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Yield and silage quality of fodder maize (*Zea mays* L.) as influenced by zinc fertilization

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Abstract
A field experiment was conducted during *rabi*, 2019-20 and 2020-21 in red loamy soils of Hyderabad to find out the response of fodder maize to different soil and foliar applications of zinc. The five treatments consisted of RDF (120 kg N - 50 kg P_2O_5 - 40 kg K_2O ha-1) without zinc and different combinations of soil and foliar applications of zinc were studied in a randomized block design with four replications. The results of the experiment revealed that (two years pooled mean) among all the treatments, the maximum plant height (297.0 cm), leaf to stem ratio (0.22), dry matter production (103.7 q ha-1) and green fodder yield (419 q ha-1) were recorded with RDF along with foliar application of 1% $ZnSO_4$ at 30 45 and 60 DAS (T_5). All the growth parameters and yield were superior over other treatments the lowest was recorded with no Zn + RDF (T_1). The highest B: C ratio (2.9) Net returns and gross returns was realized with application of Recommended dose of fertiliser along with Foliar spray of 1% $ZnSO_4$ at 20, 45 and 60 days (T_5). Lowest was recorded with no Zn application T_1. Hence, it can be concluded that foliar application of zinc at three different stages had significant influence on the growth parameters and green fodder yield of fodder maize.

Keywords: Fodder maize, zinc sulphate, growth parameters and green fodder yield, silage, bio fortification

Introduction
India is blessed with diversified type of livestock. Its livestock sector is one of the largest in the world. It has 56.7% of world's buffaloes, 12.5% cattle, 20.4% small ruminants, 1.5% pigs and 3.1% poultry. The importance of livestock in Indian agriculture is well recognized. Livestock not only provides food security through supply of milk, meat and self- employment of both men and women but also plays an important role for poverty alleviation of smallholder. At present, the country faces a net deficit of 61.1 per cent green fodder, 21.9 per cent dry crop residues and 64% concentrate feeds. In India the cropped area under fodder is only 4.2 to 4.4% of the total cultivated area and there is hardly any scope of expansion due to increasing pressure on agricultural land for food and cash crops. To meet out the needs of the ever increasing livestock population, the production as well productivity of fodder is to be increased. Maize being a rich source of water-soluble carbohydrates and low protein content is considered to be ideal crop for silage production due to its low buffering capacity and easy ensilage.

Maize (*Zea mays* L.) is one of the most versatile and multi utility crop, having wider adaptability in diverse ecologies. Globally, it is known as queen of cereals because of its highest genetic potential. The mineral zinc is essential as a micronutrient (Hafeez *et al.*, 2013) [7]. Zinc is the only element present in all the six enzyme classes (Broadley *et al* 20017) [2] it also plays a role in the carbohydrate metabolism, the regulation of cellular membrane protein synthesis and pollen formation (Cakmak, 2002) [4]. As an important nutrient for plant, Zinc plays a critical role in fodder quality (Mahdi *et al.*, 2012; Mohan *et al.*, 2014) [17, 14]. However more than 50% Indian soils especially southern India is low in zinc resulting in zinc deficiency specially Zn sensitive crop like maize. Due to these factors, regular supply of zinc is needed in maize raising both as food and forage crops. Zinc deficiency not only adversely affects plant growth but also impairs health of livestock. Therefore, a field study was undertaken to study the effect of zinc on growth and yield of fodder maize variety 'African tall' through soil and foliar applications.

Material and Methods
A field experiment was carried out during *rabi* 2019-20 and 2020-21 at College Farm college

of agriculture, PJTSAU, Hyderabad. The soil characteristics of the experimental site was sandy clay loam in texture, near neutral in reaction, medium in organic carbon, low in available nitrogen and zinc, and medium in available phosphorus and potassium. The experiment was laid out in a randomized block design with five treatments and replicated four times. The treatment comprised of soil and foliar applications of zinc *viz.*, Recommended dose of fertilizers (RDF) alone (120 kg N - 50 kg P_2O_5 - 40 kg K_2O ha-1) without zinc application (T_1), RDF + soil application of 15 kg $ZnSO_4$ ha-1 (T_2), RDF + soil application of 25 kg $ZnSO_4$ ha-1 (T_3), RDF + Foliar spray of 1% $ZnSO_4$ at 20 and 45 days (T_4) and RDF+ Foliar spray of 1% $ZnSO_4$ at 20,45 and 60 days (T_5).

