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Zinc management effects on quality and nutrient yield of fodder maize (*Zea mays*)

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ABSTRACT

Relationship between zinc deficiencies in soil that inturn in crop plants, animal and ultimately in human nutrition is reported in several studies. Agronomic fortification through soil and foliar application of zinc could be viable option to improve the productivity and quality of fodder maize, which ultimately helps in alleviate zinc deficiency in animals. Therefore, we attempted to evaluate the performance of fodder maize (*Zea mays* L.) in two consecutive *kharif* seasons, i.e. 2014 and 2015. The experiment was laid out in split plot arrangement with two main-plot treatments consisting of varieties (African tall and J-1006) and six sub-plot treatments of zinc fertilization (Zn_0-No zinc sulphate; Zn_1-10 kg/ha $ZnSO_4$ as basal dose ; Zn_2 -20 kg/ha $ZnSO_4$ as basal dose ; Zn_3 -0.5% one foliar spray of $ZnSO_4$ at 30 DAS ; Zn_4 -0.5% two foliar spray of $ZnSO_4$ at 30 and 45 DAS and Zn_5 -10 kg/ha $ZnSO_4$ as basal dose +0.5% one foliar spray at 30 DAS). Results shows that both the verieties tested were found statistically at par for all the tested parameters except crude protein (CP) content, in which J-1006 accumulated higher CP over African tall. The highest green and dry fodder yield were recorded with Zn_2 (60.16 and 14.15 tonnes/ha) which was on par to Zn_5 and Zn_4 while lowest with Zn_0 (46.69 and 10.25 tonnes/ha). Likewise CP, ether extract (EE) and ash content and their yields found maximum with treatment soil application @ 20 kg $ZnSO_4$ followed by combined fertilization soil application @ 10 kg $ZnSO_4$ + one foliar spray of 0.5% Zn sulphate and two foliar spray of 0.5% of Zn sulphate. However, in contrast to these the maximum values of neutral detergent fiber (NDF), acid detergent fiber (ADF) and acid detergent lignin (ADL) reported with Zn_0 (66.87, 43.43 and 5.44% DM) while lowest with Zn_4 (64.30, 41.56 and 5.20% DM). The zinc fertilization of maize with 20 kg/ha $ZnSO_4$ hepta hydrate as basal dose resulted in 31.3 and 50.9% higher zinc content and uptake, respectively over control. Overall, our study suggest that zinc fertilization of maize through soil and/or foliar spray can enhance not only fodder productivity and quality but also improve, nutrient uptake of fodder maize in north-western region of India and elsewhere under similar agro-climatic conditions.

Key words: Fodder maize, Foliar zinc nutrition, Productivity and Quality

Lower productivity of cattle and buffalos under Indian condition is accountable mainly due to unavailability of quality feed and fodder, improper nutrition, inadequate health-care and management. At present, the country faces a net deficit of 35.6% green fodder, 10.95% dry crop residues and 44% concentrate feed ingredients (Anonymous 2013). Under current scenario, forage based economical feeding strategies are required to reduce the cost of livestock product as the feed alone constitutes 60-70% of the total milk production cost. However, there is tremendous pressure of livestock on available total feed, fodder, as land available for fodder production has been decreasing, and there is hardly any scope of expansion due to increasing pressure on agricultural land for food and cash crops. Thus, any attempt towards enhancing feed availability and economizing the feed cost would result in increased margin of profits to livestock owners. The solution therefore, lies in increasing quality fodder production on limited space and time.

Maize (*Zea mays* L) is one of the most versatile and multi utility cereal and commonly known as queen of cereals due to its highest genetic potential and wider adaptability under diverse agro-ecological conditions. It is not only a source of food, feed, fodder and industrial raw material but also known to provide enormous opportunity for crop diversification, value addition and employment generation. Worldwide, maize is the critical fodder crop because of its high yielding ability per unit area and time than other forage

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crops and wider adaptability to larger climatic situations. It is an ideal fodder crop because of its quick growing nature, succulency, palatability and excellent quality without any toxicant at any stage of crop growth. Maize being highly exhaustive in nature, demands good nutrient management. Among different nutrients micronutrients especially zinc (Zn) plays an important role in quality fodder production. Direct linkages between available micronutrient in the soil and their contents in forage and fodders have been widely studied and clearly established and it's also common in case of zinc (Nube and Voortman 2006, Jat *et al.* 2014). Zinc is essential for plants, animals and human nutrition, thus opportunities for simultaneously addressing the deficiencies by applying them as supplemental fertilizer to crops, benefiting both farmers (better yields) and consumers (micronutrient-enriched food/fodder).

