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Response of Maize (*Zea mays* L.) in Uptake of Micronutrients at Developmental Stages by Foliar Application of Secondary and Micronutrients

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ABSTRACT

In addition to the macronutrients (N, P, K, Ca, Mg and S), micronutrients (Fe, Mn, Zn, Cu, B and Mo) are required for optimal plant growth. In India deficiencies that occur are related to specific crop requirements and soils and are wide spread. For evaluation, correction of wide spread deficiencies of micronutrients and to emerge a viable nutrient recommendation to maize crop a field experiment was conducted during the kharif season of 2015 in the sandy loam soils of Agricultural College Farm, Mahanandi, Andhra Pradesh. The objective of the study was to identify the micronutrients uptake by maize and the effect on grain production, and to recommend micronutrients that would improve the quality and quantity of the produce. No significant yield advantage was found between the recommended amounts of major plant nutrients of nitrogen (N), phosphorous (P_2O_5) and potash (K_2O) at a rate of 250:60:60 kg per hectare and the various combinations of secondary and micronutrients. Application of recommended dose of fertilizers with 0.1 per cent $ZnSO_4$ showed the significant effect on uptake of micronutrients by maize crop. Response of maize to micronutrients was consistent, where amount of N, P, and K were adequate in the leaf samples. Diethylene triamine penta acetic acid (DTPA) extractable Zn was found to be below the critical level while Fe and manganese (Mn) were adequate. Zinc content in maize leaf was deficient, whereas Cu and Mn were in the normal range and Fe was in excess.

Key words: *Maize, Micronutrients, DTPA and Uptake.*

INTRODUCTION

Maize (*Zea mays* L.) is an important cereal crop of the world and has economic value in livestock[8]. It is considered as one of the two important cereal crops in India and plays a fundamental role in human and animal feeding[5]. Increasing maize production became one of the most important goals of the Indian government to satisfy human and animal demands.

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In the last two decades, several investigators in India reported positive response of different field crops to micronutrient fertilization[6]. Micronutrients are required in small amounts and they affect directly or indirectly photosynthesis, vital processes in plant such as respiration, protein synthesis and reproduction phase Marschner[11]. Manganese has an essential role in amino acid synthesis by activating a number of enzymes particularly decarboxylases and dehydrogenases of the tricarboxylic acid cycle. Zinc plays an important role as a metal component of enzymes (superoxide dismutase, carbonic anhydrase and RNA polymerase) or as a functional, structural, or regulator cofactor of a large number of enzymes Kabata and Pendias[10].

Micronutrients are trace elements that are required by plants or animals in small amounts (generally less than1 lb per acre in the case of crops). Each micronutrient has a range of safe and sufficient intake. Intake in excess of this range may be toxic and intake below this range may cause deficiency problems. The range of optimal intake for each micronutrient is specific to each plant or animal. Kanwal *et al.*, stated that the crop uptake and removal of micronutrients and other trace elements is a function of crop type, soil type and the trace element. Plants absorb trace elements through their roots. Generally, trace elements must be in the free ion form before they can enter the root membrane. However, chelates and other soluble complexes can protect trace elements from precipitation and absorption reactions, increasing the solubility of trace elements, and enhancing transport of trace elements to the root surface. Plants can also absorb trace elements through their leaves and foliar uptake can be a significant route of entry for elements such as cadmium, copper and zinc. The quantity of micronutrients and other trace elements removed when a crop is harvested is a function of yield and concentration of the element in the plant material that is removed.

Trace elements are not uniformly distributed in plant tissues. The amounts of micronutrients and other trace elements in plant parts is determined by: 1. The concentration and species of the trace element in soil solution, 2. Movement of the trace element to the roots, 3. Absorption of the trace element from the root surface into the root. and 4. Translocation of the trace element to the various plant parts. Translocation is a function of element, plant type, age of plant and plant part. In general, Zn, B and Mo are easily translocated and others such as Cu, Mn and Fe are not as easily translocated within most crops. When micronutrients and other trace elements are applied to the soil, they enter the soil nutrient cycle which can be shown of in terms of gains, removals, internal transformations and losses (Fig :1) to avoid these losses the study was designed based on the foliar application of nutrients to enhance the uptake and availability of micronutrients.

