zn source, DAP was performed at par with Nano Zn (ZnO), but a marginal rice yield (0.13 t/ha) increased with $ZnSO_4$. It may be due to soil microbes's role in bio-weathering and bio-degradation of nano particle and solubilizing of rock phosphate in soil for which higher yield may be obtained to nano rock phosphate. Similar observation was made by Veronica et al. (2015). The straw yield of rice was varied from 4.2 to 6.05 t ha^{-1} (Table 1).

The concentration of Zn in root, shoot and grain

Table 3. Effect of Nano Zn and Nano rock phosphate on P concentration (%) and uptake (kg/ha) in grain and straw of rice (mean value).

Treatments	Concentration (%)		Uptake (kg/ha)	
	Grain	Straw	Grain	Straw I
T_1 – Control	0.15	0.16	5.23	6.48
T_2 – 100% NK	0.16	0.16	6.05	8.13
T_3 – 100% NPK (P through DAP)	0.17	0.17	7.16	9.43
T_4 – T_3 + Nano Zn @ 1.5 kg/ha	0.18	0.15	8.07	6.92
T_5 – T_3+Zn @ 5 kg/ha as $ZnSO_4$	0.18	0.15	7.50	7.24
T_6 – T_2+Nano rock phosphate @ 60 kg/ha	0.16	0.17	6.07	9.03
T_7 – T_6+Nano Zn @ 1.5 kg /ha	0.18	0.17	7.20	7.24
T_8 – T_6+Zn @ 5 kg / ha through $ZnSO_4$	0.18	0.16	7.40	9.47
CD (0.05)	–	–	3.44	3.55

Table 4. Effect of Nano Zn and Nano rock phosphate on Zn uptake (g/ha) in grain and straw of rice (mean value).

Treatments	Uptake (g/ha) Grain	Straw	Total (g/ha)
T_1 – Control	62.29	169.10	231.39
T_2 – 100% NK	74.30	224.30	298.60
T_3 – 100% NPK (P through DAP)	82.67	326.60	409.27
T_4 – T_3 + Nano Zn @ 1.5 kg/ha	95.51	262.10	357.61
T_5 – T_3 + Zn @ 5 kg/ha as $ZnSO_4$	90.55	332.40	422.95
T_6 – T_2 + Nano rock phosphate @ 60 kg/ha	67.14	259.50	326.64
T_7 – T_6 + Nano Zn @ 1.5 kg/ha	84.42	225.40	309.82
T_8 – T_6 + Zn @ 5 kg/ha through $ZnSO_4$	80.77	233.80	314.57
CD (0.05)	20.54	80.50	

are presented in Table 2. It was observed that initial zinc concentration in root was higher than shoot and grain. It varied from 50 to 83.6 ppm with a mean of 70.6 ppm in root, from 38.7 to 66.9 ppm with a mean of 52.4 ppm in shoot. The rice grain concentration varied from 17.6 to 21.6 ppm with a mean of 20.3 ppm, respectively. The decrease in transfer coefficient of Zn from root to shoot might be due to higher accumulation of Zn in roots which may be attributed to the fact that roots are the first target organ to come in contact with the metals, therefore, higher accumulation has occurred in the root tissues (Singh and Agrawal 2010). The decreases transfer coefficient of Zn from shoot to grain might be related to their higher harvest index which lead to dilution of Zn in grain. The concentration ratio of grain : shoot : root in the order : 1 : 2.6 ; 3.5, respectively. Similar observation was made by Liu and Xing (2008).

The P concentration in rice grain varied from 0.15–0.18% and 0.15–0.17% in rice straw (Table 3). Highest grain Zn and P concentration of 21.6 mg/kg and 0.18% were obtained with nano zinc. The P concentration was more in DAP than nano RP. The uptake of Zn varied from 60.3 to 95.5 g/ha in rice grain whereas 169.1 to 332.4 g/ha in rice straw (Table 4). The total uptake of Zn from rice plant varied from 231.4–422.9 g/ha. The ZnHI was highest in the plot receiving the treatment of NPK + Nano Zn and also the Nano rock phosphate with Nano Zn (Table 5). It indicated the maximum utilization of Zn by rice crop, as a result the yield was higher. The uptake efficiency (UEI) was also higher in the above treatments (Table 5). Similar observation was made by Tarafdar et al. (2015) on maize. The post harvest soil (Table 1) showed that Zn content in all the treatments were above the control whereas maximum Zn concentration were found in soil in the treatment NPK + Nano Zn @ 1.5 kg/ha.

Conclusion

It may be concluded that the application of nano zinc had increased the yield of rice over zinc sulfate. The application of Diammonium phosphate had performed higher yield than nano rock phosphate. The ZnHI was highest in the plot receiving the treatment of NPK + Nano Zn and also the Nano rock phosphate

Table 5. Effect of Nano Zn and Nano rock phosphate on ZnUE, YEI, ZnHI and UEI of rice.

Treatments	ZnUE	YEI	ZnHI	UEI
T_1 – Control	–	–	–	–
T_2 – 100% NK	–	–	–	–
T_3 – 100% NPK (P through DAP)	–	0.80	–	–
T_4 – T_3 + Nano Zn @ 1.5 kg/ha	0.57	0.89	0.27	0.65
T_5 – T_3+Zn @ 5 kg/ha as $ZnSO_4$	0.15	0.84	0.21	0.55
T_6 – T_2+Nano rock phosphate @ 60 kg/ha	–	0.81	–	–
T_7 – T_6+Nano Zn @ 1.5 kg /ha	0.37	0.91	0.27	0.75
T_8 – T_6+Zn @ 5 kg / ha through $ZnSO_4$	0.14	0.75	0.26	0.74

with Nano Zn (Table 5). It indicated the maximum utilization of Zn by rice crop, as a result the yield was higher. The uptake efficiency (UEI) was also higher in the above treatments (Table 5). Similar observation was made by Tarafdar et al. (2015) on maize. The post harvest soil (Table 1) showed that Zn content in all the treatments were above the control whereas maximum Zn concentration were found in soil in the treatment NPK + Nano Zn @ 1.5 kg/ha.

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