Zn has vital role in stabilization of RNA, DNA, ribosomes and is involved in the immune system of animals, deficiency of which affects the health and milk production severely. According to ICAR-IISS, Bhopal, across the states more than 50% soil samples tested were found deficient in zinc; while in Haryana this digit reached up to 60%. The deficiency of zinc in soil will lead to poor yield as well as quality of fodder. Since, zinc is also a major nutrient in animal nutrition; if we properly manage its deficiencies in soil the problem associated with lower level of zinc in animals can be rectified. With this hypothesis the current study was planned to access limited information about scheduling, method and dose of zinc application for better quality and yield of maize in different maize cultivars.

MATERIALS AND METHODS

A field experiment was conducted during two consecutive *kharif* seasons of 2014 and 2015, at research farm (29º45' N, 76º58' E and at an altitude of 245 m above mean sea level) of Forage Research and Management Centre, ICAR-NDRI, Karnal, Haryana. The climate of the study area is semi-arid, with a mean annual rainfall of 650 mm (70-80% of which received during monsoon season) with the mean annual evaporation of 850 mm. Daily meteorological parameters during cropping season were recorded at ICAR-CSSRI meteorological observatory. The mean minimum, maximum temperature and total rainfall during this study period of *kharif* 2014 and 2015 (June-August) was 23.7ºC, 33.3ºC and 451 mm, respectively. The soil of research site (before *kharif* 2014) was sandy clay loam in texture with 7.8 pH, Walkley–Black C (0.61%), EC (0.32 dS/m), $KMnO_4$ oxidizable N (191 kg/ha), 0.5 M $NaHCO_3$ extractable P (18.5 kg/ha) and 1 N NH_4 OAC extractable K (256 kg/ha) and diethylene triamine penta acetic acid (DTPA) extractable Zn (0.46 mg/kg). The experiment was conducted with two main-plot treatments consisting of varieties (African tall and J-1006) and six sub-plot treatments of zinc fertilization (Zn_0-No zinc sulphate; Zn_1-10 kg/ha $ZnSO_4$ as basal dose; Zn_2 -20 kg/ha $ZnSO_4$ as basal dose ; Zn_3-0.5% one foliar spray of $ZnSO_4$ at 30 DAS ; Zn_4-0.5% two foliar spray of $ZnSO_4$ at 30 and 45 DAS and Zn_5-10 kg/ha $ZnSO_4$ as basal dose +0.5% one foliar spray at 30 DAS). The experiment was designed in split-plot arrangements with three replications at fixed site. The each experimental unit consisted of 5.0 m × 3.40 m plots.

Zinc sulphate heptahydrate having Zn content of 21% was used in study. The field was deep ploughed by chisel plough to break the hard pan below the plough layer and laser levelled before start of the experiment. The planting of crop involved one ploughing each with cultivator, disc harrow and thereafter planking was done. The crop was sown on 5 June 2014 and 1 June 2015, using seed rate at 60 kg/ha with spacing of 30 cm × 10 cm. The recommended dose of major nutrients (120 kg N and 60 kg P_2O_5/ha) were applied to all the treatments, of which full dose of P and half N were applied at sowing time and remaining half nitrogen were top dressed as urea at 30 days after sowing. At the time of top dressing, fertilizer was broadcasted and care was taken so that the fertilizers were mainly applied on targeted crop rows only. In case of zinc management, to achieve uniform soil application, $ZnSO_4$ was dissolved in water and then sprayed in the plots as per treatments as basal. While for treatments having foliar spray, 0.5% solution of $ZnSO_4$ (5 kg $ZnSO_4$ in 100 litre of water) were made and sprayed at 30 and 45 DAS. In view of best weed management, Atrazine @ 1.0 kg a.i./ha was applied as pre-emergence (PE) to control weeds.

The crop was harvested manually on 10 August 2014 and 7 August 2015, at the age of 65 days for green fodder purpose. Fresh fodder yield recorded and plant samples collected at harvest were dried in hot air oven at 60°C for 48 hr. These oven-dried samples of plants were ground to pass through 40 mesh sieve in a Macro-Wiley Mill and used for chemical analysis. Finally milled sample were analyzed for DM (AOAC 2005, method 934.01), ash (AOAC 2005, method 942.05) and Kjeldahl Nitrogen (AOAC 2005, method 984.13). Ether extract (EE) was analyzed according to AOAC (2005, method 920.39). Crude protein content in corn was determined by multiplying the N concentration by 6.25. Neutral detergent fiber was assayed by the procedures of Van Soest *et al*. (1991), without heat stable amylase and sodium sulfite for roughages. Acid detergent fiber was analyzed according to AOAC (2005, method 973.18). Both neutral detergent fiber and acid detergent fibers were expressed without residual ash. Zn in straw samples was analysed on a di-acid ($HClO_4$ + HNO_3 in 3:10 ratio) digest on an Atomic Absorption Spectrophotometer (Prasad *et al.* 2006) and the uptake of the Zn was calculated by multiplying Zn concentrations with respective yield of corn stover in each treatment.

