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Effect of secondary and micronutrients on uptake, mobilization and partitioning of nutrients from source to sink in maize hybrid

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Abstract
Reduced atmospheric nutrient deposition, in conjunction with higher grain sale prices and steadily increasing yields of maize (*Zea mays* L.) has many growers considering an increase in secondary and micronutrient applications. Limited information exists quantifying requirements of S, Mg, Ca, Zn, Mn, Cu, Fe, and B across a wide yield range for modern maize production systems. The objective of this study was to evaluate macro- and micronutrient accumulation and partitioning in maize. Supplemental fertility modestly increased biomass and yield (2%), but did not alter nutrient partitioning or harvest index. Nutrients with high harvest index (i.e., percentage of total nutrient accumulation partitioned to grain) values included P (83%), N (71%), Cu (64%), and S (60%), which may serve as a limitation to high yield. Seasonal patterns of nutrient accumulation suggested that K and Fe were acquired primarily during late vegetative growth while the uptake of N, P, Ca, Mg, S, Zn, Mn, B, and Cu were more equally distributed between vegetative and seed-filling growth phases. These results document the rate and duration of macro- and micronutrient accumulation in maize, and highlight the importance of adequate nutrient availability during key crop growth periods.

Keywords: Maize, nutrients, accumulation and partitioning

Introduction

A successful soil fertility program includes consideration of all macro, secondary, and micronutrients critical for maize (*Zea mays* L.) growth and development. While maize macro nutrient requirements necessitate consideration on an seasonal basis, micronutrient (Zn, Mn, Cu, Fe, B) deficiencies are less common due to smaller crop removal amounts and typically adequate soil supply in most maize producing regions where the soil pH is maintained between 6.0 and 7.0 (Rego *et al*., 2007) [12]. However, maize grain sale prices have increased dramatically since 2000 to a record high of 16 kg^{-1} on average during 2017, with prices reaching 18 kg^{-1} during certain months. These record high maize prices has prompted many growers to use various products such as foliar micronutrient fertilizers prophylactically to potentially increase yield. These prophylactic applications are often combined with other in-season herbicide and/or fungicide applications that range from seedling to flowering growth stages, instead of targeted near periods of peak nutrient uptake. In past research, maize yield response to micronutrient applications has varied as a result of environmental conditions such as soil mineralogy, organic matter, pH, moisture, temperature, and aeration. Precise knowledge of micronutrient uptake, partitioning and removal could help determine proper application timing and rates to combat inconsistency and increase the probability of a positive yield response. Therefore, the objective of our study was to quantify S, Mg, Ca, Zn, Mn, Cu, Fe, and B uptake, partitioning, and removal patterns and rates across a wide range of environments and genetics, and therefore, yield range, to compliment and improve our understanding of soybean secondary and micronutrient requirements.

Material and methods

Field experiment was conducted in 2015 at Agricultural College Farm, Mahanandi, Andhra Pradesh which fall under semi-arid tropics (Table 1) and soil characters in presented in table 2. The experiment 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 $ZnSO_4$ @ 0.2 per cent, T_8: RDF + foliar application of one per cent each of $CaNO_3$, $MgNO_3$ and sulphur + foliar application of $ZnSO_4$ @ 0.2 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 amount of nitrogen was applied in three splits i.e., at sowing, at 30-35 DAS and remaining at 50-55 DAS in the form of urea and phosphorus and potassium was applied as di ammonium phosphate and muriate of potash were applied as basal dose at the time of sowing, Whereas secondary nutrients and zinc was was supplied as foliar spray at 20-25 DAS in the form of $CaNO_3$, $MgNO_3$, wet table 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.

Table 1: location and weather parameters of experiment plot

Season	Latitude and longitude	Soil	temperature (ºc)		Rainfall (mm)	Relative humidity (%)	Wind speed (km hr^{-1})
			Maximum	Minimum			
Kharif 2015	15°.51′N, 78°.61′E	Sandy loam	33.24	22.73	59.92	72.55	3.71

Seasonal biomass and nutrient accumulation was determined using a repeated measures approach by sampling. Each plant was separated into stem and grain tissue components. Stem tissues were dried at 70°C to a 0% moisture concentration for dry weight determination. Grain nutrient content was determined from hand-sampled plants while grain yield and nutrient uptake was measured using combine-harvested grain. Stem and grain tissues were ground to pass through a 2-mm mesh screen for nutrient concentration analysis. All samples were analyzed for N, P, K, Ca, Mg, S, Zn, Mn, B, Fe, and Cu. Tissue nutrient concentrations and dry weight were used to algebraically derive nutrient content.

$$\text{Uptake of nutrient (kg ha}^{-1}\text{)} = \frac{\text{Nutrient content (\%)}}{100} \times \text{Drymatter yield (kg ha}^{-1}\text{)}$$

