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Response of brinjal to micronutrients in medium black calcareous soils

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Abstract
A field experiment was conducted at Vegetable Research Station, Junagadh Agricultural University, Junagadh, Gujarat, during *Rabi* 2015-16 and 2016-17 to study the response of brinjal to micronutrients application in medium black calcareous soils of Saurashtra Region of Gujarat. The results revealed that significantly higher mean green fruit yield, stalk yield, plant height, no of fruits per plant, fruit length and average fruit weight as well as S, Fe, and Zn uptake by fruit and stalk of brinjal and soil available nutrients (S, Fe and Zn) were registered with soil application of micronutrients (15 kg $FeSO_4$ ha^{-1} and 8 kg $ZnSO_4$ ha^{-1}) as per soil test value. While, foliar application of multi-micronutrients supplementation through 1.0% spray having Fe-4.0%, Mn-0.1%, Zn-5.0%, Cu-0.5% and B-0.5% grade-IV at 45, 60 and 75 days after transplanting (DAT) resulted in significantly higher uptake of Mn and Cu by fruit and stalk. The magnitude of increased in fruit yield was 27.0% owing to soil application of $FeSO_4$ 15 kg ha^{-1} + $ZnSO_4$ 8 kg ha^{-1} over control. The application of micronutrients as per soil test value significantly increased the availability of Fe and Zn and application of multi micronutrient formulation Grade-V 40 kg ha^{-1} significantly increased the availability of Mn and Cu in soil after harvest of tomato crop. The foliar application of multi-micronutrients treatments did not produced significant effect of soil available micronutrients in soils after harvest of crop.

Keywords: Brinjal, yields and yield attributes, micronutrients mixture, uptake, soil available micronutrients

Introduction
In India brinjal is the fourth most important vegetable crop grown after potato, onion and tomato. The market share for vegetables produced in India is as follows: 26.7% potato, 8.6% onion, 8.5% tomato, 8.4% brinjal. A significant progress has been made in the production of brinjal during the past two decades. Amongst different states, West Bengal comes at the top with 28% share in national brinjal production, followed by Orissa (21%), Bihar (12%) and Gujarat (10%). In Gujarat, brinjal is grown in area of 76.75 thousand ha, with 1341.05 thousand tons of production and productivity of 17.47 t/ha. In the quest of further enhancing crop production to feed million of people, more and more marginal lands were brought under intensive cultivation by extensive use of micronutrients free high analysis fertilizers which further aggravated the deficiencies of micronutrients all over the country. These deficiencies became a serious obstacle in achieving higher crop yields. For realizing higher yields, chemical fertilizers must be applied with balance proportion of micronutrients. Wide spread deficiencies of micronutrients are frequently reported in soils of India Rattan and Sharma (2004) [10] and in Gujarat (Patel *et al.*, 1998) [6]. Micronutrients mixtures provide essential micronutrient in proportionate doses, thereby ensuring the crop yields through balance plant nutrition. Polara *et al.*, (2017) [9] reported that the okra yields significantly increased due to soil application of 15 kg $FeSO_4$ ha^{-1} and 8 kg $ZnSO_4$ ha^{-1} as per soil test value at the time of sowing along with recommended dose of NPK. Although, the requirement of micronutrients like Zn, Cu, Mn, Fe, B and Mo are relatively less but their role in normal crop production is indispensable because of their active role in plant metabolic processes involving cell wall development, respiration, photosynthesis, chlorophyll formation, enzyme activity and nitrogen fixation. Direct spray of micronutrients to foliage of the crop is very beneficial.

Materials and Methods
A field experiment was conducted consecutive two years during *Rabi* –2015-16 and 2016-17 at Vegetable Research Station, (Latitide 21^{O} 30' N, longitude 70026' E and altitude 61m) Junagadh Agricultural University, Junagadh-Gujarat for studying the response of brinjal (cv. GJB 3) to micronutrients in medium black calcareous soils. There were eight treatments *viz*., T_1 - Control (recommended dose of NPK); T_2 – multi micronutrient mixture Grade-I (General); T_3 - multi micronutrient mixture Grade-II (For Zn deficiency); T_4 - multi

micronutrient mixture Grade-III (For Fe deficiency); T_5 - multi micronutrient mixture Grade- IV (For Zn and Fe deficiency) and soil application treatments T_6 - multi micronutrient mixture mixture Grade-V (Soil application @ 20 kg ha^{-1}), T_7 - micronutrient mixture mixture Grade-V (Soil application @ 40 kg ha^{-1}) and T_8 - soil application of micronutrients as per soil test value ($FeSO_4$ 15 kg ha^{-1} and $ZnSO_4$ 8 kg ha^{-1} at the time of transplanting). The multi-micronutrient mixture grades having composition shown as under were prepared in the laboratory.

