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Productivity, quality and nutrients uptake of maize (*Zea mays*) as affected by sources and levels of zinc

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ABSTRACT

A field experiment was conducted in two consecutive kharif seasons of 2012 and 2013 at Panwari village, Agra (U.P.) to study the effect of sources and levels of zinc on productivity, quality and uptake of nutrients in maize (Zea mays L.). The experiment was laid out in randomized block design with two sources (zinc oxide and zinc sulphate) and five levels of zinc (0, 2, 4, 6 and 8 kg Zn ha^{-1}) with three replications. The results indicated that significantly higher green foliage and dry matter yields were obtained with zinc sulphate as compared to zinc oxide. The green foliage and dry matter yields of maize were significantly improved with the increase in the levels of zinc and the highest green foliage (32.19 t ha^{-1}) and dry matter (9.62 t ha^{-1}) yields were recorded with 6 kg Zn ha^{-1}. Application of 6 kg Zn ha^{1} resulted in 30.1% higher green foliage and 26.2% dry matter yield than the yield obtained in the control (24.74 t ha^{-1} green foliage and 7.654 t ha^{-1} dry matter). The content of crude fibre and protein remained unaffected by sources of zinc but increased significantly with increasing Zn doses, thus maize fertilized with 6 kg Zn ha^{-1} recorded the highest yield of protein (106.0 kg ha^{-1}). The maximum value of protein content (11.17%) was recorded with 8 kg Zn/ha. The uptake values of N, P, K and S by maize were not affected with sources of zinc but zinc uptake increased significantly with zinc sulphate over zinc oxide. The uptake of nutrients in maize crop increased significantly up to 6 kg Zn ha^{-1} followed by reductions at 8 kg Zn ha^{-1}. Nutrient status in post harvest soil was not affected with sources of zinc but improved significantly with Zn levels. The status of available N and Zn improved significantly up to 8 kg ha^{-1} whereas P, K, and S contents increased up to 4 kg Zn ha^{-1}.

Keywords: Maize, quality, soil fertility, sources and levels, yield, zinc.

INTRODUCTION

Maize is the third most important cereal crops after rice and wheat in India. Besides, providing nutrients for human/animals maize serves as a basic raw material for the production of starch, oil, protein, alcoholic beverages and food sweeteners. The productivity of maize is quite low mainly due to sub-optimal application of fertilizers. Further, the quality of maize is an important aspect affected greatly by mineral nutrition. Continuous and imbalanced use of selected fertilizer nutrients have resulted in deterioration of soil health, increasing per unit cost of production and decline in the rate of growth of productivity. The farmers, by and large use mainly nitrogen and phosphorus as plant nutrients in maize cultivation and as a consequences, deficiencies of Zn and other micronutrients are increasing (Shukla 2011). Zinc is one of the essential plant micronutrient and its importance for crop productivity is similar to that of major nutrients. Zinc has specific and essential physiological functions in plant metabolism. It plays major role in synthesis of tryptophan, which is precursor of indole acetic acid. Zinc is also important in protein synthesis. Zinc deficiency is wide spread throughout the country. Nearly 50% of cultivated soils in India are low in plant available zinc and these soils are under intensive cultivation with no or little application of zinc fertilizers. As low soil Zn status is an important limiting factor responsible for poor yields of the crops, it is imperative to evaluate the response of Zn nutrition on maize productivity. Therefore, zinc management needs greater attention in crop production systems to combat with wide spread zinc deficiency in many maize growing areas.Zinc deficiency is most commonly corrected by application of zinc sulphate as of its high solubility and low cost. Several zinc products are available in the market but these are beyond the reach of farmers. Since not much work has been done to assess the response of maize to zinc fertilization irrespective of source of Zn. Therefore, present study was undertaken to study the effect of sources and levels of zinc on yield and quality of maize.