All data recorded were analyzed with the help of analysis of variance (ANOVA) technique (Gomez and Gomez 1984) for split-plot design using SAS 9.3 software (SAS Institute, Cary, NC). The least significant test was used to decipher the main and interaction effects of treatments at 5% level of significance ($P<0.05$).

RESULTS AND DISCUSSION

Effect on fodder yields

The critical analysis of data on pooled basis shows that amongst tested varieties no significant variation was found for green and dry fodder yield. However, significant enhancement in both green as well as dry fodder yields of maize was recorded with Zn fertilization. Significant improvements in maize fodder yields (green and dry) over the control were recorded for all Zn treatments, with the highest green and dry fodder yield (pooled basis) with Zn_2 (60.16,14.15 tonnes/ha) respectively which was not statistically different from Zn_5 (59.71,13.50 tonnes/ha) and Zn_4 (59.32,13.14 tonnes/ha) (Table 1). In the present study green and dry fodder yields of maize were the highest with the soil application @ 20 kg $ZnSO_4$ followed by combined fertilization soil application @ 10 kg $ZnSO_4$ + one foliar spray of $ZnSO_4$ (0.5%) and two foliar spray of $ZnSO_4$ (0.5%) at 30 and 45 DAS, this could be due to the higher amount of $ZnSO_4$ used as basal dose and also due the fact that soil application was made at planting which makes early availability of Zn for various metabolic activities for better growth and yield, while foliar application at 30 and 45 DAS gave higher photosynthetic activities at later stages. The positive and encouraging effects of Zn fertilization on fodder yields of corn has also been observed by Kumar (2013) under similar agro-climatic condition.

Effect on fodder quality

Chemical composition showed that all the quality parameters of fodder maize were not influenced significantly by cultivars (Table 2) except for CP. The higher CP content of J-1006 might be due to its higher leaf growth and leaf stem ratio as compared to African Tall, in turn resulted into higher uptake of nitrogen which ultimately leads to higher CP content (Kumar *et al*. 2016). Zinc fertilization through various options showed significant effect on the chemical composition of the fodder maize over the no zinc application (Table 2). Likewise fodder yields, the quality parameters, i.e. CP, EE and ash (pooled basis) also followed the similar trend and found maximum with the soil application @ 20kg $ZnSO_4$(10.39,2.22,7.85%) followed by combined fertilization soil application @ 10 kg $ZnSO_4$ + one foliar spray of 0.5% $ZnSO_4$ (10.05, 2.13, 7.55%) and two foliar spray of 0.5% of $ZnSO_4$ (9.99,2.12,7.53%), respectively. The higher crude protein content could be attributed due to fact that optimum levels of zinc in the plants are known to enhanced nitrogen uptake thus nitrogen plays critical role in protein synthesis. Significant improvement of ash and ether content in corn fodder might be due to fact the higher availability of zinc promote the growth and dry matter accumulating capacity of the plants and synergistic effect of zinc on the availability of nitrogen further add in the enhancement of these quality parameters.

NDF, ADF and ADL content of the fodder significantly affected through zinc fertilization (Table 2) and showed declining trend with increase in zinc fertility levels. The maximum values of NDF, ADF and ADL (pooled basis) reported with Zn_0 (66.87, 43.43, 5.44 %) while lowest with Zn_4 (64.30, 41.56, 5.20 %). However these parameters in

Table 1 Effects of varieties and zinc sulphate on green and dry fodder yield of maize (Pooled basis)

Treatment	Green fodder yield (tonnes/ha)	Dry fodder yield (tonnes/ha)
Varieties		
African tall	53.71	12.61
J-1006	56.90	12.25
SEm±	4.08	1.07
CD (P=0.05)	NS	NS
Zinc sulphate levels		
Zn_0	46.69	10.25
Zn_1	53.10	11.96
Zn_2	60.16	14.15
Zn_3	52.84	11.57
Zn_4	59.32	13.14
Zn_5	59.71	13.50
SEm±	3.06	0.86
CD (P=0.05)	6.24	1.75

Zn_0-No zinc sulphate; Zn_1-10 kg/ha $ZnSO_4$ as basal dose; Zn_2 -20 kg/ha $ZnSO_4$ as basal dose ; Zn_3 -0.5% one foliar spray of $ZnSO_4$ at 30 DAS ; Zn_4 -0.5% two foliar spray of $ZnSO_4$ at 30 and 45 DAS and Zn_5 -10 kg/ha $ZnSO_4$ as basal dose +0.5% one foliar spray at 30 DAS.

