Environment & Ecology 35 (2C) : 1256—1260, April—June 2017
Website: environmentandecology.com ISSN 0970-0420

Effect of Nano Zinc Oxide Formulations on Growth Parameters of Maize in A Calcareous Vertisol

S. P. Chaitra, N. S. Hebsur

Received 28 July 2016 ; Accepted 22 August 2016 ; Published online 5 September 2016

Abstract Green house experiment was conducted during 2014 to study the response of maize to foliar spray of nano ZnO formulations in a Vertisol. The pot culture experiment was conducted with eleven treatments involving various concentrations of nano ZnO in completely randomized block design with four replications carried for 60 days. Ten kg of soil was taken whereas, nano ZnO (<50 nm size) particles were purchased from Sigma Aldrich company was used. Chelated bulk $ZnSO_4.7H_2O$ was used as a reference material. A known concentration of nano ZnO at 100, 250, 500, 750, 1000, 1250 and 1500 ppm were used for this study. The foliar spray was taken up at 30 DAS and effect of these treatments on plant height, number of leaves, leaf area plant^{-1}, chlorophyll content and dry matter production were studied. Results revealed that plant height, number of leaves per plant, leaf area per plant, chlorophyll content and dry matter production were recorded higher in treatment receiving foliar spray of nano ZnO @ 750 ppm compared to bulk $ZnSO_4$. $2H_2O$ and lower values were recorded in the absolute control whereas, higher concentrations @ 1250 and 1500 ppm exhibited detrimental effects on growth of maize crop.

Keywords Nano Zno, Foliar spray, Maize, Growth parameters, Vertisol.

S. P. Chaitra*, N. S. Hebsur
Project Assistant, Sujala-III project, NBSS and LUP Regional Center, Hebbal, Banglore 24, Karnataka, India
e-mail: chaitrasp.sp@gmail.com
*Correspondence

Introduction

Zinc is an essential micronutrient for humans, animals and plants. Maize is known as an indicator plant for evaluation of Zn deficiency in soils. Plants absorb Zn in the form of Zn^{+2}. The functional role of Zn includes auxin metabolism, nitrogen metabolism, influence on the activities of enzymes, cytochrome synthesis and stabilization of ribosomal fractions and protection of cells against oxidative stress. The most common symptoms of zinc deficiency in maize include the development of whitish (white bud) or yellowish stripes parallel to the midrib on the young leaves and acute shortage stunted growth with shortened internodes. Necrotic spots and reddish color may develop on leaves at advanced stage of zinc deficiency. Zinc deficiency has been identified as one of the main problems limiting agricultural production particularly in calcareous soils. Because of increased cropping intensity on marginal lands, lesser use of FYM and micronutrient carriers and also use of mixture of foliar sprays and chelates have led to very little residual fertility which lead to enhanced zinc deficiency.

Nano-materials can be applied in designing more soluble and diffusible sources of zinc fertilizer for increased plant productivity. Nano-materials being smaller in size, with high specific surface area and reactivity are proposed to be the materials for the new millennium. Nano-particles with small size and large surface area are supposed to be the ideal forms for use as a Zn carrier in plants. Farmers are using both sulfates and chelated Zn (Zn EDTA / Zn

EDDHA) for soil and foliar applications, but their efficacy is low. In the light of the above, the present study was undertaken to investigate the promotory or inhibitory effects of various concentrations of nano ZnO particles on growth parameters of maize in a calcareous Vertisol.

Materials and Methods

Green house experiment was conducted in the Department of Soil Science College of Agriculture Dharwad during 2014 to study the effect of nano zinc oxide [ZnO] formulations on growth parameters of maize in a Vertisol are discussed below.

Soil sample was processed and analyzed for important physical and chemical properties by employing standard methods. The soil was clay in texture and slightly alkaline in reaction (pH 7.8) with low electrical conductivity (0.19 dS/m). The organic carbon content was medium (5.70 g/kg) and calcareous in nature ($CaCO_3$ 9%) with low available nitrogen (219.5 kg N/ha), medium available phosphorus (34 kg P_2O_5 / ha) and high available potassium (448 kg K_2O / ha). The soil was sufficient in all micro nutrients except zinc and iron.

The pot culture experiment was conducted with eleven treatments involving various concentration of nano ZnO in completely randomized block design with four replications.

Treatment details

T_1 : Absolute control (No RPP, only water spray at 30 DAS), T_2 : RPP (Water spray at 30 DAS, T_3 : Foliar $ZnSO_4.7H_2O$ @ 0.5% at 30 DAS, T_4 : Foliar nano ZnO @ 100 ppm at 30 DAS, T_5 : Foliar nano ZnO @ 250 ppm at 30 DAS, T_6 : Foliar nano ZnO @ 500 ppm at 30 DAS, T_7 : Foliar nano ZnO @ 750 ppm at 30 DAS, T_8 : Foliar nano ZnO @ 1000 ppm at 30 DAS, T_9 : Foliar nano ZnO @ 1250 ppm at 30 DAS, T_{10} : Foliar nano ZnO @ 1500 ppm at 30 DAS, T_{11} : Control–$ZnSO_4.7H_2O$ (Water spray at 30 DAS).