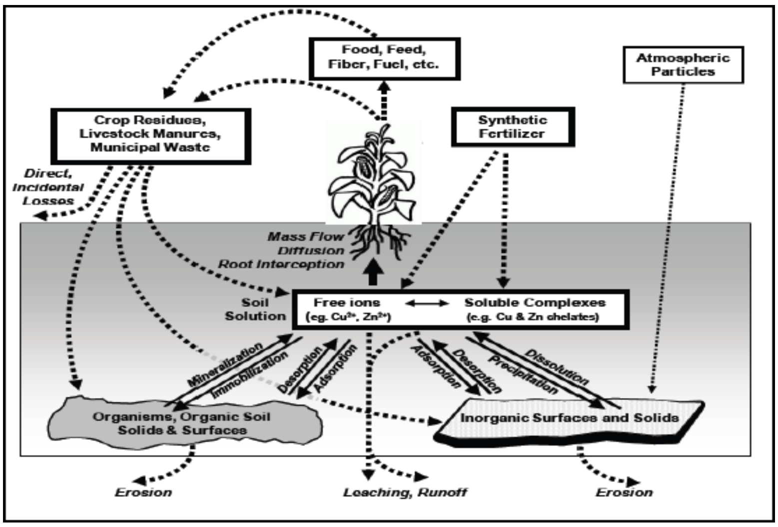

Fig. 1: Behaviour of micronutrients in soil (Flaten *et.al.*, 2004)

MATERIAL AND METHODS

A field experiment was carried out with maize hybrid P3369, under irrigated conditions during *kharif,* 2015 on sandy loam soils of Agricultural College Farm, Mahanandi, Andhra Pradesh which was laid out in a randomized block design having nine treatments and replicated thrice. The treatments consisting of T_1 : Control, T_2 : RDF: 250-60-60 kg N-P_2O_5-K_2O ha^{-1}, T_3 : RDF + foliar application of one per cent $CaNO_3$, T_4 : RDF+ foliar application of one per cent $MgNO_3$, T_5 : RDF + foliar application of one per cent sulphur, T_6 : RDF + foliar application of one per cent each of $CaNO_3$, $MgNO_3$ and sulphur, T_7 : RDF + foliar application of $ZnSO_4$ @ 0.1 per cent, T_8 : RDF + foliar application of one per cent each of $CaNO_3$, $MgNO_3$ and sulphur + foliar application of $ZnSO_4$ @ 0.1 per cent and T_9 : RDF + micronutrient mixture @ 0.2 per cent. The crop was sown on ridges with spacing 75cm x 15cm on second fortnight of July 2015 and harvested on 23.11.2015. The recomeneded dose of nitrogen was applied in the form of urea in three splits i.e., at sowing, at 30-35 DAS and remaining at 50-55 DAS and the recommended phosphorus and potassium were applied as diammonium phosphate and muriate of potash as basal dose at the time of sowing. Whereas secondary nutrients, zinc and micronutrients were supplied as foliar spray at 20-25 DAS in the form of $CaNO_3$, $MgNO_3$, wettable sulphur and $ZnSO_4$ respectively. Micronutrient mixture consists of Boron (B) 1.5%, Copper (Cu) 0.5%, Iron (Fe) 3.4%, Manganese (Mn) 3.2%, Molybdenum (Mo) 0.05% and Zinc (Zn) 4.2%. Carbofuran 3G granules @ 5 kg ha^{-1} was applied to control the stem borers. All the cultural practices were taken up as per the recommendations made by ANGRAU. At 30, 60 and 90DAS leaf samples were taken from the second and third leaves from the top of plant for chemical analysis. Plant samples were washed with water then dried at 70°C for 48 hrs and the nutrients were analyzed after digestion of plant samples with mixture of concentrated H_2SO_4 and $HClO_4$ acids. The total micronutrient concentrations: Fe, Mn, Zn, Cu, B and Mo were analyzed in plant digests using atomic-absorption spectrophotometry. All micronutrient concentrations were expressed in g ha^{-1}.

