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Influence of Nano Zinc Oxide on Yield and Economics of Maize (*Zea mays* L.)

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Abstract

A field study was conducted during *kharif* 2018 at Zonal Agricultural Research Station, GKVK, UAS, Bengaluru to know the effect of nano zinc oxide particles on growth and yield of maize. In field, eight treatments were laid out in RCBD with three replications and the cultivar used was BRMH-1. The results revealed that seed priming with 800 ppm of nano zinc oxide for 30 minutes and foliar application of nano ZnO at 500 ppm along with RDF (FYM @ 10 t + 150 kg N +75 kg P_2O_5 and 37.5 kg K_2O $ha^{-1)}$ recorded higher cob length (21.2 cm), number of kernels cob^{-1} (616.8), 100 kernels weight (30.80 g) ultimately resulted in higher kernel yield (8750 kg ha^{-1}) and stover yield (11136 kg ha^{-1}), higher gross returns (Rs.1,33,636/- ha^{-1}) and net returns (Rs.84,777/- ha^{-1}). Whereas, higher B:C ratio of 3.45 was recorded in the seed treated with 800 ppm of nano zinc oxide for 30 minutes with recommended dose of fertilizer.

Keywords: Nano ZnO, $ZnSO_4$ and Maize

Maize (*Zea mays* L.) is the third most important cereal crop in the world after wheat and rice with an area of 185.9 m ha, production of 1075.5 mt and average productivity of 5790 kg ha^{-1} (Anon., 2017). In India, it is cultivated on an area of 9.89 m ha with a production of 25.9 mt and the productivity of 2690 kg ha^{-1} (Anon., 2017). In Karnataka, it is cultivated on an area of 1.3 million ha with a production of 4.4 million tonnes with an average productivity of 2970 kg ha^{-1} (Anon., 2017a). It comes up well under a wide range of soil and climatic conditions, there is a lot of scope to expand the present maize yields.

Indian soils are being exhausted heavily as 30 mt of nutrients removed, while 20 mt added by crops leaving a shortage of 10 mt consistently. Fertilizer response ratio of crops has declined radically. Socio and economic issues such as exodus of people from farming, inaccessibility of labourers and raising cost of cultivation add enormous pressure on agricultural scientists to evolve technologies that target multifaceted problems of Indian agriculture.

Nano technology is a field of assembly among life sciences, material science and information technology. It is a rising field of science capable of resolving issues and problems that are impossible to tackle in engineering and biological sciences. Among the advancement in sciences, nano technology is being visualized as a rapidly evolving field that has potential to revolutionize agriculture and food systems and improve the condition of the poor.

Nano technology is gradually moving from the experimental stage to the operational and practical stage. This will lead to a more tangible presence of the technology in the agricultural sector (Baruah and Dutta, 2009). In this regard, using nano fertilizer to control release of nutrients can be an effective step towards achieving sustainable agriculture and sustainable environment (Cui *et al*., 2010).

The present study was taken up to investigate the promontory or inhibitory effects of various concentrations of ZnO nano particles on growth and yield of maize (*Zea mays* L.). Nano particles with small size and large surface area are expected to be the ideal forms for use as a Zn fertilizer in plants. Farmers are using both sulphates and chelated Zn (with ethylene di ammine tetra acetic acid, EDTA) for soil and foliar applications; however, the efficacy is low.

Material and Methods

A field experiment was conducted during *kharif* 2018 at Zonal Agricultural Research Station, GKVK, UAS, Bengaluru to know the effect of nano zinc oxide particles on growth and yield of maize. The soil was red sandy loam having nearly neutral pH (6.56), low electrical conductivity (0.17) and medium in available nitrogen (445.69 kg ha^{-1}), phosphorous (46.36 kg ha^{-1}), potassium (243.9 kg ha^{-1}) and Zinc (0.45 ppm). The experiment was laid out in a RCBD having eight treatments with three replications. The treatment consisted of five levels of nano zinc oxide as foliar application at 30 DAS and zinc sulphate (10 kg ha^{-1} and 0.5 %) applied to soil and foliage, respectively.

