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Satdev
Department of Soil Science and Agricultural Chemistry, NM College of Agriculture, Navsari Agricultural University, Navsari, Gujarat, India

VJ Zinzala
Department of Soil Science and Agricultural Chemistry, NM College of Agriculture, Navsari Agricultural University, Navsari, Gujarat, India

Bharat N Chavda
Department of Soil Science and Agricultural Chemistry, NM College of Agriculture, Navsari Agricultural University, Navsari, Gujarat, India

Lokesh Kumar Saini
Department of Soil Science and Agricultural Chemistry, NM College of Agriculture, Navsari Agricultural University, Navsari, Gujarat, India

Effect of nano ZnO on growth and yield of sweet corn under South Gujarat condition

Satdev, VJ Zinzala, Bharat N Chavda and Lokesh Kumar Saini

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Abstract
A field experiment was conducted at College Farm of Navsari Agricultural University, Navsari to study the impacts of ZnO nanoparticles on growth and yield of sweet corn. Total twelve treatment of bulk ZnO, $ZnSO_4$ and ZnO nanoparticles (ZnO-NPs) were taken as seed treatment and foliar application during experimentation. Among different treatments, foliar application ZnO-NPs (M_3) @ 500 ppm gave significantly higher growth attributes *viz.* plant height at 60 DAS (173.67 cm) and harvest (198.85 cm), and yield attributes *viz.* number of cob per plant (1.73), cob length (30.13 cm) and cob girth (19.66 cm) as well as cob yield (18.98 t/ha) and straw yield (7.12 t/ha) of sweet corn.

Keywords: Foliar application, nano ZnO, Seed treatment and sweet corn

1. Introduction
Agriculture forms the backbone of third world economics. In the 21st century, day by day increase in population and demand results in the need for great efficient agriculture products. Micronutrient deficiencies are a growing concern in the India, resulting in diverse health and social problems like mental retardations, immune system impairments and overall improper health. Because the concentration of Zinc in cereal is inherently very low and growing of cereals on Zn-deficient soils further decreases Zn concentration grains. Therefore, it is not surprising that high Zinc deficiency incidence in humans occurs mostly on areas where soils are deficient in plant available form of Zinc, India soils are one of the most Zinc deficient soils in the world. About 50% of cultivated soils of India are low in plant-available form of Zinc. These soils are under intensive cultivation of cereals like, wheat and rice with no or little application of Zn fertilizers. These facts clearly indicate an emergency need for improved Zinc content of grains in India.

Nanotechnology is an emerging new technology and promises to substantially help in agriculture, which can lead to a new revolution in agriculture. Nanotechnology has ability to solve many of the agriculture related problems with tremendous improvement, as compared to conventional agriculture systems. The use of nanoparticles in the growth of plants is a recent practice. Few studies have investigated the effects of nanoparticles on corn growth. Among the metal oxides, Zn-oxide nanoparticles have lot of attention due to their extensive properties. Zinc oxide is recognized as one of the safe substance by the United States Food and Drug Administration. The present study deals with the effect of ZnO nanoparticles (ZnO-NPs) on growth and yield of sweet corn.

2. Materials and Methods
An experiment was conducted during 2017-18 at college farm of Navsari Agricultural University, Navsari. The farm is located at $20^0 92'$ N and $72^0 89'$ E at an altitude of about 10 meter above MSL. The soil of experimental field was clay in texture having $pH_{1:2.5}$ 7.78, $EC_{1:2.5}$ 0.43 dS/m and organic carbon 0.79%. The soil was medium in available N (180kg/ha) and available P_2O_5 (33 kg/ha) and high in available K_2O (354 kg/ha).
ZnO nanoparticles were synthesized by precipitation methods at central instrumental laboratory, Navsari Agricultural University, Navsari by using various chemical compounds *viz.* by mixing of 1M of zinc sulphate [$ZnSO_4$] and 2M of potassium hydroxides [KOH] (M_1); 0.2M of zinc nitrate [$Zn(NO_3)_2$] and 0.4M of potassium hydroxide [KOH] (M_2) (Ghorbani *et al.*, 2015) [6] and by 0.5M of zinc nitrate $Zn(NO_3)_2$] and 1M of Urea [$CO(NO_2)_2$]

Corresponding Author:
Satdev
Department of Soil Science and Agricultural Chemistry, NM College of Agriculture, Navsari Agricultural University, Navsari, Gujarat, India

(M$_3$) (Sabir *et al.,* 2014) [15].