Table 2 Effects of varieties and zinc sulphate on quality parameters of fodder maize (Pooled basis)

Treatment	CP (%)	EE (%)	Ash (%)	NDF (%)	ADF (%)	ADL (%)
Varieties						
African tall	8.92	1.89	6.84	66.15	42.83	5.36
J-1006	9.78	2.07	7.38	64.66	41.84	5.24
SEm±	0.26	0.06	0.17	0.98	0.62	0.08
CD (P=0.05)	0.84	NS	NS	NS	NS	NS
Zinc sulphate levels						
Zn_0	7.14	1.50	5.64	66.87	43.43	5.44
Zn_1	9.55	2.02	7.21	66.04	42.76	5.36
Zn_2	10.39	2.22	7.85	64.48	41.67	5.22
Zn_3	8.98	1.91	6.88	66.28	42.88	5.36
Zn_4	9.99	2.12	7.53	64.30	41.56	5.20
Zn_5	10.05	2.13	7.55	64.48	41.69	5.22
SEm±	0.44	0.09	0.27	0.95	0.59	0.08
CD (P=0.05)	0.89	0.19	0.55	1.95	1.21	0.16

Zn_0-No zinc sulphate; Zn_1-10 kg/ha $ZnSO_4$ as basal dose; Zn_2 -20 kg/ha $ZnSO_4$ as basal dose ; Zn_3 -0.5% one foliar spray of $ZnSO_4$ at 30 DAS ; Zn_4 -0.5% two foliar spray of $ZnSO_4$ at 30 and 45 DAS and Zn_5 -10 kg/ha $ZnSO_4$ as basal dose +0.5% one foliar spray at 30 DAS.

Table 3 Effects of varieties and zinc sulphate on nutrient yield (kg/ha) of fodder maize (Pooled basis)

Treatment	CP (kg/ha)	EE (kg/ha)	Ash (kg/ha)
Varieties			
African tall	1139.94	241.15	871.72
J-1006	1204.32	254.63	908.81
SEm±	94.68	20.08	72.12
CD (P=0.05)	NS	NS	NS
Zinc sulphate levels			
Zn_0	719.58	151.27	570.11
Zn_1	1146.57	241.52	863.81
Zn_2	1468.52	312.64	1110.64
Zn_3	1038.14	219.85	794.72
Zn_4	1299.36	274.96	981.09
Zn_5	1360.61	287.11	1021.23
SEm±	100.78	21.48	73.00
CD (P=0.05)	205.82	43.86	149.08

Zn_0-No zinc sulphate; Zn_1-10 kg/ha $ZnSO_4$ as basal dose; Zn_2 -20 kg/ha $ZnSO_4$ as basal dose ; Zn_3 -0.5% one foliar spray of $ZnSO_4$ at 30 DAS ; Zn_4 -0.5% two foliar spray of $ZnSO_4$ at 30 and 45 DAS and Zn_5 -10 kg/ha $ZnSO_4$ as basal dose +0.5% one foliar spray at 30 DAS.

Table 4 Effects of varieties and zinc sulphate on Zn content (mg/kg DM) and uptake (g/ha) of fodder maize (Pooled basis)

Treatment	Zn content (mg/kg)	Zn uptake (g/ha)
Varieties		
African tall	42.00	536.61
J-1006	42.15	518.97
SEm±	1.19	42.16
CD (P=0.05)	NS	NS
Zinc sulphate levels		
Zn_0	32.13	325.13
Zn_1	42.99	514.26
Zn_2	46.76	662.09
Zn_3	40.39	467.27
Zn_4	44.95	586.16
Zn_5	45.24	611.84
SEm±	1.96	45.39
CD (P=0.05)	4.00	92.70