The treatment details are as follows :

T_1: Seed priming with Nano ZnO @ 800 ppm for 30 minutes

T_2: T_1+Foliar application of Nano ZnO @ 200 ppm

T_3: T_1+Foliar application of Nano ZnO @ 300 ppm

T_4: T_1+Foliar application of Nano ZnO @ 400 ppm

T_5: T_1+Foliar application of Nano ZnO @ 500 ppm

T_6: T_1+Foliar application of Nano ZnO @ 600 ppm

T_7: Foliar application of $ZnSO_4$ @ 0.5 per cent

T_8: Soil application of $ZnSO_4$ @ 10 kg ha^{-1}

RDF: FYM @ 10 t + 150 kg N +75 kg P_2O_5 and 37.5 kg K_2O ha^{-1} was applied for all the treatments.

Preparation of Particle Suspensions and Zinc Ion Solution

The nano particles were suspended directly in double distilled water (DDW) and dispersed by using magnetic stirrer for 30 min. Small magnetic beeds were placed in the suspensions for stirring before use to avoid aggregation of the particles. Zinc ion (Zn^{2+}) solution was prepared by dissolving zinc sulfate heptahydrate ($ZnSO_4.7H_2O$) in DDW.

The cultivar of maize BRMH-1 was sown at 60 cm × 30 cm spacing. All other agronomic practices were followed as per the UAS, Bengaluru recommended package of practices (Anon., 2016). Observations were made at 30, 60, 90 and at harvest in respect of growth parameters and the yield and yield parameters of maize were recorded at harvest. The experimental data were analyzed using ANOVA technique. The significance of the treatment effect was judged with the help of "F" table and tested at 5 per cent probability level.

Results and Discussion

Effect of Nano Zinc Oxide Particles on Yield and Yield Attributes of Maize

Significantly higher cob length, number of kernels per cob, test weight, kernel yield and stover yield was

Table 1

Effect of nano zinc oxide particles on growth and growth attributes of maize

Treatments	Plant height(cm)	Number of leaves $plant^{-1}$	Leaf area (cm^2 $plant^{-1}$)	Total Dry weight (g $plant^{-1}$)
T_1: Seed priming with Nano ZnO @ 800 ppm for 30 minutes	254.9	9.4	2305	298.9
T_2: T_1+Foliar application of Nano ZnO @ 200 ppm	263.6	9.6	2465	328.9
T_3: T_1+Foliar application of Nano ZnO @ 300 ppm	268.4	9.8	2698	348.7
T_4: T_1+Foliar application of Nano ZnO @ 400 ppm	272.2	11.4	3192	365.5
T_5: T_1+Foliar application of Nano ZnO @ 500 ppm	286.5	12.2	3616	387.5
T_6: T_1+Foliar application of Nano ZnO @ 600 ppm	268.5	10.8	3133	358.2
T_7: Foliar application of $ZnSO_4$ @ 0.5 %	254.7	8.6	2195	281.3
T_8: Soil application of $ZnSO_4$ @ 10 kg ha^{-1}	246.1	8.4	2022	262.0
S.E(m)±	8.00	0.64	168.4	11.68
C.D. at 5 %	24.28	1.97	511.0	35.46

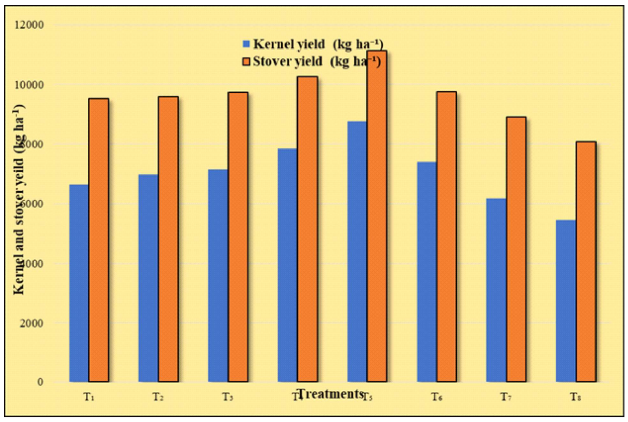

Fig.1: Effect of nano zinc oxide particles on kernel yield and stover yield of maize