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MATERIALS AND METHODS

A field experiment was conducted during kharef seasons of 2012 and 2013 at farmer's field at Panwari (Agra) which is situated at 27^o 14' N latitude and 77^o 78' longitude at an altitude of 168 meter above the mean sea level..The experimental site is characterized by semi-arid climate with extreme temperature during summer (45 to 48° C) and very low temperature during winter (as low as 2°C). The average rainfall is about 650 mm, most of which is received from June to September. The experimental soil was sandy loam in texture having pH 7.9, organic carbon 3.2 g kg^{-1}, available N 152 kg ha^{-1}, available P 9.5 kg ha^{-1}, available K 106 kg ha^{-1} available S 15 kg ha^{-1}, and available (DTPA) Zn 0.56 mg kg^{-1}. The experiment was laid out in randomized block design with three replications. The treatments consisted of two sources of Zn (zinc oxide and zinc sulphate) and five levels of Zn (0, 2, 4, 6 and 8 kg ha^{-1}). Maize (var.Vijay) was sown in third week June in both the years. A basal dose of 100 kg N, 60 kg P_2O_5 and 40 kg K_2O ha^{-1} was applied through urea, di-ammonium phosphate and muriate of potash, respectively. Half dose of N and full dose of P and K were applied at the time of sowing of maize. Remaining N was top dressed after one month of sowing. Crop was harvested green foliage yield of the crop was recorded at harvest. The plant samples were digested in di-acid mixture of HNO_3: $HClO_4$ (10:4) and sulphur content was determined turbiditimetrically (Chesnin and Yien, 1951). Phosphorus, K and Zn in di-acid digest were determined by vanadomolybdate yellow colour method (Jackson, 1973),, flame photometer and atomic absorption spectrophotometer, respectively. Nitrogen content was estimated by modified Kjeldahl method and protein content was calculated by multiplying with a factor of 6.25. Crude fibre content in plants was determined as per method suggested by AOAC (1970). The uptake of nutrients was obtained as product of their concentrations and dry matter yield. Post harvest soil samples collected after two years of experiment were air dried, ground to pass through 2 mm sieve and analyzed for organic carbon, available N (Subbiah and Asija 1956), available P (Olsen *et al.* 1954), available K (Hanway and Heidel 1952), available S after extraction with 0.15% $CaCl_2$ solution (Chesnin and Yien 1951), DTPA-Zn (Lindsay and Norvell 1978). The data thus obtained were analyzed statistically using analysis of variance technique for various parameters at 5% level of significance.

RESULTS AND DISCUSSION

Yield

The effect of zinc sources on green foliage and dry matter yield of maize was found to be significant. Zinc sulphate produced higher green foliage (30.07 t ha^{-1}) and dry matter (11.04 t ha^{-1}) yields of maize compared to zinc oxide (Table 1).

Table 1: Effect of source and levels of zinc on yield and quality of maize crop (mean of 2 years)

Treatment	Yield (t ha^{-1})		Protein content (%)	Protein yield (kg ha^{-1})	Crude fiber (%)
	Green foliage	Dry matter			
Source of Zn					
ZnO	27.45	8.13	10.92	887.7	31.08
Zn SO_4	30.07	9.43	11.04	1041.0	31.10
SEm$\pm$	0.54	0.28	0.011	18.07	0.007
CD (P=0.05)	1.59	0.84	0.033	53.66	NS
Zinc (kg ha^{-1})					
0	24.74	7.54	10.66	803.7	31.36
2	27.01	8.30	10.72	889.7	31.13
4	29.87	9.13	10.85	990.6	31.06
6	32.19	9.62	11.04	1060.0	31.00
8	30.00	9.62	11.17	1023.2	30.90
SEm$\pm$	0.84	0.45	0.016	28.55	0.011
CD (P=0.05)	2.50	1.32	0.046	84.78	0.032

This increase in yield may be attributed to higher solubility of zinc sulphate than zinc oxide. With successive increase in Zn levels, green foliage and dry matter yield increased significantly up to 6 kg Zn /ha but a further increase in Zn level did not significantly increase the yields. The highest green foliage (32.19 t ha^{-1}) and dry matter (9.62 t ha^{-1}) yields were recorded with 6 kg Zn/ ha which registered 30.1 and 26.2 % higher green foliage and dry matter yield, respectively over control. This increase in yields due to Zn application may be attributed to the fact that Zn is main yield limiting plant nutrient in Zn deficient soils. Applied Zn is reported to enhance the absorption of native as well as added major nutrients and thereby improves overall growth and development of plant and ultimately the yields. In addition the beneficial influence of Zn application on the yield of maize may be attributed to its role in various enzymatic reactions, growth processes, hormone production and protein synthesis and also the translocation of photosynthates to reproductive parts thereby leading to higher yield of crop (Latha *et al.* 2001 and Chandel *et al.* 2014).

Quality

The difference in protein content in maize seed as affected by zinc sources was non-significant. However, a slightly greater amount of protein in maize was recorded with zinc sulphate (Table 1). Increasing levels of Zn significantly increased the protein content in maize crop from 10.66 to 11.17 percent with 8 kg Zn/ha. The increase in protein content owing to Zn addition might be attributed to its involvement in the nitrogen metabolism. Singh *et al.* (2016) reported an increase in protein content with Zn application in maize seeds. Corresponding application of Zn also increased the protein yield from 803.7 to 1060.0 kg ha^{-1}. The increases in protein yield were significant up to 6 kg Zn/ha over the control. Since variation in protein content has genetic and biochemical limitation, the protein yield is more influenced by dry matter yield and thus followed almost trend similar to dry matter yield. Dwivedi *et al.* (2001) also reported similar results. The sources of zinc had no significant effect on protein production. However the higher values of protein yield were recorded in maize with addition of zinc sulphate over zinc oxide. Crude fibre content was not affected significantly with sources of zinc. Increasing levels of zinc significantly decreased the crude fibre content in maize plants and minimum value (30.90%) was recorded at 8kg Zn ha^{-1}.

