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Interaction effect of potassium and zinc on yield and nutrient uptake of forage maize (*Zea mays* L.) grown on loamy sand soil

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Abstract
The pot experiment was carried out at net house of the department of soil science and agricultural chemistry, B. A. College of Agriculture, Anand Agricultural University, Anand on the "Interaction Effect of Potassium and Zinc on Yield and Nutrient Uptake of Forage Maize (*Zea Mays* L.) Grown on Loamy Sand Soil" during summer season of the year 2015. The experiment was laid out in a completely randomized design (factorial) with three repetitions. The three levels of K_2O (0, 30 and 60 kg ha^{-1}) and Zn (0, 10 and 20 kg ha^{-1}) were selected in the experiment. The combination of potassium @ 60 kg ha^{-1} along with zinc @ 20 kg ha^{-1} gave significantly the highest green forage and dry matter yield over the rest of combinations. Treatment combination of K_2O @ 60 kg ha^{-1} along with Zn @ 20 kg ha^{-1} recorded significantly the higher phosphorus, potassium and zinc uptake by the crop than rest of the combinations, but was at par with K_2Zn_3.

Keywords: Forage Maize, Uptake, Potassium, Yield, Zinc

Introduction
Maize (*Zea mays* L.) is a monaceous plant belongs to the family Poaceae commonly cultivated in tropical areas and grown as summer crop in temperate regions. In India, maize ranks fifth in area and third in production & productivity among cereal crops. The important maize growing states in India are Punjab, Haryana, Uttar Pradesh, Madhya Pradesh, Bihar, Maharashtra, Rajasthan, Tamil Nadu, Gujarat, Andhra Pradesh and Jammu Kashmir. The area under maize crop in Gujarat is about 7800 ha, whereas in India is about 9.0 M ha. The average yield of green fodder maize is about 30 to 55 t ha^{-1} (Anon., 2013) [1]. Maize forage production solves the problem of livestock feed shortage during winter. Maize fodder contains relatively high concentration of soluble carbohydrates, crude protein content (8-9 %), crude fiber content (30.2 %), ash content (6.6 %), potassium content (1.4-1.6 %) and zinc content (25-30 %). Maize crop can use extensively as a silage crop in both temperate and tropical climates because of its high biomass yield. One of the main reasons for more attention to micronutrients, except their role in increasing productivity, is the role of potassium fertilizer in drought resistance and raises the quality of agricultural products by using zinc sulfate (Moinuddin *et al*.). Potassium activates many enzymes and plays an important role in the maintenance of electrical potential gradients across cell membranes and the generation of turgor in plants. It regulated for photosynthesis, protein synthesis and stomatal movement. It is also the major cation for the maintenance of cation-anion balances (Marschner, 1995) [5]. Reports regarding Zn with K fertilization with regard to growth, productivity and quality of forage maize are very limited. It is possible that higher yield potential of forage maize in soils with marginal K and Zn deficiency can be achieved by K and Zn application. As summer maize grown area is increasing day by day in Gujarat due to increasing facilities of irrigation. The depletion of K and Zn is found in some location of middle Gujarat. So it is very important to generate information of dose of K and Zn application to maize crop. This study was aimed to find out the interaction effect of K and Zn nutrition on yield and nutrient uptake of forage maize.

2. Materials and Methods
A pot experiment entitled, "Interaction Effect of Potassium and Zinc on Yield and Nutrient Uptake of Forage Maize (*Zea Mays* L.) Grown on Loamy Sand Soil" was carried out during

