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Studies on the influence of micronutrients on yield, quality and economics of bitter gourd (*Momordica charantia*) cv. CO 1

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Abstract
Field experiment was carried out to study the effect of micronutrients along with magnesium on growth, flowering and yield of bitter gourd. Seven treatment combinations involving the micronutrients *viz*., Zn, Fe, B and Cu and magnesium were imposed with three replications in randomized block design during two seasons *viz*., August 2016 and January 2017. Results showed that, among the treatments, foliar application of $ZnSO_4$+$FeSO_4$+$MgSO_4$ each @ 0.5% at 35 and 45 DAS recorded significantly maximum values for yield and yield attributing traits like fruit length, fruit girth, fruit diameter, flesh thickness, single fruit weight, number of fruits, yield per plant and estimated yield per hectare. Foliar application of $ZnSO_4$+$FeSO_4$+$MgSO_4$ each @ 0.5% + $CuSO_4$ @ 0.1%+ Boric acid @ 0.3% at 35 and 45 DAS recorded significantly maximum values for quality traits like ascorbic acid, total soluble solids and iron content in fruits. The benefit cost ratio was also highest in the treatment T_4 (foliar spray of $ZnSO_4$ + $FeSO_4$+ $MgSO_4$ each @ 0.5% at 35 and 45 DAS) which recorded a value of 3.16.

Keywords: Micronutrients, bitter gourd, yield, quality

Introduction
Bitter gourd (*Momordica charantia* L.) is one of the important vegetable crops belonging to the family Cucurbitaceae. In India, bitter gourd was cultivated in an area of about 79,000 hectare and the production was 8,07,000 metric tonnes during 2013-14 (Anon,2015) [1]. Among all cucurbitaceous vegetables, fruit of bitter gourd records the highest calorific value. In terms of medicinal properties, bitter gourd ranks first among the cucurbits due to higher nutritive value being rich in all the essential vitamins and minerals especially vitamin A (210 IU/100g), vitamin C (88 mg/100g), iron (1.8 mg/100g), phosphorus (55mg/100g), calcium (20 mg/100g) and momordicin (29 mg/g). Micronutrients are usually required in minute quantities, nevertheless, are vital to the growth of plant (Benepal, 1967) [2]. Micronutrients are to be necessarily taken up by the plants from soil or supplemented through foliar application for good growth and yield of crops and maximizing the efficient use of applied N, P and K. In the absence of these micronutrients, the plants suffer from physiological disorders which eventually lead to imbalanced growth and low yield. Nowadays micronutrients are gradually gaining momentum among the vegetable growers because of their beneficial nutritional support and at the same time ensure better harvest and returns. Applying foliar micronutrients is one tool to maintain or enhance plant nutritional status and improve the yield and quality of vegetables. To conquer the micronutrient deficiency and to improve the productivity and quality, there is an urgent need to study the efficiency of micronutrients in bitter gourd. Hence, the present investigation was made to study the effect of foliar application of micronutrients on yield and quality of bitter gourd.

Materials and Methods
To study the response of micronutrients on yield and quality of bitter gourd (*Momordica charantia* L.) cv. CO 1, the field experiment was carried out at the experimental field of College Orchard, Department of Vegetable Crops, Horticultural College and Research Institute, Tamil Nadu Agricultural University, Coimbatore during 10.8.2016 (I season) and 16.1. 2017 (II season) (2 seasons). It is situated at an elevation of 426.72 m, between 11^{o} N latitude and 77^{0} E longitude. The soil type is sandy clay loam with a pH of 7.8 and EC of 0.52 dsm^{-1}.The soil available N, P and K was 177 kg, 16 kg and 1235 kg per ha respectively.

The experiments was laid out with seven treatments in a randomized block design (RBD) with three replications. The treatments included the foliar spray of $ZnSO_4$, $FeSO_4$ and $MgSO_4$ each @ 0.5%, $CuSO_4$ @ 0.1% and Boric acid @ 0.3% at 35 DAS and 35 and 45 DAS in different combinations with a control (without any spray) as given in table 1.

Table 1: Treatment details of the experiment.

Treatment No.	Treatment detail
T_1	Foliar spray of $ZnSO_4$+ $FeSO_4$+ $MgSO_4$ each @ 0.5% at 35 DAS
T_2	Foliar spray of $ZnSO_4$ + $FeSO_4$+ $MgSO_4$ each @ 0.5% +$CuSO_4$ @ 0.1% at 35 DAS
T_3	Foliar spray of $ZnSO_4$+ $FeSO_4$+ $MgSO_4$ each @ 0.5% +$CuSO_4$ @ 0.1% + Boric acid @ 0.3 % at 35 DAS
T_4	Foliar spray of $ZnSO_4$ + $FeSO_4$+ $MgSO_4$ each @ 0.5% at 35 and 45 DAS
T_5	Foliar spray of $ZnSO_4$ + $FeSO_4$+ $MgSO_4$ each @ 0.5% + $CuSO_4$ @ 0.1% at 35 and 45 DAS
T_6	Foliar spray of $ZnSO_4$+ $FeSO_4$+$MgSO_4$ each @ 0.5%+ $CuSO_4$ @ 0.1%+ Boric acid @ 0.3% at 35 and 45 DAS
T_7	Control (without any spray)