Uptake of nutrients

Zinc sulphate as a source of zinc was superior to zinc oxide for utilizing greater amounts of nitrogen by maize crop. However, the difference between these two sources was statistically non-significant. Nitrogen uptake by maize crop increased significantly with increasing levels of Zn and the highest N uptake was observed with 6 kg Zn ha^{-1}, i.e. 170.1 kg ha^{-1} and lowest in the control, i.e. 128.2 kg ha^{-1} (Table 2). Thus, the beneficial effect of Zn on photosynthesis and metabolic processes augments the production of photosynthates and their translocation in different plant parts, which ultimately increased the uptake of N in maize crop. These results are in accordance with the findings of Singh *et al.* (2008). Addition of zinc as zinc sulphate to the soil brought about greater amount of P uptake by maize crop than that of zinc oxide. This may be attributed to higher production of dry matter due to zinc sulphate application. However, the effect of sources of zinc on P uptake was statistically non–significant. Phosphorus uptake by maize crop increased at lower levels of zinc due to increase in yield but at higher level of zinc, it decreased due to reduced P content in maize crop. This decrease in P uptake with higher dose of zinc might be due to antagonistic effect between P and Zn. Similar results were reported by Chandel *et al.*(2014). The uptake of potassium by maize crop was not affected significantly due to sources of zinc, but higher value of K uptake was recorded with zinc sulphate application. The uptake of K by maize crop was significantly increased with increasing levels of Zn up to 6 kg Zn ha^{-1}. The magnitude of increase in K uptake with 6 kg Zn ha^{-1} was 31.2 % in maize crop over control. The results are in accordance with the findings of Singh *et al.* (2016). The uptake of sulphur by maize crop was not affected significantly with the sources of zinc. However, relatively higher uptake value of sulphur was noted with zinc sulpate addition. There was a significant increase in sulphur uptake by maize crop with the application of Zn up to 6 kg ha^{-1} over the control. Thereafter, a reduction in S uptake was noted at higher level of zinc (Singh *et al.* 2016).Zinc sulphate resulted in maximum uptake of Zn in maize crop at any level of Zn compared with respective levels of Zn from zinc oxide. This increase may be attributed to increased dry matter yield of maize with zinc sulphate. The uptake of Zn by maize crop increased significantly with increasing doses of Zn and it was highest with the application of 8 kg Zn ha^{-1}. The increase in Zn uptake by maize crop with 8 kg Zn ha^{-1} was 87.1 per cent over the control. The increase in Zn was in consonance with higher dry matter yield and increase in Zn content in maize crop with increase in Zn levels (Kar *et al.* 2007.

Table 2: Effect of sources and levels of zinc on uptake of nutrients by maize and status of nutrients in post harvest soil (mean of 2 years)

Treatment	Nitrogen (kg ha^{-1})	Phosphorus (kg ha^{-1})	Potassium (kg ha^{-1})	Sulphur (kg ha^{-1})	Zinc (g ha^{-1})	Org. C (g kg^{-1})	Avail. Nutrients (kg ha^{-1})		
							N	P	K
Source of Zn									
ZnO	138.4	29.6	170.0	24.7	258.1	3.1	159.0	9.0	0.58
$ZnSO_4$	162.7	32.8	208.3	28.1	304.1	3.2	160.0	8.8	0.62
SEm$\pm$	2.29	1.12	3.93	1.29	5.83	0.005	0.63	0.007	0.010
CD (P=0.05)	6.79	NS	11.67	NS	17.33	NS	NS	NS	0.029
Zn (kg ha^{-1})									
0	128.2	26.7	158.7	20.6	190.1	.30	158.0	9.0	0.51
2	139.4	29.7	173.2	23.9	235.1	0.30	159.0	9.0	0.58
4	156.6	33.9	193.2	27.5	293.2	0.31	161.2	9.4	0.61
6	170.1	35.2	208.2	31.3	348.0	0.31	161.7	9.4	0.65
8	159.5	31.6	192.1	29.9	355.7	0.32	161.0	9.4	0.65
SEm$\pm$	3.61	1.81	6.21	2.02	9.21	0.008	1.02	9.3	0.66
CD (P=0.05)	10.74	5.39	18.42	6.04	27.36	NS	NS	0.011	0.016

Soil fertility

The status of organic carbon in post harvest soil was not improved significantly with sources and ievels of zinc over control. The sources of zinc were not effective in enhancing the status of available nitrogen in post harvest soil but levels of zinc enhanced the status of available N in soil and maximum amount was noted with 6 kg Zn ha^{-1}. The difference in available N status of the soil due to zinc levels was not significant. The status of available P was not improved significantly with sources and levels of zinc. The trend was just opposite for DTPA extractable Zn content where the values increased with increasing levels of Zn, though the overall level remained medium. It is inferred from the present study that soil application of Zn up to a dose of 6 kg ha^{-1} is beneficial compared to control for yields of maize crop. Also an improvement in quality of maize and uptake of nutrients was recorded with zinc application. Therefore, the present study highlights that application of Zn up to a dose 6 kg/ha as zinc sulphate is beneficial for forage maize cultivation in alluvial region of Western Uttar Pradesh.

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