Table 1: Chemical composition of Micronutrient formulations grades approved by Govt. of Gujarat

Sr. No.	Grade	Content (%)				
		Fe	Mn	Zn	Cu	B
	For foliar spray					
1.	Mixture Grade I (General)	2	0.5	4.0	0.3	0.5
2.	Mixture Grade II (for Zn deficiency)	2	0.5	8.0	0.5	0.5
3.	Mixture Grade III (for Fe deficiency)	6	1.0	4.0	0.3	0.5
4.	Mixture Grade IV (for Fe & Zn deficiency)	4	1.0	6.0	0.5	0.5
	For soil application					
5.	Mixture Grade V	2	0.5	5.0	0.2	0.5

The mixture grade I and V were prepared on the basis of average removal of micronutrients by different crops and rest of grades II to IV on the basis of wide occurrence of Zn or Fe or Zn and Fe deficiencies in soils of Gujarat. Rate of application of T_2, T_3, T_4 and T_5 - 1% foliar spray and soil application T_6 - 20 kg ha^{-1}, and T_7 - 40 kg $ha^{-1}$and T_8-soil application of micronutrients as per soil test values ($FeSO_4$ 15 kg ha^{-1} and $ZnSO_4$ 8 kg ha^{-1}).The treatments were repeated four times in randomized block design. The soil of the experimental field was clayey in texture and had $pH_{2.5}$- 7.6, $EC_{2.5}$ - 0.49 dS m^{-1}, available N - 204 kg ha^{-1}, available P_2O_5 - 307 kg ha^{-1}, available K_2O - 270 kg ha^{-1}, available S-18.6 mg kg^{-1}, Fe - 9.8 mg kg^{-1}, Mn -21.2 mg kg^{-1}, Zn - 0.75 mg kg^{-1} and Cu -1.82 mg kg^{-1}. The recommendation dose of 100 kg N ha^{-1}, 37.5 kg P_2O_5 ha^{-1} and 37.5 kg K_2O ha^{-1} was applied through urea, diammonium phosphate and muriate of potash, respectively, to all plots. Half of the N and full of P_2O_5 and K_2O were applied as basal at transplanting and remaining half N was top dressed at 45 day after transplanting. Seedlings of brinjal variety GJB 3 were transplanted in rows with spacing 75 x 60 cm. All the standard recommended cultural practices and plant protection measures were followed throughout the experimental periods. The green fruits and stalk samples were oven dry at 60º C in oven. The oven dried fruits and stalk samples were finely ground and were digested with di-acid mixture of HNO_3: $HClO_4$ (3:1) as per the procedure outline by Jackson (1973) [4]. Sulphur in digest determined by turbidimetric method (Chesnin and Yien, 1951) [2]. The micronutrients in digest were determined by Atomic Absorption spectrophotometer (Lindsay and Norvell 1978) [5]. The soil samples drawn from the experimental field at harvest were analyzed for available micronutrients by extracting with 0.005 M DTPA and the contents were determined by atomic absorption spectrophotometer and sulphur by Turbidimetric method (Chaudhary & Cornfield, 1966) [1]. The micronutrients and sulphur removal by crop was calculated by multiplying the concentration values. Data were statistically analyzed by using standard method.

Results and Discussion

Yield

The application of micronutrients as a soil application or foliar spray significantly influenced yield and yield attributing characters of brinjal. The green fruit and stalk yields of brinjal improved due to foliar and soil application of micronutrients mixture in both years as well as in pooled basis. The significantly higher green fruit (33.24, 40.94 and 37.09 t ha^{-1}) and stalk (2647, 3240 and 2944 kg ha^{-1}) yields were recorded with application of micronutrients as per soil test value (15 kg $FeSO_4$ ha^{-1} + 8 kg $ZnSO_4$ ha^{-1}) in the year 2015-16, 2016-17 and in pooled results, respectively (Table 2) and which was statistically at par with treatment T_5 (foliar spray of 1.0% multi-micronutrient formulation Grade IV at 45, 60 and 75 days after transplanting -DAT) in both the years and in pooled basis with respect to green fruit yield. The magnitude of increased in fruit yield was 27.0% owing to soil application of 15 kg $FeSO_4$ ha^{-1} + 8 kg $ZnSO_4$ ha^{-1} over control. The results clearly indicated that application of micronutrients either through soil or foliar spray was found beneficial for increase in the yield of brinjal. Increased yield of brinjal due to micronutrients application may be attributed to enhanced photosynthesis activity and increased in production and accumulation of carbohydrates and favorable effect on vegetative growth, and retention of flowers and fruits. Satpute *et al*. (2013) [11] revealed that the increased dry matter production may be attributed to greater accumulation of photosynthates by vegetative parts and fruits in okra. The findings are in agreement with those reported by Polara *et al*. (2017) [9] in okra crop and Vekaria *et al.* (2018) [12] in garlic crop.