1. RPP : FYM @ 10 ton + 150 kg N +75 kg P_2O_5 + 37.5 kg K_2O + 25 kg $ZnSO_4.7H_2O$+25 kg $FeSO_4$ / ha. 2. From treatments T_3 to T_{11}, RPP is common except soil application of $ZnSO_4.7H_2O$. 3. Absolute control (Only water spray at 30 DAS). 4. Control (RPP without $ZnSO_4$. 7 H_2O).

Ten kg of soil was taken and filled into polythene bags. Nano ZnO (<50 nm size) was used. Chelated bulk $ZnSO_4.7H_2O$ was used as a reference material. A known amount of nano ZnO powder was weighed and put in water to obtain 100, 250, 500, 750, 1000, 1250 and 1500 ppm nano ZnO suspensions. The suspension was then dispersed by magnetic stirrer for 30 minutes to avoid aggregation of the particles. The maize hybrid used in the investigation was Super-900M. Ten kg of soil was mixed with required quantity of manures and chemical fertilizers and filled into polythene bags as per treatments. Maize seeds were sown in each bag and one plant per bag was maintained throughout the experiment. The foliar spray was taken up at 30 DAS. Ten ml of known concentration of nano ZnO was sprayed to each plant. Growth parameters and chlorophyll content in leaf were recorded at 35 and 60 DAS.

Results and Discussion

The plant height of maize did not differ significantly at 35 DAS. However, plant height of maize differed significantly at 60 DAS. Treatment receiving foliar spray of nano ZnO @ 750 ppm recorded the highest plant height at 60 DAS (135.5 cm) and the lowest was recorded with absolute control (99.88 cm). Treatment T_8 was on par with T_7, treatments T_9, T_{10} receiving higher concentration of nano ZnO recorded lower plant height. Whereas, higher nano ZnO concentrations @ 1250 and 1500 ppm exhibited detrimental effects on growth of maize crop (Table 1). Similar results were also obtained by several earlier workers. Prasad et al. [1] observed that nano ZnO promoted seed germination, seedling vigor, early flowering and higher chlorophyll content in leaf. They also observed beneficial effects of NPs in enhancing plant growth, development and yield in peanut at lower doses, but at higher concentrations ZnO NPs were detrimental just as the bulk nutrients. Pramod et al. [2] found that at certain optimum concentration, the mung bean seedlings treated with nano ZnO showed good growth over control and beyond that concentration retardation in growth was observed.

Table 1. Plant height, number of leaves and leaf area plant^{-1} of maize as influenced by foliar application of nano ZnO formulation at different growth stages. 1. RPP : FYM @ 10 ton+150 kg N+75 kg P_2O_5+37.5 kg K_2O+25 kg $ZnSO_4.7H_2O$+25 kg $FeSO_4$ / ha. 2. From treatments T_3 to T_{11}, RPP is common except soil application of $ZnSO_4.7H_2O$. 3. Absolute control (only water spray at 30 DAS). 4. Control (RPP without $ZnSO_4.7H_2O$). DAS–Days after sowing, Values denoted by same alphabets do not differ significantly.