DAS- Days after sowing

AR grade of $ZnSO_4$, $FeSO_4$, $MgSO_4$, $CuSO_4$ and Boric acid were used for foliar spraying. For all the treatments, recommended dose of fertilizers were applied as common. All the recommended agronomical practices were followed for the crop. Spraying was done using knapsack sprayer and the leaves were wetted thoroughly with fine mist. During the course of investigation, observations on yield and quality parameters of the crop were recorded in both the seasons. Five plants were selected at random in each treatment per replication and utilized for recording observations on the following characters *viz*., number of fruits, single fruit weight (g), fruit length (cm), fruit girth (cm), fruit diameter (cm), flesh thickness (cm), yield per plant (kg) and estimated yield per hectare (tonnes) and quality traits *viz*., ascorbic acid (mg 100 g^{-1}), total soluble solids (°brix) and iron content (mg 100 g^{-1}) in fruits. The statistical analysis for the observations recorded was performed according to the method suggested by Panse and Sukhatme (1985) [7]. The critical difference was worked out at five per cent (0.05) probability. The pooled analysis was carried out over the two seasons. The benefit cost analysis was carried out and presented.

Results and Discussion

The results of the present investigation indicated that the yield and quality characters of bitter gourd were significantly influenced by foliar application of micronutrients.

Yield Parameters

The maximum number of fruits per plant, single fruit weight, fruit length, fruit girth, fruit diameter, flesh thickness, fruit yield per plant and estimated yield per hectare were recorded in T_4 ($ZnSO_4$ + $FeSO_4$+ $MgSO_4$ each @ 0.5% at 35 and 45 DAS) and the minimum was noticed in T_7 (Control) (table 2 and 3). The increase in yield of bitter gourd by the direct influence of micronutrients might be due to higher rate of photosynthesis and sugar formation and also due to translocation of more photosynthates to growing fruits which ultimately led to higher production of dry matter and consequently more yield. Also, the various reactions in plant metabolism are catalyzed by micronutrients. Zinc as an essential catalyst in the synthesis of auxin from tryptophan would have encouraged the auxin biosynthesis in the active source which would have led to higher transport and accumulation of photosynthates in these sinks in fruits and improved the yield. These results are in conformity with those of Dongre *et al.* (2000) [4] for yield per plant, yield per plot and yield per hectare in chilli and Ravichandran *et al.* (1995) [10] in brinjal. The iron might have helped in better absorption of nutrients resulting in efficient physiological and metabolic activities of plant. This increased yield in this study might be due to the combined beneficial effect of zinc, iron and magnesium application on plant. Similar results were reported by Lashkari *et al.*, (2007) [5] in cauliflower. The combined beneficial effect of zinc and iron application in improving the yield was reported by Vala *et al.* (2014) [14] in bitter gourd and Dongre *et al.* (2000) [4] in chilli. The higher yield observed due to the micronutrient and magnesium application might be attributed to enhanced chlorophyll contents, enzymatic activity, rapid increase in photosynthetic activities, accumulation of photo synthesis by vegetative parts and its subsequent translocation to the sink, favourable effect on vegetative growth and retention of flower and fruit. These might have increased the number of fruits per plant besides improving in the fruit size, which ultimately led to higher production of dry matter and yield. These results are conformity with the results reported by Saravaiya *et al.* (2014) [11] in tomato.

Quality Parameters

Among the treatments, T_6 ($ZnSO_4$+ $FeSO_4$+$MgSO_4$ each @ 0.5%+ $CuSO_4$ @ 0.1%+ Boric acid @ 0.3% at 35 and 45 DAS) recorded highest ascorbic acid, total soluble solids and iron content with a mean value of 63.08 mg 100 g^{-1}, 5.46 °brix and 1.72 mg 100g^{-1} respectively followed by T_4 ($ZnSO_4$+ $FeSO_4$+$MgSO_4$ each @ 0.5% at 35 and 45 DAS) and the lowest was recorded in T_7 (Control) (table 4).

These might be attributed to higher synthesis of carbohydrates at higher zinc and boron level. They have an important role in photosynthesis and related enzyme activity which might have led to increase in sugar. These results are in consonance with the findings of Rab and Haq (2012) [9] and Nighat Mushtaq *et al.* (2016) [6] in tomato. The favourable effects of Zn and Fe on higher TSS and ascorbic acid content obtained in this study could be due to the positive response of bitter gourd to micronutrient application. Besides, vigorous plant growth, mainly in terms of foliage, resulted in efficient production of photosynthetic products and these might have developed healthy fruits. Another reason could be that the application of Zn and Fe regulate various metabolic activities of plants and are involved in the auxin production. This is in line with the findings of Satpute *et al.* (2013) [12] in bhendi.