Growth and yields attributes

The two year mean data in Table 3 revealed that the significantly higher growth and yields attributes *viz*., plant height (74.1 cm), no of fruits per plant (24.7), fruit length (14.7 cm) and average fruit weight (151 g) were recorded with treatment T_8 (Application of micronutrients as per soil test values of $FeSO_4$ 15 kg ha^{-1} and $ZnSO_4$ 8 kg ha^{-1}) and this treatment was at par with treatment T_5 (Foliar spray of 1.0% micronutrients mixture Grade IV at 45, 60 and 75 days after transplanting). The results clearly indicated that the application of micronutrients either through soil or foliar spray found beneficial for increase in growth and yields attributes of brinjal. These micronutrients play a vital role in the physiology of plants. The increase in growth and yield attributes due to micronutrients might be due to their role in fundamental processes involved in the cellular mechanism and respiration. This effect is positive for improvement in fruits size and fruit weight. Boron exhibits pronounce effect in improving the yield attribute and yield. It takes part in active photosynthesis, which ultimately helps towards increase in number and weight of fruits. These findings confirm the results reported by Polara *et al*. (2017) [9], Vekaria *et al.* (2018) [12] and Satpute *et al*. (2013) [11].

Micronutrients uptake

The perusal of two year mean data on uptake of sulphur and micronutrients (Fe, Mn, Zn and Cu) by fruit and stalk revealed that application of micronutrients either soil or spray was found significantly superior in respect of S, Fe, Mn, Zn and Cu uptake (Table 4 & 5). Significantly higher uptake of S (19.3 and 8.7 kg ha^{-1}), Fe (979 and 817 g ha^{-1}) and Zn (109 and 99 g ha^{-1}) uptake by fruit and stalk of brinjal were registered with soil application of micronutrients ($FeSO_4$ 15 kg ha^{-1} and $ZnSO_4$ 8 kg ha^{-1}) as per soil test value. While, foliar application of multi-micronutrients supplementation through 1.0% spray having Fe-4.0%, Mn-0.1%, Zn-5.0%, Cu-

0.5% and B-0.5% grade-IV at 45, 60 and 75 days after transplanting (DAT) resulted in significantly higher uptake of Mn (278 and 206 g ha^{-1}) and Cu (48.7 and 44.0 g ha^{-1}) by fruit and stalk. The improvement in the nutrients use efficiency could be attributed to an enhancement in absorption and assimilation of the micronutrients which provided balanced nutrition to the crops for higher growth and thereby nutrients uptake which ultimately resulted into higher yield of the crops. The increase in uptake of micronutrients by brinjal crop due to use of multi-micronutrients fertilizers have also been reported by several workers Ghritlahare *et al.*, (2015) [3], Patel *et al.* (2008) [7], Polara *et al.* (2017) [9] and Vekaria *et al.* (2018) [12].

Soil available nutrients

The data given in Table 6 revealed that the soil application of micronutrients significantly enhanced the available S and DTPA extractable Fe, Zn, Mn and Cu in soil after harvest of crop. The application of micronutrients as per soil test value (T_8) significantly increased the availability of S, Fe and Zn (20.2, 13.5 and 0.924 mg kg^{-1}, respectively) and application of multi micronutrient formulation grade V 40 kg ha^{-1} significantly increased the availability of Mn and Cu (23.5 and 2.09 mg kg^{-1}) in soil after harvest of brinjal crop, respectively. The foliar application of multi-micronutrients treatments did not produced significant effect of soil available micronutrients in soils after harvest of crop. In general, the average contents of DTPA-extractable micronutrients of the soil improved due to application of multi-micronutrients through soil application at the end of the experiment. Similar results were also reported by Patel *et al.* (2008 [7], Polara *et al.* (2017) [9] and Vekaria *et al.* (2018) [12].

Table 2: Effect of micronutrients on brinjal yield

Treatments	Green fruit yield (t/ha)			Stalk yield (kg/ha)		
	2015-16	2016-17	Mean	2015-16	2016-17	Mean
T_1. Control	26.18	31.22	28.70	2105	2528	2316
T_2. Grade I	30.12	36.07	33.09	2491	3005	2748
T_3. Grade II	29.31	34.05	31.68	2253	2616	2434
T_4. Grade III	29.85	36.22	33.03	2402	2907	2655
T_5. Grade IV	31.48	38.78	35.13	2445	3013	2729
T_6. Grade V @ 20 kg ha^{-1}	28.23	33.70	30.96	2253	2669	2461
T_7. Grade V @ 40 kg ha^{-1}	29.44	35.88	32.66	2263	2740	2502
T_8. As per STV	33.24	40.94	37.09	2647	3240	2944
SEm ±	1.20	1.60	1.03	106	90	69
C.D. at 5%	3.53	4.69	2.94	312	264	198
C.V. %	8.1	8.9	8.9	9.0	6.3	7.6
Y x T						
SEm ±			1.46			98
C.D. at 5%			NS			NS