Fodder maize was sown on 7th November 2019 and 5th November 2020 at a spacing of 30 × 10 cm and harvested on 3rd February 2020 and 4th February 2021 at the age of 85 days for green fodder purpose. The fodder maize variety of African tall with a seed rate of 40 kg ha ^{1} and spacing of 30 x 10 cm was used in this experiment. All the plots were supplied with (Recommended dose of fertilizer) 120 kg of N ha^{-1} and 50 kg of P_2O_5 ha^{-1} in which full dose of P_2O_5 and half dose of N was applied as basal dose while the remaining half of the N was supplied on the knee-high stage by broad-casting. Zinc sulphate was applied as per the treatments i.e. Soil application of $ZnSO_4$ at two days after basal application of N, P, K and foliar application of 1% $ZnSO_4$ at 30 45 and 60 DAS as per the treatments). Green fodder, dry matter yield and growth parameters *viz* plant height, number of leaves, stem girth and leaf to stem ratio were measured. To check out the quality of the fodder crop, representative samples were oven-dried sample at 60 °C to constant weight to determine dry matter (DM) content, was ground using a Wiley mill to pass through a 1 mm sieve and were stored into an airtight polythene bags till further analysis. Proximate principles namely crude protein (CP), crude fiber (CF), ether extract (EE) and total ash was determined according to AOAC (2000) [1]. Neutral detergent fibre was measured following methods of Van Soest *et al.*, 1991 [20]. The data emanating from the present investigation is tabulated after statistical analysis following the randomized block design technique using MS excel, functional analysis (comparison means of $ZnSO_4$ soil vs foliar application) suggested by LeClarg *et al*. (1962) and those sampled over periods to measurement over time analysis suggested by Gomez and Gomez (1984) [6]. Inferences are drawn and critically discussed. Statistical significance was tested by F-value at 0.05% level of probability and critical difference (CD) was worked out where ever the effects were significant. Treatment differences that were non–significant were denoted as "NS".

Results and Discussion

Growth parameters

Growth parameters like plant height (297.0 cm), No of leaves (13.9) stem girth (8.10 cm) leaf to stem ratio (0.304) were recorded highest with RDF +Foliar spray of 1% Zn SO4 at 15, 30, 45 and 60 days (T_5) which was differed significantly over soil and foliar application of Zn at various stages compared to Recommended dose of fertilizer + No Zn application (T_1). Foliar application of Zn at 1.0% considerably increased the plant height and other growth attributes. This may be due to the positive effect of Zn applied at higher doses. Zn aids in the synthesis of growth hormones and plays a vital role in cell elongation. Increase in plant height with respect to increased Zn application rate indicates maximum vegetative growth of plant under higher Zn availability. This finding is in relevance with Yasin *et al.* 2018.

The highest dry matter production (103 q ha-1) at harvest was produced with the treatment T_5 *i.e;* RDF with foliar application of 1% $ZnSO_4$ at 30 45 and 60 DAS, which was significantly superior over other treatments (Table-1). The percentage increase in dry matter production of the treatments with zinc (soil and foliar application) compared to the RDF (T_1 no zinc) alone treatment ranged from 9 to 39 percent. The lowest values for all growth parameters were recorded with the treatment that applied only RDF without zinc which differed significantly from other treatments. This might be due to involvement of zinc in biosynthesis of plant hormones by activating tryptophan, which is a precursor of Indole acetic acid (auxin). IAA is a component of various enzymes, such as carbonic anhydrase and alcoholic dehydrogenase, which have a suggestive role in chlorophyll formation, photosynthesis and metabolic reactions in plants. It also involves in protein synthesis, cell division and cell elongation, which in turn promotes the vertical growth of the plant, photosynthates accumulation and thereby improving the plant biomass production. The results are in accordance with those of Mahdi *et al*. (2012) [17], Mohan and Singh (2014) [14], Sulthana (2015) [22], Kumar *et al.* (2018).