B:C ratio

The maximum cost benefit ratio of 3.16 was obtained by foliar spray of $ZnSO_4$ + $FeSO_4$+ $MgSO_4$ each @ 0.5% at 35 and 45 DAS (T_4) recording Rs 3,27,042 /ha as net return followed by T_1 (foliar spray of $ZnSO_4$ + $FeSO_4$+ $MgSO_4$ each @ 0.5% at DAS) (2.87) obtaining Rs 2,82,321/ha as net return. The lowest B:C ratio was found in control (1.91) which recorded minimum net return of Rs 1,35,800/ha. (table

5). The highest net return and B: C ratio occured under these treatments was due to highest fruit yield. These findings are in conformity with the observations of Bhatt *et al.* (2004) [3], Patil *et al.* (2008) [8] and Singh and Verma (1991) [13] in tomato, who obtained maximum benefit cost ratio with micronutrients combinations.

Conclusion

The treatment T_4 (foliar spray of $ZnSO_4$ + $FeSO_4$+ $MgSO_4$ each @ 0.5% at 35 and 45 DAS) produced highest values for yield and yield attributing characters and B:C ratio and second best values for quality parameters. Thus it can be concluded that this treatment can be promoted for obtaining higher yield and quality in bitter gourd.

Table 2: Effect of micronutrient spray on yield and yield attributing traits in bitter gourd cv. CO 1(Pooled analysis of two seasons)

Treatment	No. of fruits plant^{-1}	Single fruit weight (g)	Fruit length (cm)	Fruit girth (cm)	Fruit diameter (cm)	Flesh thickness (cm)
T_1	23.79	106.08	106.08	11.41	5.48	1.35
T_2	19.34	90.32	90.32	11.47	5.28	1.31
T_3	20.14	91.94	91.94	10.45	5.07	1.26
T_4	26.86	112.57	112.57	11.80	5.62	1.39
T_5	21.43	93.00	93.00	10.91	5.38	1.29
T_6	22.18	95.32	95.32	10.88	5.26	1.28
T_7	17.42	85.35	85.35	10.17	4.95	1.25
S. Ed.	0.30	1.20	1.20	0.22	0.09	0.02
CD (P=0.05)	0.62*	2.49*	2.49*	0.45*	0.19*	0.04*

Table 3: Effect of micronutrient spray on yield plant^{-1} (kg) and estimated yield (t ha^{-1}) in bitter gourd cv. CO 1(Pooled analysis of two seasons)

Treatment	Yield/plant (kg)			Estimated yield (t ha^{-1})		
	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean
T_1	2.28	2.01	2.15	22.81	20.51	21.66
T_2	1.82	1.34	1.58	18.20	13.40	15.80
T_3	2.03	1.58	1.81	20.35	15.80	18.07
T_4	2.55	2.24	2.40	25.48	22.40	23.94
T_5	2.08	1.82	1.95	20.82	18.20	19.51
T_6	2.11	1.96	2.03	21.06	19.49	20.28
T_7	1.58	1.28	1.43	15.82	12.77	14.29
S. Ed.	0.06	0.03	0.03	0.59	0.15	0.30
CD (P=0.05)	0.13*	0.06*	0.07*	1.28*	0.32*	0.62*

Table 4: Effect of micronutrient spray on quality traits in bitter gourd cv. CO 1(Pooled analysis of two seasons)

Treatment	TSS (°brix)	Ascorbic acid (mg 100 g^{-1})	Iron content (mg 100 g^{-1})
T_1	4.45	58.29	1.70
T_2	4.09	59.94	1.68
T_3	4.20	61.93	1.65
T_4	5.46	63.08	1.72
T_5	4.34	60.51	1.68
T_6	5.77	64.99	1.76
T_7	3.78	55.90	1.61
S. Ed.	0.0089	0.4389	0.009
CD (P=0.05)	0.0183*	0.9042*	0.019*

Table 5: Effect of micronutrient spray on economics of cultivation in bitter gourd cv. CO 1 per hectare (Mean of two seasons)

Treatment	Estimated yield (t ha^{-1})	Cost of cultivation (Rs.)*	Gross return**	Net return (Rs.)	B:C Ratio
T_1	21.66	150878	433200	282321	2.87
T_2	15.80	150923	316000	165076	2.09
T_3	18.07	150998	361400	210401	2.39
T_4	23.94	151757	478800	327042	3.16
T_5	19.51	151847	390200	238352	2.57
T_6	20.28	151997	405600	253602	2.67
T_7	14.29	150000	285800	135800	1.91

* It excludes the construction of pandal cost

**Fruits were sold @ Rs. 20 per kg

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