recorded in seed treatment with 800 ppm of nano ZnO for 30 minutes followed by foliar application of nano ZnO at 500 ppm *i.e.,* T_5(21.2 cm, 616.8, 30.80 g, 8750 kg ha^{-1} and 11136 kg ha^{-1} respectively), Seed treatment with 800 ppm of nano ZnO for 30 minutes followed by foliar application of nano ZnO at 400 ppm (20.7 cm, 604.0, 29.37 g, 7848 kg ha^{-1}, and 10254 kg ha^{-1}, respectively)was the next best treatment (Table 2). The improvement in yield and yield attributes might be due to improved growth factors like plant height (286.5 cm), number of leaves (12.2), leaf area (3616 cm^2 plant^{-1}) and dry matter production (387.5 g plant^{-1}). This was mainly due to small size and large effective surface area of nano particles which could easily penetrate into the plant leading to better uptake of zinc. Zinc plays as an activator of enzymes in plants and is directly involved in the bio synthesis of auxin, which produces more cells and dry matter that in turn will be stored in seeds as sink. Thus, the increase in kernel yield is more expected, (Parmar Snehal Bhai, 2016). At higher concentration of ZnO nano particles, kernel yield decreased, these results were in accordance with reports on radish, rapeseed, ryegrass, corn and lettuce (Lin and Xing, 2007). Increase in stover yield in the present study can be attributed to significant increase in dry matter accumulation in plants which in turn mainly attributed to increase in growth factors like plant height.

Effect of Nano Zinc Oxide Particles on Growth and Growth Attributes of Maize

Significantly higher plant height, number of leaves per plant, leaf area per plant and dry matter production

TABLE 2

Effect of nano Zinc oxide particles on yield and yield attributes of maize

Treatments	Cob length (cm)	Number of kernels cob^{-1}	Test weight (g)	Kernel yield (kg ha^{-1})	Stover yield (kg ha^{-1})
T_1: Seed priming with Nano ZnO @ 800 ppm for 30 minutes	19.1	519.4	28.93	6632	9520
T_2: T_1+Foliar application of Nano ZnO @ 200 ppm	19.5	549.4	29.07	6985	9592
T_3: T_1+Foliar application of Nano ZnO @ 300 ppm	19.9	570.6	29.30	7148	9739
T_4: T_1+Foliar application of Nano ZnO @ 400 ppm	20.7	604.0	29.37	7848	10254
T_5: T_1+Foliar application of Nano ZnO @ 500 ppm	21.2	616.8	30.80	8750	11136
T_6: T_1+Foliar application of Nano ZnO @ 600 ppm	20.1	594.1	29.33	7400	9742
T_7: Foliar application of $ZnSO_4$ @ 0.5 %	18.5	498.9	27.93	6161	8896
T_8: Soil application of $ZnSO_4$ @ 10 kg ha^{-1}	18.3	466.9	26.63	5441	8076
S.E(m)±	0.57	16.65	0.70	266.21	313.60
C.D. at 5 %	1.74	50.53	2.14	807.54	951.29