Green fodder yield (q ha-1)

The highest green fodder yield of maize (419 q ha-1) was recorded with foliar application of $ZnSO_4$ @ 1% at 30 45 and 60 DAS along with RDF (T_5). The percentage increase in green fodder yield under these treatments over T_1 (no zinc application) ranged 7 to 25 per cent. Application of only RDF without zinc application (T_1) resulted in significantly the lowest green fodder yield (333 q ha-1). The maize variety African tall on an average yielded significantly more green fodder by the application of Zn SO_4 through the soil or foliar spray. Nonetheless, spraying (406 q ha^{-1}) was more productive than soil application (376 q ha^{-1}) consistently in the two years of experimentation.

The increase in green fodder yield might be due to the role of zinc in various growth processes like photosynthesis, nitrogen metabolism, protein synthesis, hormone production and regulation of auxin concentration in the plants. These favorable impacts of zinc resulted in taller plants, increase in no of leaves, leaf to stem ratio and dry matter production which might have reflected in terms of higher green fodder yields. Moreover, the quantity of nutrients absorbed due to soil application of zinc may not be sufficient to meet the crop demands at reproductive stage. Supplementing the nutrients through foliage at vegetative and flowering might have better nutrient balance and thereby regaining of photosynthetic efficiency of the plant at post anthesis period results in increased yield attributes and green fodder yield of maize (Kumar *et al.*, 2018). Foliar spray of zinc enhances the function of ps-2nd which increases the photosynthesis rate and promotes the formation of tryptophan which is a precursor of auxin hormone that finally leads to the rapid growth rate. Potassium also helps in easy translocation of assimilates resulting in improvement of net assimilation rate (NAR) which finally trigger higher fodder yield (Kumar *et al.*, 2015, 2018)

Table 1: Growth parameters and green fodder yield of fodder maize in response to fortification with soil and foliar spray of zinc. (Pooled mean of two years).

Treatments	Plant height cm	No of leaves plant	Leaf to stem ratio	Stem girth in cm	Dry matter Production q ha^{-1}	Green fodder yield q ha^{-1}
T_1- No Zn	264.4	11.87	0.153	6.75	74	333
T_2 -$ZnSO_4$ @ 15 kg ha^{-1}	274.6	12.66	0.173	7.20	83	366
T_3 -$ZnSO_4$ @ 25 kg ha^{-1}	284.4	13.13	0.190	7.59	89	389
T_4 - Foliar spray of 1% $ZnSO_4$ at 20 and 45 days	291.6	13.64	0.185	7.81	93	392
T_5 -Foliar spray of 1% $ZnSO_4$ at 20, 45 and 60 days	297.6	13.98	0.218	8.10	104	419
S.Ed±	3.1	0.13	0.007	0.08	2	3
CD (p=0.05)	6.4	0.27	0.014	0.16	4	7
Mean of Zn SO_4 ~ soil	279.5*	12.90*	0.182*	7.40*	86*	378*
Mean of Zn SO_4 ~ foliar spray	294.6*	13.81*	0.201*	7.95*	98**	406**
Significance for mean of soil vs foliar spray †	†	†	†	†	††	††

Note: Asterisks at different growth stages for mean of Zn SO_4 ~ soil and foliar sprays represent their effect vs no zinc application.
† shows the level of significance for mean effect of soil vs foliar spray
NS= Not significant; *=Significant at 1% and **= Significant at 5%

Significantly higher organic matter content (94.5%) was recorded in the control (T_1 no zinc) treatment followed by other treatments (T_2, T_3 T_4) and (T_5). The lowest organic matter (92.7%) content was recorded with the treatment where 100% RDF+1% Zn foliar spray at 20, 45 and 60 days was applied (Table 2). Under different treatments, organic matter content decreased with increasing nutrient application. This might be due to the inverse relation of OM with total ash content in the fodder sample. On the other hand, significantly higher DM (%) was attained from treatment of T_5 -Foliar spray of 1% $ZnSO_4$ at 20, 45 and 60 days with RDF application, which was significantly superior over all other treatments. Similar result with the application of, zinc, were earlier reported by other research workers (Chand *et al.*, 2017) [5]. The data on total ash content (%) of fodder maize (Table 2) indicates that different zinc nutrient application has significantly (P=0.05) improved the ash content (%) over the control. Higher ash content (%) was obtained with application of 100% RDF+ Foliar spray of 1% $ZnSO_4$ at 20, 45 and 60 days (T_5). This might be due to the favorable effect of balanced nutrition on growth and development of plants which further increases the nutrient demand leading to higher assimilation of nutrients within the plant system. Again synergistic effect of zinc with nitrogen, potassium, and some other micronutrient also contribute to the ash content of the fodder crop (Jamil *et al.*, 2015) [10]. Significantly higher CP (crude protein) total ash and ether extract was recorded on the treatment of 100% RDF+ Foliar spray of 1% $ZnSO_4$ at 20, 45 and 60 days. Nitrogen and potassium plays an important role in the activation of nitrate reductase enzyme that involves in the protein synthesis process, thus increase crude protein, ash and ether extract (Hasanuzzaman *et al.*, 2018) [8]. Zn is essential for the activity of RNA polymerase, protects ribosome and is also involved in function and stability of genetic material that plays a direct role in amino acid synthesis resulting in improved protein content (Panda *et al.*, 2020) [15].