summer season of year 2015. The experiment was conducted in the net house of the department of Soil Science and Agricultural Chemistry, B. A. College of Agriculture, Anand Agricultural University, Anand. The experiment was laid out in a completely randomized design (factorial) with three repetitions. The experiment contains three levels of K_2O (0, 30 and 60 kg ha^{-1}) and Zn (0, 10 and 20 kg ha^{-1}). For conducting the pot experiment, the soil from surface layer (0-15 cm) was collected, after collecting the required quantity of bulk fill up the earthen pot of fifteen kg capacity. In each pot, treatment wise eight seeds of maize were sown. After germination, maize plants were thinned to five plants per pot. The recommended full dose of phosphorus was applied at the time of sowing, while half recommended dose of nitrogen were applied at sowing and half at 30 DAS. The K_2O and Zn were applied in the form of KCl (muriate of potash) and $ZnSO_4$ (zinc sulphate). Pots were regularly watered and weed free condition was maintained till 60 DAS required for tasseling stage of maize crop. The observations like plant height at 30 DAS and at harvest were taken in accordance with the crop growth in pots. Top dressing of 50 % N in the form of urea was done at 30 DAS. When the maize was at tasseling stage (60 DAS), the plants were uprooted carefully. The fresh and oven dry weight of shoot and roots were recorded from each pot. The soil of experimental site was Typic Ustochrepts having loamy sand soil texture. All the data recorded during the study period were statistically analyzed by using standard methods as suggested by Steel and Torrie (1982) [7].

Table 1: Initial physico - chemical properties of the soil used for pot study

Sr. No	Characteristics	
1	pH (1:2.5)	8.05
2	EC (1:2.5) dS m^{-1}	0.18
3	Organic carbon (%)	0.350
4	Available N (kg ha^{-1})	197
5	Available P_2O_5 (kg ha^{-1})	27
6	Available K_2O (kg ha^{-1})	228
7	DTPA- Zn (ppm)	0.39

3. Result and Discussion

Combination effect of potassium and zinc on the green and dry forage yield of maize is given in Table 2 and Table 3, respectively. Data pertaining to yield as influenced by K × Zn interaction showed increasing trend in yield with increasing level of Zn and K. Significantly the highest green yield (392 g pot^{-1}) was found in combination of K_3Zn_3 (60 kg K_2O ha^{-1} + 20 kg Zn ha^{-1}) over the rest of treatments. Significantly lower yield (280 g pot^{-1}) was reported in combination of K_1Zn_1 (0 kg K_2O ha^{-1} + 0 kg Zn ha^{-1}), but it was at par with combination treatments of K_2Zn_1 (30 kg K_2O ha^{-1} + 0 kg Zn ha^{-1}) and K_1Zn_2 (0 kg K_2O ha^{-1} + 10 kg Zn ha^{-1}). While data on dry matter yield (Table.3) showed that significantly higher yield (68.50g pot^{-1}) was observed in combination of K_3Zn_3 (60 kg K_2O ha^{-1} + 20 kg Zn ha^{-1}), but it was at par with K_3Zn_2 (60 kg K_2O ha^{-1} +10 kg Zn ha^{-1}) and K_2Zn_3 (30 kg K_2O ha^{-1} + 20 kg Zn ha^{-1}). Significantly lower yield (44.48 g pot^{-1}) was found in control (K_1Zn_1) and was at par with K_2Zn_1, K_3Zn_1, K_1Zn_2 and K_2Zn_2 treatment combinations.

The interaction effect between potassium and zinc was found significant in respect of green and dry matter yield. The increase in yield ascribed attributed to the reason that potassium along with zinc possibly increased the concentrations of N, P and K ions of soil solution and ultimately affected vigorous root development of plant leading to higher photosynthesis to the sink which in turn resulted in better development of yield. The results of present study are in agreement with those reported by Sutaria *et al.* (2013) [8] in forage sorghum, Maleki *et al.* (2014) [4] in maize and Yadav *et al.* (2014) [9] in pearl millet crop.

Table 2: Interaction effect of potassium and zinc on green forage yield (g pot^{-1}) of maize

Treatments	Zn_1 (0 kg ha^{-1})	Zn_2(10 kg ha^{-1})	Zn_3(20 kg ha^{-1})
K_1 (0 kg ha^{-1})	280	290	301
K_2 (30 kg ha^{-1})	284	349	370
K_3 (60 kg ha^{-1})	307	352	392
S.Em ±	6.03		
C.D. at 5 %	17.32		
C.V. %	4.54		

Table 3: Interaction effect of potassium and zinc on dry matter yield (g pot^{-1}) of maize

Treatments	Zn_1 (0 kg ha^{-1})	Zn_2 (10 kg ha^{-1})	Zn_3 (20 kg ha^{-1})
K_1 (0 kg ha^{-1})	44.48	49.58	57.55
K_2 (30 kg ha^{-1})	46.19	50.64	65.51
K_3 (60 kg ha^{-1})	46.26	64.15	68.50
S.Em ±	2.25		
C.D. at 5 %	6.46		
C.V. %	10.07		