The physico-chemical characterstics of experiment plot were determined and shown in table 1. The pH of the soil had the mean value of 7.58 which shows that the soil was neutral pH. The soil soil texture was sandy loam. From the analysis data it shown that experimental site was medium in organic carbon (0.46%), N (287 kg ha^{-1}), P_2O_5 (149 kg ha^{-1}) and high in K_2O (742 kg ha^{-1}). Exchangeable calcium, magnesium (10.41 and 7.22 C mol. (P^+) kg^{-1}) and available sulphur (13 ppm) were sufficient in availability whereas, micronutrients availability (Fe, Mn, Zn, Cu, B and Mo) was more than their critical limits.

Table 1: Characteristics of the experiment soil in study area

Soil parameters	Values	Reference
Physical analysis :		
Sand (%)	68.37	
Silt (%)	10.91	Piper, 1966
Clay (%)	10.73	
Texture	Sandy loam	
Chemical analysis :		
Soil pH (1: 2.5 soil water suspension)	7.58	Jackson, 1973
Electrical conductivity (dS m^{-1})	0.08	Jackson, 1973
Organic carbon (%)	0.46	Walkley and Black, 1934
Nutrient analysis :		
Available Nitrogen (kg ha^{-1})	287.31	Subbiah and Asija, 1956
Available Phosphorus (kg ha^{-1})	149.76	Olsen *et. al.*, 1954
Available Potassium (kg ha^{-1})	742.44	Jackson, 1973
Exchangeable Ca (C mol.(P+)kg^{-1})	10.41	
Exchangeable Mg (C mol.(P+)kg^{-1})	7.22	
Available S (ppm)	13.22	
Available Fe (ppm)	5.61	Jackson, 1973
Available Mn (ppm)	3.17	
Available Zn (ppm)	3.46	

Available Cu (ppm)	0.59
Available B (ppm)	0.52
Available Mo (ppm)	0.18

Table 2: ***Effect of secondary and micronutrients on micronutrients (Fe, Mn, Zn, Cu, B and Mo) uptake (g ha^{-1}) of maize***

Treatments	Fe uptake (g ha^{-1})			Mn uptake (g ha^{-1})			Zn uptake (g ha^{-1})			Cu uptake (g ha^{-1})			B uptake (g ha^{-1})			Mo uptake (g ha^{-1})		
	30DAS	60DAS	90DAS	30DAS	60DAS	90DAS	30DAS	60DAS	90DAS	30DAS	60DAS	90DAS	30DAS	60DAS	90DAS	30DAS	60DAS	90DAS
T_1	82.02	201.62	265.38	26.6	38.9	84.48	15.02	63.15	152.29	4.99	24.57	54.48	5.59	26.91	56.11	0.70	2.00	3.88
T_2	148.15	256.59	347.34	31.37	78.44	157.29	40.25	189.25	262.19	11.72	53.10	95.58	12.89	55.75	89.91	1.27	4.78	8.30
T_3	163.03	287.28	382.83	35.04	86.92	188.3	45.85	210.34	340.59	12.62	56.37	94.56	14.56	57.77	91.51	1.34	4.91	9.79
T_4	171.46	293.43	399.06	35.88	92.25	178.83	44.17	208.76	333.47	12.39	57.13	97.02	15.06	55.73	94.07	1.41	6.37	9.47
T_5	168.58	292.72	386.72	33.63	88.90	173.78	44.78	205.53	322.77	11.05	53.48	98.68	13.25	54.31	97.32	1.47	5.88	10.63
T_6	173.36	309.04	400.26	36.56	96.35	199.25	58.19	203.97	339.85	13.38	57.79	101.14	15.36	57.71	98.69	1.17	7.11	10.92
T_7	177.19	336.60	416.67	36.39	99.13	202.30	63.44	236.91	345.23	12.98	60.14	110.93	12.98	61.66	101.86	1.59	7.57	12.73
T_8	184.77	304.26	439.86	36.72	96.32	190.16	67.37	221.49	358.29	13.61	56.00	107.67	15.46	56.00	98.16	1.82	6.96	9.58
T_9	181.95	334.11	403.50	36.19	98.06	181.56	60.49	229.54	353.91	13.10	56.20	109.02	14.70	57.79	104.47	1.64	7.32	11.71
S.Em±	0.64	4.64	10.94	0.28	0.93	2.02	0.90	2.29	2.63	0.44	1.08	2.46	0.15	0.53	0.94	0.02	0.07	0.17
CD (P=0.05)	1.91	13.93	32.81	0.84	2.78	6.07	2.69	6.87	7.88	1.34	3.26	7.44	0.46	1.60	2.82	0.05	0.20	0.51