Table 2: Physio-chemical parameters of soil of experiment plot

Soil parameters	values
Soil pH (1: 2.5 soil water suspension)	7.4
Electrical conductivity (dS m^{-1})	0.08
Organic carbon (%)	0.46
Available Nitrogen (kg ha^{-1})	287.31
Available Phosphorus (kg ha^{-1})	149.76
Available Potassium(kg ha^{-1})	742.44
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
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

Results

In the experiment, half dose of nitrogen (125 kg ha^{-1}), full doses of phosphorous (60 kg ha^{-1}) and potassium (60 kg ha^{-1}) in the form of urea (46 per cent N), di ammonium phosphate (DAP) (18 per cent N and 46 per cent P_2O_5) and muriate of potash (MOP) (60 per cent K_2O) was applied as basal at the time of sowing. The remaining half dose of nitrogen (125 kg ha^{-1}) was applied at 35 and 55 DAS in two equal splits. The adequate and split application of nutrients at different stages of crop resulted in higher growth and nutrient uptake due to release of sufficient amount of nutrients (Saragoni and Poss, 2000) [13] this results were confirmed by Ashok Kumar *et al.* (2008) [2].

The data regarding the nitrogen, phosphorus and potassium uptake by plants at by whole plant and at harvest both by grain and stover indicated that uptake of primary nutrients influenced by application of micronutrient mixture along with recommended dose of NPK. A comparison of uptake in plant parts showed that nitrogen and phosphorus uptake was more in grain than that of stover at the time of harvest, but potassium content was higher in stover than grain. Adequate availability of nutrients ensures the greater level of absorption and translocation to the plant parts during growing period thereby increased quantities of nutrients in cob and stover which shows higher values for the uptake of N, P and K by maize (Massey and Gaur, 2006) [11].

i. Effect of secondary and micronutrients on uptake of nutrients by maize stem

The results on total uptake by maize stem was significantly highest in T_9 (RDF + Foliar application of 0.2 per cent micronutrient mixture) for all the nutrients (Table 3). 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) considered as next best treatment which shown better uptake and translocation to plant and was on par with T_6, (RDF + Foliar application of 1 per cent each of $CaNO_3$, $MgNO_3$ and Sulphur) and T_7 (RDF + Foliar application of $ZnSO_4$ @ 0.1 per cent). The addition of phosphorus influenced the uptake of P by plant and enhances the production of small roots and root hairs, which in turn facilitated the high absorbing capacity per unit of dry weight (Hussaini *et al.* 2008) [9]. The nutrient uptake by the whole plant increased substantially during the growth period which indicates that a steady supply of nutrients throughout the growing season is needed. Accumulation of this micronutrient by the maize was linear during the whole plant cycle and increased until the late stages However, at physiological maturity accumulated greater amount of nutrients in sink (Borges *et al.,* 2009) [5].

ii. Effect of secondary and micronutrients on uptake of nutrients by maize grain

During the experimentation some treatments were supplied with foliar application of micronutrients along with primary and secondary nutrients. There was a varied response among the treatments in the uptake and translocation to the grain (Table 3). Among all the treatments, T_9 (RDF + Foliar application of 0.2 per cent micronutrient mixture) showed the highest uptake for all the nutrients and it was on par with T_6 (RDF + Foliar application of one per cent each of $CaNO_3$, $MgNO_3$ and Sulphur). Ashoub *et al.* (1998) [1] showed that application of manganese increased the dry weight per plant, grain yield, stover yield and Mn uptake of crop. The foliar application of sulphur with RDF (T_5) was noted as on par with T4 (RDF + Foliar application of one per cent $MgNO_3$) and superior over T_3 (RDF + Foliar application of one per cent $CaNO_3$) and RDF. Lowest nutrient uptake was noted with control (T_1). The result of uptake of nutrients due to the increase in either DM yield or Zn concentration which accumulated Zn content in the various plant parts is supported by Kanwal *et al*., (2010) [10]. The maximum values of Zn accumulation by maize crop were observed at physiological maturity (Borges *et al.* 2009) [5]. Etang *et al*. (2014) [8] reported that foliar application of Cu to maize, not only enhances the production but also increases the tissue content.

Discussion

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 by grain, Stover as well as total 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.