Table 3: Effect of micronutrients on growth and yield attributes of brinjal

Treatments	Plant height (cm)	No. of Branches per plant	Plant spread (cm)	No of Fruits per plant	Fruit length (cm)	Fruit Girth (cm)	Avg. Fruit Wt. (g)
T_1. Control	61.7	3.2	72.0	19.5	10.6	15.6	116
T_2. Grade I	67.3	3.5	73.2	20.7	11.8	15.9	135
T_3. Grade II	63.4	3.4	72.7	21.2	11.4	15.7	138
T_4. Grade III	73.0	3.6	73.1	22.4	13.0	16.4	138
T_5. Grade IV	71.3	3.7	69.8	23.9	14.7	17.1	146
T_6. Grade V @ 20 kg ha^{-1}	63.5	3.4	70.3	20.5	11.3	16.4	130
T_7. Grade V @ 40 kg ha^{-1}	69.1	3.4	71.2	22.5	13.4	16.2	143
T_8. As per STV	74.1	3.6	73.4	24.7	14.7	17.0	151
SEm ±	1.8	0.1	2.4	0.5	0.4	0.5	3
C.D. at 5%	5.1	NS	NS	1.6	1.1	NS	9
C.V. %	7.4	8.8	9.2	7.1	8.6	8.9	7
Y x T							
SEm ±	2.5	0.2	3.3	0.8	0.5	0.7	4
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS

Table 4: Effect of micronutrients on nutrients uptake by brinjal fruit

Treatments	S	Fe	Mn	Zn	Cu
	(kg/ha)	(g/ha)			
T_1. Control	12.9	566	148	52	31.6
T_2. Grade I	16.5	701	193	71	44.7
T_3. Grade II	16.5	658	172	92	39.0
T_4. Grade III	16.5	812	244	82	40.9
T_5. Grade IV	18.6	813	278	97	48.7
T_6. Grade V @ 20 kg ha^{-1}	15.0	678	198	70	37.7
T_7. Grade V @ 40 kg ha^{-1}	16.1	777	205	83	41.2
T_8. As per STV	19.3	979	207	109	40.6
SEm ±	0.7	26	9	3	1.2
C.D. at 5%	2.1	75.1	26	8	3.5

C.V. %	12.9	10.0	12.7	10.2	8.5
Y x T					
SEm ±	1.1	37	13.1	4	1.7
C.D. at 5%	NS	NS	NS	NS	NS

Table 5: Effect of micronutrients on nutrients uptake by brinjal stalk

Treatments	S	Fe	Mn	Zn	Cu
	(kg/ha)	(g/ha)			
T_1. Control	5.8	488	103	53	29
T_2. Grade I	7.4	645	167	76	43
T_3. Grade II	6.8	571	161	76	35
T_4. Grade III	6.9	692	197	71	38
T_5. Grade IV	7.6	703	206	89	44
T_6. Grade V @ 20 kg ha^{-1}	6.2	579	159	73	35
T_7. Grade V @ 40 kg ha^{-1}	6.7	637	159	80	37
T_8. As per STV	8.7	817	144	99	38
SEm ±	0.2	26	7	4	2
C.D. at 5%	0.6	74	20	11	5
C.V. %	9.1	11.4	12.1	14.1	12.8
Y x T					
SEm ±	0.3	37	10	5	2
C.D. at 5%	NS	NS	NS	NS	NS

Table 6: Effect of micronutrients on nutrients availability in soil after harvest of brinjal

Treatments	S	Fe	Mn	Zn	Cu
	(ppm)				
T_1. Control	15.3	9.2	18.3	0.634	1.72
T_2. Grade I	16.6	9.4	18.2	0.648	1.68
T_3. Grade II	15.9	10.2	19.6	0.603	1.78
T_4. Grade III	17.0	10.5	19.4	0.684	1.70
T_5. Grade IV	16.9	10.4	19.8	0.649	1.78
T_6. Grade V @ 20 kg ha^{-1}	18.4	11.9	22.5	0.778	2.01
T_7. Grade V @ 40 kg ha^{-1}	18.3	12.5	23.5	0.801	2.09
T_8. As per STV	20.2	13.5	19.6	0.924	1.78
SEm ±	0.6	0.4	0.7	0.031	0.06
C.D. at 5%	1.6	1.0	1.9	0.089	0.16
C.V. %	9.0	9.3	9.2	12.4	8.9
Y x T					
SEm ±	0.8	0.5	0.9	0.044	0.08
C.D. at 5%	NS	NS	NS	NS	NS

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