Statistical Analysis: Data were statistically analyzed by applying the technique of analysis of variance for randomized block design and significance was tested by F-test[16]. The critical difference for examining the treatment means for their significance was calculated at 5 per cent level of probability.

RESULTS

Effect of secondary and micronutrients on micronutrients uptake of maize:

During the experimentation treatments were supplied with foliar application of secondary and micronutrients along with soil application of recommended dose of fertilisers. There was a varied response among the treatments in the uptake and micronutrient contents in the plant tissue. The various observations of recorded data on micronutrient uptake at 30, 60 and 90 DAS indicated that uptake was increased with advance in the age of the crop up to harvest, due to the increased concentration and drymatter production. Rate of uptake was higher between 30 to 90 DAS and lower at harvest.

Iron (Fe) uptake: Perusal of the data revealed that iron uptake was influenced by foliar application of secondary and micronutrients. The data regarding the Fe uptake by whole plant at 30, 60 and 90 DAS and at harvest both by grain and stover are presented in Table: 2. At 30 DAS, the treatment T_8 (RDF + Foliar application of one per cent each of $CaNO_3$, $MgNO_3$ and Sulphur + $ZnSO_4$ @ 0.1 per cent) (184.77 g ha^{-1}) was superior over the rest of treatments but was on par with T_9 (RDF + Foliar application of 0.2 per cent micronutrient mixture). Foliar application of one per cent of $CaNO_3$ with RDF (T_3) was on par with foliar application of one per cent of $MgNO_3$ with RDF (T_4) and these were superior over T_5 (RDF + Foliar application of 1 per cent Sulphur) and RDF (T_2). At 60 DAS, foliar application of $ZnSO_4$ @ 0.1 per cent with RDF (T_7) resulted highest iron uptake (336.60 g ha^{-1}) and was on par with foliar application of 0.2 per cent micronutrient mixture with RDF (T_9). The data on iron uptake by whole plant at 90 DAS showed that maximum uptake (439.67 g ha^{-1}) was done by foliar application of $ZnSO_4$ @ 0.1 per cent with RDF (T_7) and was on par with foliar application of 0.2 per cent micronutrient mixture with RDF (T_9) and foliar application of one per cent each of $CaNO_3$, $MgNO_3$ and Sulphur with RDF (T_6). The iron uptake with foliar application of all secondary nutrients with RDF (T_6) was superior over the treatments with individual secondary nutrient foliar application with RDF (*i.e.*, T_3 (RDF + Foliar application of one per cent $CaNO_3$), T_4 (RDF + Foliar application of one per cent $MgNO_3$) and T_5 (RDF + Foliar application of one per cent Sulphur) and all these treatments were significantly superior over the RDF (T_2).

Manganese (Mn) uptake: Manganese uptake by maize crop increased with the crop growing period (Table: 2). Based on analysis data, it is noticed that manganese uptake by maize crop was increased with pass on off days during crop growing period. At 30 DAS, T_8 (RDF + Foliar application of one per cent each of $CaNO_3$, $MgNO_3$ and Sulphur + $ZnSO_4$ @ 0.1 per cent) recorded maximum uptake (36.72 g Mn ha^{-1}) which was at par with foliar application of $ZnSO_4$ @ 0.1 per cent with RDF (T_7), foliar application of 0.1 per cent micronutrient mixture with RDF (T_9), foliar application of one per cent each of $CaNO_3$, $MgNO_3$ and Sulphur with RDF (T_6) and foliar application of one per cent $MgNO_3$ with RDF (T_4). Foliar application of one per cent Sulphur with RDF (T_5) and RDF alone (T_2) were on par with other. During 60 DAS, data showed that T_7 (RDF + Foliar application of $ZnSO_4$ @ 0.1 per cent) (99.13 g Mn ha^{-1}) recorded better among the treatments tried and it was at par with T_9 (RDF + Foliar application of 0.2 per cent micronutrient mixture) and T_6 (RDF + Foliar application of one per cent each of $CaNO_3$, $MgNO_3$ and Sulphur). At 90 DAS the treatment T_7 (RDF + Foliar application of $ZnSO_4$ @ 0.1 per cent) recorded highest Mn uptake (202.30 g ha^{-1}) which was on par with T_6 (RDF + Foliar application of one per cent each of $CaNO_3$, $MgNO_3$ and Sulphur).