		Plant height (cm)		Number of leaves plant^{-1}		Leaf area plant^{-1} (cm^2)	
	Treatments	35 DAS	60 DAS	35 DAS	60 DAS	35 DAS	60 DAS
T_1 :	Absolute control (NO RPP, only water spray at 30 DAS)	25.73^{a}	99.88^{l}	5.25^{b}	9.50^{h}	174.1^{c}	393.6^{h}
T_2 :	RPP (water spray at 30 DAS)	31.78^{a}	115.1^{ef}	7.25^{a}	11.50^{c-f}	199.0^{a}	423.8^{d}
T_3 :	Foliar $ZnSO_4.7H_2O$ @ 0.5% at 30 DAS	29.9a	124.9^{bc}	7.00^{a}	12.5$^{a–c}$	184.1^{bc}	445.9^{b}
T_4 :	Foliar nano ZnO @ 100 ppm at 30 DAS	28.88^{a}	110.5^{g}	7.00^{a}	10.75$^{e–g}$	190.9^{ab}	414.0^{ef}
T_5 :	Foliar nano ZnO @ 250 ppm at 30 DAS	26.93^{a}	113^{fg}	6.75^{a}	11.25$^{d–g}$	193.1^{ab}	419.9^{de}
T_6 :	Foliar nano ZnO @ 500 ppm at 30 DAS	29.00^{a}	121.6^{cd}	6.5^{ab}	12.00$^{b–d}$	185.9^{b}	434.7^{c}
T_7 :	Foliar nano ZnO @ 750 ppm at 30 DAS	29.65^{a}	135.5^{a}	6.25^{ab}	13.25^{a}	194.0^{ab}	462.1^{a}
T_8 :	Foliar nano ZnO @ 1000 ppm at 30 DAS (approx equivalent to $ZnSO_4.7H_2O$ at 0.5%)	28.87^{a}	128^{b}	6.25^{ab}	12.75$^{a–b}$	194.1^{ab}	454.9^{a}
T_9 :	Foliar nano ZnO @ 1250 ppm at 30 DAS	28.25^{a}	118.2^{de}	6.75^{a}	11.75$^{b–e}$	191.3^{ab}	426.6^{cd}
T_{10} :	Foliar nano ZnO @ 1500 ppm at 30 DAS	29.50^{a}	104.1^{b}	6.25^{ab}	10.25$^{g–h}$	192.8^{ab}	398.7^{gh}
T_{11} :	Control (water spray at 30 DAS)	28.50^{a}	106.0^{h}	6.75^{a}	10.50$^{f–h}$	189.2^{ab}	405.5^{fg}
	SEm±	2.26	1.21	0.44	0.35	3.57	3.05
	CD (p = 0.05)	NS	3.47	1.2	1.02	10.26	8.76
	CV (%)	6.02	2.08	8.50	6.17	3.76	1.43

Number of leaves in maize also differed significantly at 35 and 60 DAS at 35 DAS T_2 which received RPP recorded the highest number of leaves. However, there is an increase in number of leaves to foliar application of nano ZnO at 60 DAS but increase was observed upto 750 ppm. Treatment receiving foliar spray of nano ZnO @ 750 ppm (T7) recorded the highest number of leaves (Table 1). Whereas, higher concentrations @ 1250 and 1500 ppm exhibited detrimental effects on growth of maize crop. Prasad et al. [1] observed that nano ZnO promoted seed germination, seedling vigor, early flowering and higher chlorophyll content in leaf. They also observed beneficial effects of NPs in enhancing plant growth, development and yield in peanut at lower doses, but at higher concentrations ZnO NPs were detrimental just as the bulk nutrients.

The leaf area per plant differed significantly at 30 and 60 DAS as expected at 35 DAS the highest leaf area per plant was recorded (199.0 cm^2) in the treatment (T_2) receiving RPP at 60 DAS leaf area per plant increased with increasing concentration of nano ZnO upto 750 ppm and thereafter decreased at both stages. Treatment receiving foliar spray of nano ZnO @ 750 ppm (T_7) recorded the highest leaf area per plant (462.1 cm^2) (Table 1). Thus, it can be stated that foliar application of fertilizers enhances the accumulation and translocation of assimilates which leads to prolonged vegetative phase and better photosynthetic capacity of plant producing higher leaf area. Liang et al. [3] reported that combined application of fertilizer and carbon nanoparticles promoted tobacco growth, as evident by the significant increase in plant height, leaf area and dry matter accumulation.

Table 2. Chlorophyll content and dry matter production of maize as influenced by foliar application of nano ZnO formulation at different growth stages. 1. RPP : FYM @ 10 ton+150 kg N+75 kg P_2O_5+37.5 kg K_2O+25 kg $ZnSO_4.7H_2O$+25 kg $FeSO_4$ / ha. 2. From treatments T_3 to T_{11}, RPP is common except soil application of $ZnSO_4.7H_2O$. 3. Absolute control (only water spray at 30 DAS). 4. Control (RPP without $ZnSO_4.7H_2O$). DAS–Days after sowing, Values denoted by same alphabets do not differ significantly.