The application of higher level of NPK with micronutrients significantly improved the availability of native and applied macro and micronutrients in the soil this might be the reason for higher grain yield of maize (Ramachandrappa *et al,* 2007) [18]. Sinha *et al.* (2000) [15] noted a synergistic interaction between Zn and B nutrients, when both the nutrients were either in low or excess supply. According to Brown *et al*. (1993) [6] formation of male and female reproductive organs and pollination process are disturbed in Zn deficiency which might be attributed to the reduction of Indole acetic acid synthesis. The excess B accelerated the effects of high Zn by lowering the reduced biomass, economic yield, carbonic anhydrase activity and increased concentration of B and Zn in leaves and seeds, reducing sugars and activity of peroxidase. B is involved in carbohydrates metabolism and essentially necessary for protein synthesis, pollen germination, seed and cell wall formation (Vitosh *et al*. 1997) [19]. The use of micronutrients increased the yield and also uptake of nutrients when applied in combination with macronutrients as compared to conventional fertilization which lack micronutrients (Bakry *et al*. 2009; Singh *et al*. 2009; Azhar Ghaffari 2011) [4, 14, 3]. The present findings were in accordance with Sujatha (2005) [16] and Tetarwal *et al*. (2011) [17].

Conclusion

The application of NPK along with micronutrients resulted in 1.04 t ha^{-1} more maize yield compared to the recommended N, P, and K fertilizers. This represents a 22% yield increment over what was achieved using the recommended fertilizer, which only contains macronutrients. Although there is high variability in crop response to S and micronutrients, the high proportions of cases with increased yield underscore the need for these nutrients. S and micronutrients are holding back crop productivity especially on soils where response to macronutrients is low. Finally is conclude that uptake of major, secondary and micronutrients by maize crop was increased with application of recommended dose of fertilizers with micronutrient mixture. The increased nutrient uptake resulted in increased grain and Stover yield of maize.

Table 3: Effect of secondary and micronutrients on uptake of nutrients by maize

Treatments	Stem uptake												Grain uptake											
	Stem uptake Macronutrients (kg ha $^{-1}$)						Micronutrients (g ha $^{-1}$)						Macronutrients (kg ha $^{-1}$)						Micronutrients (g ha $^{-1}$)					
	N	**P**	**K**	**Ca**	**Mg**	**S**	**Fe**	**Mn**	**Zn**	**Cu**	**B**	**Mo**	**N**	**P**	**K**	**Ca**	**Mg**	**S**	**Fe**	**Mn**	**Zn**	**Cu**	**B**	**Mo**
T_1	13.55	4.20	46.39	16.14	7.55	9.06	113.26	54.67	61.74	39.75	45.60	3.62	44.20	13.79	11.94	9.66	4.81	6.17	96.47	51.06	119.81	35.60	39.75	1.85
T_2	31.07	9.59	81.42	25.71	10.51	12.14	219.63	125.73	146.51	80.74	53.07	5.94	59.06	18.99	16.97	10.67	6.91	8.57	120.83	90.07	181.08	42.84	52.82	2.35
T_3	34.29	9.90	84.51	28.11	12.13	14.27	274.78	140.68	152.33	86.58	56.06	6.98	64.96	24.22	18.62	12.71	8.04	9.70	133.51	111.43	197.49	60.64	66.58	3.85
T_4	32.48	11.04	85.11	26.04	12.48	13.43	303.50	142.93	153.24	90.19	58.49	8.26	66.25	24.68	19.61	12.91	8.61	9.43	152.81	112.66	203.76	62.97	68.55	4.25
T_5	32.42	10.98	81.51	26.57	12.45	14.15	291.14	136.55	159.81	83.10	55.24	7.54	64.02	24.12	18.99	12.23	8.85	8.42	137.01	103.39	193.11	53.89	55.32	4.17
T_6	33.6	11.37	84.79	27.24	11.53	15.20	274.87	148.47	156.16	90.95	59.19	7.16	64.70	24.02	18.32	12.98	9.15	9.81	139.04	103.22	189.24	57.78	62.09	5.18
T_7	33.33	11.26	82.15	26.69	11.45	14.21	310.28	140.14	161.91	93.71	60.21	8.54	64.26	24.14	19.25	12.39	8.21	9.78	149.66	111.83	205.01	59.89	71.64	5.36
T_8	32.85	11.48	82.63	27.29	11.23	14.34	293.12	145.27	162.43	92.12	53.72	7.46	64.51	23.11	18.45	12.37	8.23	9.16	144.18	95.02	202.17	52.46	73.40	4.98
T_9	34.52	11.86	89.22	28.42	12.97	15.37	323.25	149.99	164.88	96.17	64.96	8.79	68.44	25.52	20.10	13.28	9.40	9.99	165.02	113.72	211.61	66.69	74.32	5.41
S.Em±	0.29	0.11	0.89	0.18	0.17	0.29	4.20	1.70	1.24	2.23	0.87	0.05	0.41	0.21	0.21	0.09	0.14	0.18	3.07	1.02	1.63	2.14	0.63	0.04
CD (P=0.05)	0.87	0.33	2.68	0.54	0.52	0.89	12.60	5.10	3.73	6.75	2.60	0.14	1.22	0.62	0.64	0.27	0.42	0.56	9.21	3.07	4.91	6.47	1.89	0.12

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