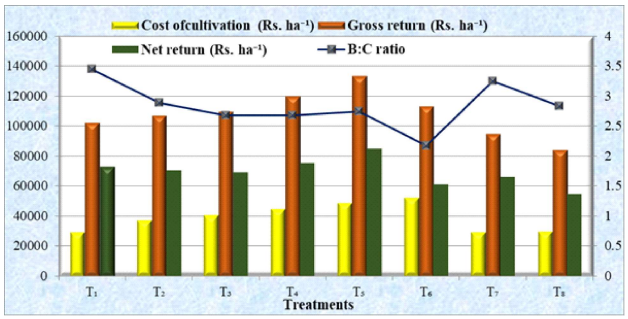

Fig. 2: Economics of nano zinc oxide particles in maize cultivation

per plant were observed in seed treatment with 800 ppm of nano ZnO for 30 minutes followed by foliar application of nano ZnO at 500 ppm (286.5 cm, 12.2, 3616 cm^2 $plant^{-1}$ and 387.5 g $plant^{-1}$) respectively. Lower plant height, number of leaves per plant, leaf area per plant and dry matter production per plant were recorded in soil application of $ZnSO_4$ @ 10 kg ha^{-1} (246.1 cm, 8.4, 2022 cm^2 $plant^{-1}$ and 262.0 g $plant^{-1}$ respectively). This is due to to adequate supply of zinc which accelerates the activity of enzyme and auxin metabolism in the plant, which in turn enlarges the cell and cell elongation resulting in taller plants (Nithya *et al*., 2018). The dry matter production depends on photosynthetic capacity of the plant which in turn depends on the dry matter accumulation in leaves. The highest dry matter production was observed as a result of higher plant height, more number of leaves $plant^{-1}$ and increase in leaf area $plant^{-1}$. These results are in accordance with the findings of Rani *et al*. (2009).

Influence of Nano Zinc Oxide on Economics of Maize Production

The cost of cultivation differed due to different treatment combinations. It was observed that seed treatment with 800 ppm of nano ZnO for 30 minutes followed by foliar application of nano ZnO at 600 ppm recorded higher cost of cultivation (Rs.52344 ha^{-1}) due to more quantity and more cost of nano ZnO. Lower cost of cultivation was incurred towards foliar application of $ZnSO_4$ @ 0.5 per cent (Rs.29265 ha^{-1}).

Higher gross and net returns were found in seed treatment with 800 ppm of nano ZnO for 30 minutes and foliar application of nano ZnO at 500 ppm, *i.e.,* T_5 (Rs.133636 ha^{-1} and Rs.84777 ha^{-1} respectively) due to higher kernel yield. Lower gross and net returns were recorded in the treatment receiving soil application of $ZnSO_4$ @ 10 kg ha^{-1} (Rs.84250 ha^{-1} and Rs.54455 ha^{-1} respectively) due to lower kernel yield obtained for this treatment.

The result showed that seed priming with 800 ppm of nano ZnO for 30 minutes recorded higher B:C ratio (3.45) due to higher kernel yield as well as comparatively low cost of cultivation. Lower B:C ratio was observed for Seed treatment with 800 ppm of nano ZnO for 30 minutes followed by foliar application of nano ZnO @ 600 ppm (2.17), because of higher cost of cultivation incurred for this treatment. Hence seed treatment with 800 ppm of nano ZnO for 30 minutes or this treatment followed by foliar

TABLE 3

Influence of nano zinc oxide on economics of maize production

Treatments	Cost of cultivation (Rs. ha^{-1})	Gross return (Rs. ha^{-1})	Net return (Rs. ha^{-1})	B:C ratio
T_1: Seed priming with Nano ZnO @ 800 ppm for 30 minutes	29656	102368	72712	3.45
T_2: T_1 + Foliar application of Nano ZnO @ 200 ppm	37219	107382	70163	2.89
T_3: T_1+Foliar application of Nano ZnO @ 300 ppm	41000	109811	68811	2.68
T_4: T_1+Foliar application of Nano ZnO @ 400 ppm	44781	120126	75345	2.68
T_5: T_1+Foliar application of Nano ZnO @ 500 ppm	48859	133636	84777	2.74
T_6: T_1+Foliar application of Nano ZnO @ 600 ppm	52344	113342	60998	2.17
T_7: Foliar application of $ZnSO_4$ @ 0.5 %	29265	95150	65885	3.25
T_8: Soil application of $ZnSO_4$ @ 10 kg ha^{-1}	29795	84250	54455	2.83

application of nano ZnO at 500 ppm can be recommenced as cost effective methods for increasing the kernel yield of maize.

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