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Effect of fertigation levels and foliar application of micronutrients on growth, yield and quality of bitter gourd

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Abstract
The purpose of the present experiment was to evaluate the effects of fertigation levels and foliar application of micronutrients during the year of 2021. An experiment was conducted in Factorial Randomized Block Design (FRBD) comprising of two factors- fertigation levels (F_1-125%, F_2-100%, F_3-75% of RDF NPK kg ha^{-1}) and foliar application (M_0 – Water spray, M_1 – Boric acid, M_2 – $ZnSO_4$, M_3 – $FeSO_4$) having twelve treatment combinations in three replications. Results showed that, among all treatment combinations (F_1M_1) i.e. 125% RDF (250:125:125 kg/ha NPK) through fertigation and foliar application of boric acid (0.1%) treatment combination was recorded significantly maximum mean values for growth and yield parameters like, vine length, number of branches at all growth stages, leaf area, number of male flowers, number of female flowers, fruit set and significantly minimum values recorded for days to first male flower appears, days to first female flower appears, sex ratio, node at which first female flower appears and yield parameters viz. number of pickings, number of fruits per vine, fruit length, fruit diameter, average fruit weight, fruit yield per vine, fruit yield per plot and yield per ha. Treatment combinations (F_1M_3) i.e. 125% RDF (250:125:125 kg/ha NPK) through fertigation and foliar application of $ZnSO_4$ (0.5%) gave the maximum value for chlorophyll index of leaves.

Keywords: Bitter gourd, fertigation, micronutrients, NPK levels, growth, yield and quality

Introduction
The most significant member of the Cucurbitaceae family of vegetables, the bitter gourd (*Momordica charantia* L.), is produced in India for its immature tuberculate fruits, which have a distinct bitter taste. Fruits contain polypeptide-P, vegetable insulin or charantin, which lowers blood sugar levels. It also contain guanylatecyclase inhibitor which impair chemical carcinogen induced increases in guanylatecyclase activity. In traditional medicine, ripe fruits are used to cure diabetes.

The two most efficient and practical ways to provide nutrients are fertigation and foliar application to maintain optimum soil fertility and produce higher yields, but a proper selection of nutrients, as well as their precise concentration and application stages, are required to increase yield and gross return. Micronutrients like iron, zinc, boron, manganese, and copper etc., have been found to be crucial in influencing the growth and development of many horticultural crops. Hence the present study was framed out, in F-1 hybrid bitter gourd.

Material and Methods
The current study was conducted in the instructional farm of the Dr. PDKV, Akola, Department of Vegetable Science, during the Kharif season of 2021. Using two factors-fertigation levels and foliar application - the experiment was laid out using a Factorial Randomized Block Design (FRBD). The soil in experimental field has available N (184 kg ha^{-1}), available P (13.5 kg ha^{-1}), available K (308 kg ha^{-1}). The experiment was laid out in 6.50 x 3.00 m plot size and seeds of F-1 hybrid were sown at 3.00 x 0.75 m spacing. The farm yard manure @ 25 t ha^{-1} was evenly distributed among all the treatments. At intervals of 10 days, water-soluble fertilizers (19:19:19 and urea) were applied based on fertigation treatment combinations. All the cultural practices were carried when and where required throughout the growth period. Foliar application of micronutrients was given at time of flower and fruit set initiation. For growth, yield, and quality parameters, the observations were recorded.

The method recommended for Factorial Randomized Block Design (FRBD) by Panse and Sukhatme (1985) [10] was used to examine the data obtained from the various observations.

Treatment means were compared by using critical difference at 5% level of significance.

Result and Discussion

Effect of fertigation levels

The data in Tables 1, 2, and 3 showed that the growth, yield, and quality of bitter gourd were significantly influenced by the different fertigation levels. Significantly maximum vine length (424.85 cm), number of branches (19.41), leaf area (71.55 cm^2), number of male flowers (377.44), number of female flowers (46.71), fruit set (85.98%), chlorophyll index (32.12) and significantly minimum days required to first male flower appears (35.43), days to first female flower appears (37.84), lowest node at which first female flower appears (8.25) and narrow male : female (sex ratio) (8.12) were recorded by fertigation level F_1 i.e. 125% RDF (250:125:125 kg/ha NPK). Yield parameters *viz.*, number of pickings (12.04), number of fruits per vine (40.19), fruit length (17.55 cm), fruit diameter (4.36 cm), fruit weight (116.78 g), fruit yield per vine (4.70 kg), fruit yield per plot (56.46 kg) and fruit yield per ha (209.11 q) were found significantly maximum at fertigation level F_1 i.e. 125% RDF (250:125:125 kg/ha NPK).