Zn_0-No zinc sulphate; Zn_1-10 kg/ha $ZnSO_4$ as basal dose ; Zn_2 -20 kg/ha $ZnSO_4$ as basal dose ; Zn_3 -0.5% one foliar spray of $ZnSO_4$ at 30 DAS ; Zn_4 -0.5% two foliar spray of $ZnSO_4$ at 30 and 45 DAS and Zn_5 -10 kg/ha $ZnSO_4$ as basal dose +0.5% one foliar spray at 30 DAS.

the maize fertilized with Zn_2-20 kg/ha $ZnSO_4$ as basal dose and Zn_5-10 kg/ha $ZnSO_4$ as basal dose +0.5% one foliar spray at 30 DAS were found at par with treatment Zn_4-0.5% two foliar spray of $ZnSO_4$ at 30 and 45 DAS. The results could be attributed to the fact that higher zinc availability resulted in higher protein synthesis and lowered the soluble carbohydrates which could be responsible for lower content of NDF, ADF and ADL in fodder of corn (Almodares *et al*. 2009). Correlation matrix presented in Table 5 showed that green fodder and dry matter yield, were negatively correlated with fiber fractions. This is also reason for lower NDF, ADF and ADL content in treatments which gave higher yields.

Effect on nutrient yields

Result of present study showed that nutrient of fodder maize not influenced significantly by cultivars. However zinc fertilization had significant effect on various nutrient yields (Table 3). The soil application @ 20 kg $ZnSO_4$ were accountable for 50.99, 51.59, 48.67 % higher EE CP, and ash yields (pooled basis), respectively, over control. However, treatments Zn_2-20 kg/ha $ZnSO_4$ as basal dose and Zn_5-10 kg/ha $ZnSO_4$ as basal dose + 0.5% one foliar spray at 30 DAS were found at par with treatment Zn_4-0.5% two foliar spray of $ZnSO_4$ at 30 and 45 DAS. The improvement nutrient yields which is a function of dry matter yield and content of these quality parameters in fodder, partly could be due to favorable effect of Zn application on growth parameters, i.e. plant height, number of leaves, leaf length and leaf width, which increased dry mater yield of the fodder maize and partly due to higher content of this parameters due to higher nutrient uptake with successive increase in the level of zinc (Kumar *et al*. 2016).

Effect on Zn content and uptake

Among varieties slightly higher zinc content as well as its uptake was observed with J-1006 than African tall (Table 4). However, both varieties failed to obtain any significant difference and remains statistically at par with each other. Soil and foliar applied zinc sulphate had significant effect on zinc content and uptake by green fodder. The zinc fertilization of maize with treatment Zn_2-20 kg/ha $ZnSO_4$ as basal dose resulted in 31.29% and 50.89 % higher zinc content and uptake (pooled basis), respectively, by the green fodder of maize over control (Zn_0). However, the treatments Zn_4-0.5% two foliar spray of $ZnSO_4$ at 30 and 45 DAS and Zn_5-10 kg/ha $ZnSO_4$ as basal dose + 0.5% one foliar spray at 30 DAS found at par with maize fertilized by Zn_2-20 kg/ha $ZnSO_4$ as basal dose.

It has been reported that zinc due to its role in photosynthesis and metabolic process augments the production of photosynthates and their translocation to different plant parts, which ultimately increase the concentration of zinc in green fodder. Increase in uptake of zinc is combined effect of substantial increase in concentration and higher dry fodder yield in influence of increasing levels of zinc (Meena *et al*. 2013).

Our study demonstrated that soil and foliar applied zinc sulphate had significant effect on fodder and nutrients yields, quality and Zn dynamics of maize fodder. Thus, it can be concluded that to realize higher productivity with enhanced quality of fodder maize Zn fertilization as basal and foliar

Table 5 Correlation coefficients of the quality parameters with yield of fodder maize

Variables	DMY	CP	EE	Ash	NDF	ADF	ADL
GFY	0.947*	0.949*	0.950*	0.952*	-0.952*	-0.966*	-0.968*
DMY		0.898*	0.903*	0.907*	-0.840*	-0.857*	-0.856*
CP			1.000*	0.999*	-0.866*	-0.888*	-0.885*
EE				1.000*	-0.862*	-0.885*	-0.883*
Ash					-0.864*	-0.887*	-0.885*
NDF						0.998*	0.996*
ADF							0.999*

*Significant at P=0.05. GFY-Green fodder yield, DMY- Dry matter yield, CP- Crude protein, EE- Ether extract, NDF- Neutral detergent fiber, ADF- Acid detergent fiber and ADL- Acid detergent lignin.

spray are quite helpful, which will further strengthen and sustain the performance of livestock in terms of health and milk production.

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