In general, lower values of fiber fractions (Crude fiber and NDF) are considered to be better. The data obtained from the experiment recorded significantly ($p=0.05$) lower value on application of 100% RDF+ Foliar spray of 1% $ZnSO_4$ at 20, 45 and 60 days over the control. The reduction of fiber fraction indicates an improvement in fodder quality which could be due to the combined application of RDF and zinc spray at vegetative and reproductive stage which reduces the soluble carbohydrate content in plant tissue and promotes protein synthesis (Chand *et al.*, 2017, Kumar *et al.*, 2020) [5, 12].

Effect of ensiling on proximate nutrient content in different Zn nutrition combinations are presented in Table 2. The results tend to increasing in proximate composition after ensiling in all treatment combinations, in ether extract, total ash contents, and in crude protein, However, decreasing in proximate constituents observed in crude fiber and NDF in all treatments, The results revealed that because of the ensiling process in progress of sugar cane molasses may altered in all parameters of proximate composition through bacterial fermentation and biochemical changes in different treatment combinations. These results are confirming the earlier report of Bakshi *et al.* (2017) [3].

Table 2: Proximate analysis of fresh fodder and silage of maize (%DM) in response to fortification with soil and foliar spray of zinc. (Pooled mean of two years).

Treatments	Fresh fodder					Silage (ensiled fodder)				
	CP	CF	EE	TAsh	NDF	CP	CF	EE	TAsh	NDF
T_1- No Zn	7.6	38.2	1.5	5.5	66.9	8.3	37.1	1.4	5.6	63.8
T_2 -$ZnSO_4$ @ 15 kg ha^{-1}	8.1	36.6	1.8	5.9	65.7	9.1	36	1.7	5.9	63.4
T_3 -$ZnSO_4$ @ 25 kg ha^{-1}	8.5	36.2	2.2	6.7	65.1	9.6	35.8	2.1	6.8	63.1
T_4 - Foliar spray of 1% $ZnSO_4$ at 20 and 45 days	8.7	35.7	2.2	6.7	64.8	10.1	35.0	2.0	6.8	62.7
T_5 -Foliar spray of 1% $ZnSO_4$ at 20, 45 and 60 days	9.3	34.1	2.4	7.1	63.3	10.6	33.5	2.2	7.2	61.1
S.E+	0.1	0.5	0.1	0.2	0.9	0.1	0.6	0.2	0.2	0.9
CD (p=0.05)	0.2	1.1	NS	0.4	1.8	0.3	1.2	NS	0.4	1.9

EE: ether extract, TAsh: total ash content, CP: crude protein, CF: crude fiber and NDF: Neutral Detergent fibre

Conclusion

Thus, it conclude that maize crop responded widely to Zn fertilization and the crop is very sensitive for Zn deficient soil. Based on the research results, it can be concluded that

among soil and foliar zinc fertilization treatments studied in fodder maize, application of 100% RDF+ Foliar spray of 1% $ZnSO_4$ at 20, 45 and 60 days (T_5) recorded significantly higher vegetative growth parameters, crude protein content, Net returns gross returns B:C Ratio over control (T_1 no zinc application). Similarly, superior quality of neutral detergent fibre (NDF) was also reported with (T_5). The same results were recorded after the silage, However, agronomically bio fortified maize will enhance the nutritional, economic security and also maintain the environmental sustainability.

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