Twelve treatment of bulk ZnO, ZnSO$_4$ and ZnO nanoparticles were used as seed treatment and foliar application *viz.* T$_1$ Control, T$_2$ ZnO seed treatment @ 3000 ppm, T$_3$ ZnO-NPs (M$_1$) seed treatment @ 1000 ppm, T$_4$ ZnO-NPs (M$_2$) seed treatment @ 1000 ppm, T$_5$ ZnO-NPs (M$_3$) seed treatment @ 1000 ppm, T$_6$ ZnSO$_4$ foliar application @ 5000 ppm, T$_7$ ZnO-NPs (M$_1$) foliar application @ 250 ppm, T$_8$ ZnO-NPs (M$_1$) foliar application @ 500 ppm, T$_9$ ZnO-NPs (M$_2$) foliar application @ 250 ppm, T10 ZnO-NPs (M$_2$) foliar application @ 500 ppm T$_{11}$ ZnO-NPs (M$_3$) foliar application @ 250 ppm, T$_{12}$ ZnO-NPs (M$_3$) foliar application @ 500ppm were taken under randomized block design with three replications.

Treatments were applied as seed treatment at the time of sowing and foliar application at 45 DAS and 60 DAS. Treatment wise different observation like periodic growth (plant population and plant height) yield attributed (number of cob per plant, cob length and cob girth) and yield (cob and straw yield) were taken from sweet corn at various growth stages. The periodic data regarding soil microbial populations were analyzed by randomized block design (Panse and Sukhatme, 1967) [12].

3. Results and Discussion
Growth and yield of sweet corn significantly responded by seed treatment and foliar application of Zn-oxide nanoparticles.

3.1 Growth attribute
The results pertaining to growth attributes of sweet corn *viz.*, plant population and plant height at 30 DAS, 60 DAS and at harvest recorded during the growth period of sweet corn. Results revealed that experimental treatments failed to exert any significant affect on plant population at 30 DAS and at harvest of sweet corn. Boonyanitipong *et al.* (2011) [3] found that the ZnO-NPs at different concentrations did not show any adverse effects on the germination. Similarly, Plant height (30DAS, 60DAS and at harvest) was considered to be an important factor to judge the vigorous growth of crop. A healthy vegetative growth is an essential prerequisite for getting higher yield.

In the present investigation seed treatment of ZnO-NPs (M$_3$) @ 1000 ppm (T$_5$) produced significantly maximum plant at 30 DAS and was at par with treatment T$_2$, T$_3$ and T$_4$ while foliar application of ZnO-NPs (M$_3$) @ 500 ppm (T$_{12}$) gave statistically maximum plant height at 60 DAS (20.9% increment over the control) and at harvest stage (16.11% increment over the control) of sweet corn and was at par with T$_8$ and T$_{10}$ in case of plant height at 60 DAS and in case of harvest all treatment was found at par except control. The effect of ZnO-NPs on plant height at 60 DAS and harvest due to foliar application of ZnO-NPs directly contact on leaf surface area of sweet corn and more efficient ZnO-NPs absorbed easily through leaf of the sweet corn. Zinc is also involve in the synthesis of some growth hormones of IAA and metabolic acid and synthesis due to the reproductive process of many plant which are very vital for grain formation as well as increase growth attributes. The ZnO-NPs are nano size more penetration capacity and increase use efficiency. Application of foliar sprays implies that the nutrients applied will be absorbed and exported from the point of application (leaf) to the point of utilization. Thus, in foliage applications, nutrients need to first travel through the leaf cuticle (Monreal *et al.*, 2016) [11]. Laware, and Raskar (2014) [9] showed that maximum plant height of onion over control due to received sprayed ZnO-NPs. Prasad *et al.* (2012) [13], Raddy R. (2017) [14], Yuvakkumar *et al.* (2011) [20], Suriyaprabha *et al.* (2012) [17], Liang *et al.* (2013) [10] and Van *et al.* (2013) [18] also reported similar finding in different-different crops.

4. Yield and yield attributes
Among the foliar application of ZnO-NPs, ZnO-NP (M$_1$) @ 250 ppm (T$_7$), ZnO-NPs (M$_2$) @ 500 ppm (T$_{10}$), ZnO-NP (M$_3$) @ 250 ppm (T$_{11}$) and ZnO-NP (M$_3$) @ 500 ppm (T$_{12}$) gave significantly higher number of cob per plant (7.51% increment over the control) and was remained at par with all the treatment except treatment T$_1$, T$_2$, T$_3$ and T$_6$. Prasad *et al.* (2012) [13] reported that application of ZnO nanoparticles in groundnut enhanced the number of pods per plant. The foliar application of ZnO-NP (M$_3$) @ 500 ppm (T$_{12}$) gave significantly higher cob length (18.58% increment over the control) and cob girth (12.61% increment over the control) and found statistically at par with treatment T$_3$, T$_7$, T$_8$, T$_9$, T$_{10}$ and T$_{11}$ in case of cob length and with all the treatment except treatmentT$_1$, T$_2$ and T$_6$ in case of cob girth. This might be due to better vegetative growth of the sweet corn under foliar application of ZnO-NPs on sweet corn.