Zinc (Zn) Uptake: With advance in age of the crop from 30 DAS up to harvest the zinc uptake of maize was increased (Table: 2). Maximum zinc uptake (67.37 g Zn ha^{-1}) at 30 DAS was recorded with T8 (RDF + Foliar application of one per cent each of CaNO3, MgNO3 and Sulphur + $ZnSO_4$ @ 0.1 per cent) which was significantly superior over rest of treatments. The treatments with individual secondary nutrient foliar application with RDF were at par with each other and superior over the RDF (T_2). At 60 DAS, significantly more zinc uptake (236.91 g Zn ha^{-1}) was noted with T7 (RDF + Foliar application of $ZnSO_4$ @ 0.1 per cent) and T_9 (RDF + Foliar application of 0.2 per cent micronutrient mixture) registered as next best treatment. At 90 DAS, more Zn uptake (358.29 g Zn ha^{-1}) was observed with treatment T8 (RDF + Foliar application of one per cent each of CaNO3, MgNO3 and Sulphur + $ZnSO_4$ @ 0.1 per cent) and it was on par with T_9 (RDF + Foliar application of 0.2 per cent micronutrient mixture). All the other treatments were significantly different with one another.

Copper (Cu) uptake : Data pertaining to Cu uptake by whole plant at 30, 60 and 90 DAS are presented in Table : 2. At 30 DAS, T8 (RDF + Foliar application of one per cent each of CaNO3, MgNO3 and sulphur + $ZnSO_4$ @ 0.1 per cent) recorded as a superior treatment among all the treatments tried and however it was at par with T6 (RDF + Foliar application of one per cent each of CaNO3, MgNO3 and Sulphur), T7 (RDF + Foliar application of $ZnSO_4$ @ 0.1 per cent) and T9 (RDF + Foliar application of 0.2 per cent micronutrient mixture). At 60 DAS, foliar application of ZnSO4 @ 0.1 per cent with RDF (T7) recorded highest Cu uptake (60.14 g ha^{-1}) and was found to be at par with T4 (RDF + Foliar application of one per cent MgNO3) and T6 (RDF + foliar application of one per cent each of CaNO3, MgNO3 and Sulphur). Copper uptake at 90 DAS showed that, maximum zinc uptake (110.93 g ha^{-1}) was by foliar application of ZnSO4 @ 0.1 per cent with RDF (T7) which was at par with T9 (RDF + Foliar application of 0.2 per cent micronutrient mixture) and T8 (RDF + Foliar application of one per cent each of CaNO3, MgNO3 and Sulphur+ $ZnSO_4$ @ 0.1 per cent).