Increased nutrient availability and uptake caused by the vigorous plant development as a result of increased fertilizer application close to the root zone results in an increase in cell size and cell elongation reported by Sharma *et al*. (2009) [13] in cucumber. The number of days needed for the commencement of the first male and female flowers, the quantity of male and female flowers on each vine, the percentage of fruit set, and the sex ratio were all significantly influenced by nitrogen levels. Similar outcomes were obtained by Meena *et al.* (2017) [7] in bottle gourd. At higher fertigation level, crop meets out its nutritional requirement at respective growth stages which leads to luxuriance growth and thereby enhancement of yield. Number of branches produced per plant directly influenced the yield of bitter gourd since more number of branches contributed more flower bearing nodes as reported by Meenakshi (2002) [8]. These outcomes matched with the findings of Arvind Kumar *et al.* (2012) [2] in bitter gourd, Abraham *et al.* (2018) [1] in bitter gourd, Sahu *et al.* (2021) [5] in bitter gourd.

Effect of foliar application

Foliar application of micronutrients showed significant effect on growth, yield and quality of bitter gourd and presented in Table 1, 2 and 3. The foliar application of M_1 i.e. boric acid @ 0.1% has recorded significant results in relation to maximum vine length (417.03 cm), number of branches (19.65), leaf area (71.35 cm^2), number of male flowers (377.49), number of female flowers (46.84), fruit set (84.86%) and significantly minimum days required to first male flower appears (35.46), days to first female flower appears (37.43), lowest node at which first female flower appears (7.99) and narrow male : female (sex ratio) (8.08). The treatment M_3 i.e. foliar application of $FeSO_4$ has recorded maximum chlorophyll index (32.17). Yield and yield attributing characters viz., number of pickings (12.85), number of fruits per vine (39.80), fruit length (18.33 cm), fruit diameter (4.39 cm), fruit weight (116.62 g), fruit yield per vine (4.65 kg), fruit yield per plot (55.83 kg) and fruit yield per ha (206.79 q) were found significantly maximum at foliar application of treatment at boric acid @ 0.1%. Due to improved photosynthesis, carbohydrate accumulation, and favorable effects on vegetative growth, foliar application of micronutrients produced fruits that were heavier as well as longer and wider. These effects may have contributed to the fruits' increased weight in addition to their larger size. These results get supported from the findings of Narayanamma *et al*. (2009) [9] in bitter gourd. The increase in yield and yield characteristics brought on by the foliar application of micronutrients may be attributed to improved photosynthesis, carbohydrate accumulation, cell wall development, and cell differentiations as they promote overall vegetative growth, biological activity of plants, and retention of more flowers and fruits, which have increased number of fruits per vine and size of fruits in addition to increasing yield in bitter gourd reported by Patil *et al*. (2013) [11]. Boron improved development by raising the levels of indole acetic acid (IAA) and the IAA/cytokinin ratio in leaves and lowering the levels of IAA oxidase inhibitors, Puzina, (2004) [12]. Similar results were also obtained by Bharti *et al.* (2018) [4] in bitter goud, Karthick *et al.* (2018) [6] in bitter gourd, Ashraf *et al.* (2020) [3] in bitter gourd.

Interaction effect of fertigation levels and foliar application of micronutrients