	Treatments	Chlorophyll content (SPAD values)		Dry matter production (g/plant)	
		35 DAS	60 DAS	35 DAS	60 DAS
T_1 :	Absolute control (NO RPP, only water spray at 30 DAS)	37.48^{b}	38.80^{e}	18.75^{b}	39.23^{g}
T_2 :	RPP (water spray at 30 DAS)	39.65^{a}	43.9^{a-d}	24.78^{a}	44.25^{c-f}
T_3 :	Foliar $ZnSO_4.7H_2O$ @ 0.5% at 30 DAS	39.13^{ab}	46.28^{ab}	23.93^{a}	47.63^{a-c}
T_4 :	Foliar nano ZnO @ 100 ppm at 30 DAS	39.05^{ab}	41.65^{b-e}	23.63^{a}	42.80^{d-g}
T_5 :	Foliar nano ZnO @ 250 ppm at 30 DAS	39.03^{ab}	42.15^{b-e}	23.38^{a}	43.35^{dg}
T_6 :	Foliar nano ZnO @ 500 ppm at 30 DAS	38.85^{ab}	45.53^{ab}	24.13^{a}	46.00^{b-d}
T_7 :	Foliar nano ZnO @ 750 ppm at 30 DAS	39.25^{ab}	48.35^{a}	23.70^{a}	51.00^{a}
T_8 :	Foliar nano ZnO @ 1000 ppm at 30 DAS (approx equivalent to $ZnSO_4.7H_2O$ at 0.5%)	38.90^{ab}	47.53^{a}	23.38^{a}	48.50^{ab}
T_9 :	Foliar nano ZnO @ 1250 ppm at 30 DAS	38.95^{ab}	44.85^{a-c}	23.30^{a}	45.75^{b-e}
T_{10} :	Foliar nano ZnO @ 1500 ppm at 30 DAS	38.48^{ab}	39.93^{c-e}	24.18^{a}	40.75^{f-g}
T_{11} :	Control (water spray at 30 DAS)	39.08^{ab}	39.05^{de}	23.85^{a}	41.63^{e-g}
	SEm±	0.58	1.55	0.56	1.31
	CD (p = 0.05)	1.67	4.46	1.60	3.77
	CV (%)	2.76	7.14	4.76	5.87

The chlorophyll content of leaf also followed the same trend as that of leaf area. Highest chlorophyll content of (48.35) was recorded at 60 DAS in the treatment receiving 750 ppm nano ZnO. Chlorophyll content of leaf increased with increasing concentration of nano ZnO upto 750 ppm and thereafter decreased. Whereas, higher concentrations @ 1250 and 1500 ppm exhibited harmful effects on growth of maize crop (Table 2). These findings are in conformity with the findings of Elham et al. [4] who reported that effect of nano TiO_2 was significant on chlorophyll (a and b) content total chlorophyll (a + b), chlorophyll a/b, carotenoids and anthocyanins. The maximum amount of pigment was recorded in the treatment of nano TiO2 spray at the reproductive stage in comparison with control treatment (water spray).

The dry matter production differed significantly at 35 DAS. Among all treatments the highest dry matter production (24.78 g plant^{-1}) was noticed in the treatment receiving RPP and lowest was recorded in absolute control (18.75 g plant^{-1}). The dry matter production differed significantly at 60 DAS and recorded highest (51.00 g plant^{-1}) in the treatment receiving nano ZnO at 750 ppm and lowest was recorded in absolute control (39.23 g plant^{-1}). Treatments T_9, T_{10} receiving higher concentration of 1250 and 1500 ppm recorded less dry matter production (Table 2). Improvement in growth parameters like plant height, number of leaves and leaf area per plant due to foliar application of nano ZnO resulted in increased dry matter accumulation. Burmana et al. [5] who observed promontory effects of nano ZnO formulations (1.5 and 10 ppm) on dry matter production in chickpea seedlings. Overall biomass accumulation improved in the ZnO nanoparticles treatments compared to zinc sulfate. Raliya and Tarafdar [6] noticed that ZnO NPs induced a significant improvement in cluster bean with respect to plant biomass, shoot and root growth, root area and chlorophyll.

References

1. Prasad TNKV, Sudhakar P, Sreenivasulu Y, Latha P, Munaswamy V, Reddy KR, Sreeprasad TSP, Sajanlal R, Pradeep T (2012) Effect of nanoscale zinc oxide particles on the germination, growth and yield of peanut. J Pl Nutr 35 : 905—927.
2. Pramod M, Dhoke SK, Khanna AS (2011) Effect of nano-ZnO particle suspension on growth of mung (*Vigna radiata*) and gram (*Cicer arietinum*) seedlings using plant agar method. J Nanotech 34 : 1—7.
3. Liang T, Yin Q, Zhang Y, Wang B, Guo W, Wang J, Xie J (2013) Effects of carbon nanoparticles application on the growth, physiological characteristics and nutrient accumulation in tobacco plants. J Food Agric Environ 11 : 954—958.
4. Elham M, Moaveni P, Farahani HA, Kiyani M (2013) Study of photosynthetic pigments changes of maize (*Zea mays* L.) under nano TiO_2 spraying at various growth stages. Springer Plus 2 : 247.
5. Burmana U, Sainib M, Kumar Praveen (2013) Effect of zinc oxide nanoparticles on growth and antioxidant system of chickpea seedlings. Toxicol Environ Chem 95 : 605—612.
6. Raliya R, Tarafdar JC (2013) ZnO nanoparticle biosynthesis and its effect on phosphorus mobilizing enzyme secretion and gum contents in cluster bean (*Cyamopsis tetragonoloba* L.). Agric Res 2 : 48—57.