Significantly higher cob yield of sweet corn (16.85% increase over the control) was recorded under foliar application of ZnO-NPs (M$_3$) @ 500 ppm (T$_{12}$) and stood at par with the treatment T$_4$, T$_7$, T$_8$, T$_9$, T$_{10}$ and T$_{11}$. Ashrafi *et al.* (2014) [1] reported that the application of nano zinc oxide @ 60g/ha, responsible for activating the enzymes by fusing with the formation of chlorophyll in most plants and accelerate company growth hormone formation, such as tryptophan. This increase in production is the main place to store carbohydrates in plant carbohydrates are grains that eventually led to an increased number of seeds per plant as a source, and storage carbohydrates, and increased the yield of wheat. Significantly higher straw yield of sweet corn (16.85% increase over the control) was recorded under the foliar application of ZnO-NPs (M$_3$) @ 500 ppm (T$_{12}$) and remained at par with treatment T$_4$, T$_7$, T$_8$, T$_9$, T$_{10}$ and T$_{11}$. Similar results were also reported by Sheykhbaglou *et al.* (2010) [16], Bakhtiari *et al.* (2015) [2], Fan *et al.* (2012) [4], Ghafari *et al.* (2013) [5], Jaberzadeh *et al.* (2013) [7], Jahanara *et al.* (2013) [8], Morteza *et al.* (2013) [11], Prasad *et al.* (2012) [13] and Wu (2013) [19] in various agronomical trials.

Table 1: Effect of ZnO-NPs on plant population of sweet corn

Treatments	No. of plant/ ha		Plant height (cm)		
	30 DAS	At harvest	30 DAS	60 DAS	At harvest
T$_1$: Control	80729	78993	43.07	137.33	166.80
T$_2$: ZnO ST @ 3000 ppm	80729	79427	61.43	144.33	183.85
T$_3$: ZnO-NPs (M$_1$) ST @ 1000 ppm	82031	80295	63.51	144.20	192.35
T$_4$: ZnO-NPs (M$_2$) ST @ 1000 ppm	80295	78226	52.85	151.89	193.18
T$_5$: ZnO-NPs (M$_3$) ST @ 1000 ppm	80628	78559	69.04	149.33	196.92
T$_6$: ZnSO$_4$ FA @ 5000 ppm	79861	77691	49.17	141.21	184.19
T$_7$: ZnO-NPs (M$_1$) FA @ 250 ppm	80830	78326	45.80	150.55	197.95

T₈: ZnO-NPs (M₁) FA @ 500 ppm	81597	79861	44.83	156.07	196.98
T₉: ZnO-NPs (M₂) FA @ 250 ppm	81163	79628	45.07	150.67	193.66
T₁₀: ZnO-NPs (M₂) FA @ 500 ppm	81597	79861	48.96	161.41	196.80
T₁₁: ZnO-NPs (M₃) FA @ 250 ppm	82031	78559	43.55	152.85	196.06
T₁₂: ZnO-NPs (M₃) FA @ 500 ppm	81597	78993	48.53	173.67	198.85
S.Em.±	1410	1554	5.61	6.42	5.70
C.D. at 5 %	NS	NS	16.46	18.82	16.72
C.V. %	3.01	3.41	18.94	7.35	5.16

ST: Seed treatment, FA: Foliar application

Table 2: Effect of ZnO-NPs on yield and yield attributes of sweet corn

Treatments	No of cob /plant	Cob length (cm)	Cob girth (cm)	Cob yield (t/ha)	Straw yield (t/ha)
T₁: Control	1.60	24.53	17.18	15.78	5.92
T₂: ZnO ST @ 3000 ppm	1.60	26.32	17.33	16.63	6.24
T₃: ZnO-NPs (M₁) ST @ 1000 ppm	1.63	27.71	18.50	16.43	6.16
T₄: ZnO-NPs (M₂) ST @ 1000 ppm	1.67	27.41	19.14	17.44	6.54
T₅: ZnO-NPs (M₃) ST @ 1000 ppm	1.67	25.21	18.63	16.31	6.12
T₆: ZnSO₄ FA @ 5000 ppm	1.60	25.53	17.21	16.40	6.15
T₇: ZnO-NPs (M₁) FA @ 250 ppm	1.73	29.27	18.55	17.88	6.71
T₈: ZnO-NPs (M₁) FA @ 500 ppm	1.70	29.97	19.29	18.75	7.03
T₉: ZnO-NPs (M₂) FA @ 250 ppm	1.70	28.33	19.18	18.26	6.85
T₁₀: ZnO-NPs (M₂) FA @ 500 ppm	1.73	29.97	19.38	18.89	7.08
T₁₁: ZnO-NPs (M₃) FA @ 250 ppm	1.73	29.77	19.05	18.44	6.91
T₁₂: ZnO-NPs (M₃) FA @ 500 ppm	1.73	30.13	19.66	18.98	7.12
S.Em.±	0.03	0.92	0.58	0.76	0.29
C.D. at 5 %	0.09	2.70	1.71	2.23	0.84
C.V. %	3.25	5.72	5.44	7.53	7.53

ST: Seed treatment, FA: Foliar application

5. Conclusion
Results of the study showed that foliar application of ZnO NPs @ 250 ppm or seed treatment ZnO NPs @ 1000 ppm enhance the growth and yield attributes and yield of sweet corn under South Gujarat condition.

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