The significantly higher P uptake (117.04 mg pot^{-1}) was observed with the application of 60 kg K_2O ha^{-1} along with 20 kg Zn ha^{-1} (K_3Zn_3), but it was at par with K_2Zn_3 (30 kg K_2O ha^{-1} + 20 kg Zn ha^{-1}) and K_3Zn_3 (60 kg K_2O ha^{-1} + 10 kg Zn ha^{-1}) (Table.4). Perusal of data given in Table 5 showed that treatment combination of K_3Zn_3 (60 kg K_2O ha^{-1} + 20 kg Zn ha^{-1}) recorded significantly higher K uptake (809 mg pot^{-1}) by maize than rest of the combinations, but it was at par with K_2Zn_3 (30 kg K_2O ha^{-1} + 20 kg Zn ha^{-1}) and K_3Zn_2 (60 kg K_2O ha^{-1} + 20 kg Zn ha^{-1}). In general, application of potassium along with zinc increased the nutrient uptake by crop, might be due to its interaction possibly increased the concentration of N, P and K ions of the soil solution and ultimately affected the vigorous root development, better K_2O fixation and better growth and development of plant leading to the higher photosynthetic activity which resulted in higher uptake of nutrients which reported by Jat *et al.* (2013) [2].

Table 4: Interaction effect of potassium and zinc on phosphorus (mg pot^{-1}) uptake by forage maize at harvest

Treatments	Zn_1 (0 kg ha^{-1})	Zn_2 (10 kg ha^{-1})	Zn_3 (20 kg ha^{-1})
K_1 (0 kg ha^{-1})	72.90	83.70	91.28
K_2 (30 kg ha^{-1})	73.02	84.68	105.03
K_3 (60 kg ha^{-1})	76.29	106.81	117.04
S.Em ±	4.20		
C.D. at 5 %	12.05		
C.V. %	11.42		

Table 5: Interaction effect of potassium and zinc on potassium uptake (mg pot^{-1}) by forage maize at harvest

Treatments	Zn_1 (0 kg ha^{-1})	Zn_2 (10 kg ha^{-1})	Zn_3 (20 kg ha^{-1})
K_1 (0 kg ha^{-1})	500	548	621
K_2 (30 kg ha^{-1})	544	588	784
K_3 (60 kg ha^{-1})	547	746	809
S.Em ±	26.32		
C.D. at 5 %	75.50		
C.V. %	10.20		

Data (Table 6) on interaction effect of potassium and zinc with respect to nutrient uptake of Zn at harvest by maize found significant. The significantly higher Zn (2.40 mg pot^{-1}) uptake was observed in K_3Zn_3 (60 kg K_2O ha^{-1} + 20 kg Zn ha^{-1}) treatment combination, however it was at par with K_2Zn_3 (30 kg K_2O ha^{-1} + 20 kg Zn ha^{-1}) treatment combination. Potassium and zinc interaction effect is synergetic on uptake of different nutrients by plant. The effect of different levels of K and Zn combination increase the uptake of zinc in maize. It's might be due to beneficial effect of potassium and zinc which promotes the formation of lateral and fibrous roots, which increase root proliferation and absorbing surface of nutrients supported by Maleki *et al*. (2014) [4].

Table 6: Interaction effect of potassium and zinc on zinc uptake (mg pot^{-1}) by forage maize at harvest

Treatments	Zn_1 (0 kg ha^{-1})	Zn_2 (10 kg ha^{-1})	Zn_3 (20 kg ha^{-1})
K_1 (0 kg ha^{-1})	1.04	1.44	1.97
K_2 (30 kg ha^{-1})	1.06	1.48	2.31
K_3 (60 kg ha^{-1})	1.11	1.92	2.40
S.Em ±	0.08		
C.D. at 5 %	0.23		
C.V. %	12.22		

4. Conclusion

From this result, It can be concluded that application of K_2O @ 60 kg ha^{-1} along with Zn @ 20 kg ha^{-1} recorded significantly higher green forage yield, dry matter yield and P, K & Zn uptake forage maize over control.

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