Boron (B) uptake : Data (Table : 2) from chemical analysis of plant at 30 DAS of maize crop revealed that T8 (RDF + Foliar application of one per cent each of CaNO3, MgNO3 and Sulphur + $ZnSO_4$ @ 0.1 per cent) accumulated more B (15.46 g ha^{-1}) into the plant and was at with T6 (RDF + Foliar application of one per cent each of CaNO3, MgNO3 and Sulphur) and T4 (RDF + Foliar application of one per cent MgNO3). Significantly lowest B uptake was noted with control (T1) (5.59 g ha^{-1}). At 60 DAS T7 (RDF + Foliar application of ZnSO4 @ 0.1 per cent) recorded significantly highest B uptake (61.66 kg ha^{-1}) and T9 (RDF + Foliar application of 0.2 per cent micronutrient mixture) was next best in B uptake and was on par with T3 (RDF + foliar application of one per cent CaNO3) and T6 (RDF + Foliar application of one per cent each of CaNO3, MgNO3 and Sulphur). Boron uptake by whole plant at 90 DAS showed that foliar application of 0.2 per cent micronutrient mixture with RDF (T9) was significantly superior over all treatments. The two treatments of foliar application of all secondary nutrients either with ZnSO4 (T_8) (or) without ZnSO4 (T_6) were at par with each other but superior to treatments with foliar application of individual nutrient of secondary nutrients with RDF *i.e.*, T_3 (foliar application of one per cent CaNO3 with RDF), T4 (RDF + Foliar application of one per cent MgNO3) and T_5 (RDF + Foliar application of one per cent Sulphur).

Molybdenum (Mo) uptake: Significant difference was clearly observed (Table :2) among the treatments on Mo uptake at 30 DAS. The treatment T_8 (RDF + Foliar application of one per cent each of $CaNO_3$, $MgNO_3$ and sulphur + $ZnSO_4$ @ 0.1 per cent) recorded significantly maximum uptake (1.82 g ha^{-1}) and it was superior over rest of the treatments. Foliar application of $ZnSO_4$ with RDF (T_7) accumulated more Mo over all the treatments of foliar application of secondary nutrients without $ZnSO_4$. At 60 DAS T_7 (RDF + Foliar application of $ZnSO_4$ @ 0.1 per cent) (7.57 g ha^{-1}) recorded significantly highest Mo uptake over rest of treatments planed and control (T_1) recorded significantly lowest Mo content. The data on molybdenum uptake by whole plant at 90 DAS resulted that T_7 (RDF + Foliar application of $ZnSO_4$ @ 0.1 per cent) (12.73 g ha^{-1}) has significantly more Mo content. Foliar application of 0.2 per cent micronutrient mixture with RDF (T_9) considered as next best treatment which was superior over the remaining treatments.

DISCUSSION

Accumulation of micronutrients by the maize was linear during the whole plant cycle and increased until the late stages. However, at physiological maturity the crop accumulated greater amount of nutrients[2].

Uptake of nutrients by crop is a function of nutrient content in plant and dry matter production per unit area. The application of fertilizers gradually increased the nutrient uptake. Foliar application of nutrients will enhance the nutrient availability of crop than other methods and this in turn enables greater absorption by maize crop. Maize crop that absorbs adequate amounts of nutrients has tremendous opportunity to produce higher growth parameters, more pronouncedly the dry matter production, leading to grater uptake of all the nutrients and the same was observed in the present study when ample nutrients were supplied in a balanced proportion. Foliar application of micronutrients could be useful for improving the nutrients status, physiological performance of maize plants[6]. It is noticed that the crop that is fertilized with the optimum amounts of major nutrients and supplied with micronutrients or either Zn, absorbs maximum amounts of nutrients which is exactly reflected in the present investigation. Higher values for the uptake of micronutrients by maize with optiuum NPK and micronutrients supplied was also evidenced by earlier researchers i.e. Aruna *et al.*[1], Duraisami *et al.*[3], Salem *et al.*[15], and Eteng *et al*.[4].

CONCLUSION

The above results showed that the application of recommended dose of fertilizers (250-60-60 kg N-P_2O_5-K_2O ha^{-1}) and foliar application of 0.1 per cent $ZnSO_4$ could be useful for improving the nutrient status, physiological performance and nutrient uptake compared to the recommended N, P, and K fertilizers. This represents a 15% uptake increment over what was achieved using the recommended fertilizer, which only contains macronutrients. Although there is high variability in crop response to micronutrients, the high proportions of cases with increased yield underscore the need for these nutrients. Micronutrients are controlling crop productivity especially on soils where response to macronutrients is low. Considering the observed incidences of low responses and variations among crops, more research is needed to unravel conditions under which application of $ZnSO_4$ and micronutrients is beneficial to farmers. The results of this study highlight the need for policy support for the research on secondary nutrients, particularly S and micronutrients and for blending them in currently used fertilizers.

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