The data regarding interaction effects of fertigation levels and foliar application presented in Table 1, 2 and 3. The interaction effect between fertigation levels and foliar application of micronutrients were found significant for growth, yield and quality of bitter gourd. The maximum vine length (451.74 cm), number of branches (20.83), leaf area (74.25 cm^2), number of male flowers (382.33), number of female flowers (50.17), fruit set (87.06%) and significantly minimum days required to first male flower appears (33.38), days to first female flower appears (36.31), lowest node at which first female flower appears (7.37) and narrow male : female (sex ratio) (7.62) were recorded in treatment combination F_1M_1 i.e. 125% RDF (250:125:125 kg/ha NPK) through fertigation and foliar application of boric acid (0.1%). The yield characters were found significant for number of pickings (13.44), number of fruits per vine (43.68), fruit length (19.44 cm), fruit diameter (4.91 cm), fruit weight (120.67 g), fruit yield per vine (5.27 kg), fruit yield per plot (63.24 kg) and fruit yield per ha (234.22 q) in treatment combination F_1M_1 i.e. 125% RDF (250:125:125 kg/ha NPK) through fertigation and foliar application of boric acid (0.1%). The quality parameter like chlorophyll index of leaf (34.70) was recorded maximum in treatment combination F_1M_3 i.e. 125% RDF (250:125:125 kg/ha NPK) through fertigation and foliar application of $FeSO_4$ (0.5%).

Table 1: Effect of fertigation levels and foliar application of micronutrients on vine length (cm), number of branches, leaf area (cm^2), Days to first male and female flower appears.

Treatments	Vine length (cm)	Number of branches	Leaf area (cm^2)	Days to first male and female flower appears	
				Male flower	Female flower
Fertigation levels (F)					
F_1- 125% NPK	424.85	19.41	71.55	35.43	37.84
F_2- 100% NPK	396.53	18.38	68.96	36.87	38.83
F_3- 75% NPK	388.79	17.59	65.47	38.20	39.42
'F' test	Sig.	Sig.	Sig	Sig.	Sig.
SE (m)±	3.38	0.12	0.16	0.19	0.16
CD at 5%	9.93	0.34	0.50	0.58	0.47
Foliar spray (M)					
M_0- Water spray	388.28	17.03	64.64	38.79	40.87
M_1- Boric acid @ 0.1%	417.03	19.65	71.35	35.46	37.43
M_2- $ZnSO_4$ @ 0.5%	407.88	18.76	68.75	36.26	38.15
M_3- $FeSO_4$ @ 0.5%	400.39	18.40	69.91	36.82	38.35
'F' test	Sig.	Sig.	Sig.	Sig.	Sig.
SE (m)±	3.91	0.13	0.19	0.23	0.18
CD at 5%	11.47	0.39	0.60	0.67	0.54
Treatment combinations	**Interaction (FXM)**				
F_1M_0	403.09	17.23	66.57	38.32	39.92
F_1M_1	451.74	20.83	74.25	33.38	36.31
F_1M_2	436.74	19.86	70.94	34.74	37.19
F_1M_3	407.85	19.73	71.11	35.27	37.96
F_2M_0	384.84	17.07	64.45	38.74	40.91
F_2M_1	403.43	19.75	71.52	35.56	37.32
F_2M_2	396.18	18.58	69.45	36.14	38.19
F_2M_3	401.68	18.13	70.43	37.04	38.90
F_3M_0	376.90	16.78	63.12	39.32	41.77
F_3M_1	395.91	18.39	71.03	37.44	38.66
F_3M_2	390.72	17.85	67.30	37.90	39.08
F_3M_3	391.63	17.32	69.07	38.14	38.18
'F' test	Sig.	Sig.	Sig.	Sig.	Sig.
SE (m) ±	6.77	0.23	0.34	0.48	0.32
CD at 5%	19.86	0.68	1.02	1.44	0.94

Table 2: Effect of fertigation levels and foliar application of micronutrients on node at which first female flower appears, number of male and female flowers, male: female sex ratio, fruit set%, chlorophyll index.

Treatments	Node at which first female flower appears	Number of male and female flowers and male: female (sex) ratio			Fruit set%	Chlorophyll index
		Male flower	Female flower	Male: Female (sex) ratio		
Fertigation levels (F)						
F_1- 125% NPK	8.25	377.44	46.71	8.12	85.98	32.12
F_2- 100% NPK	8.77	374.71	44.81	8.39	82.98	29.16
F_3- 75% NPK	9.23	371.37	42.12	8.83	79.63	28.13
'F' test	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.
SE (m)±	0.05	0.32	0.29	0.03	0.77	0.16
CD at 5%	0.15	0.98	0.88	0.10	2.27	0.47
Foliar spray (M)						
M_0- Water spray	10.11	369.80	40.72	9.08	79.47	26.60
M_1- Boric acid @ 0.1%	7.99	377.49	46.84	8.08	84.86	31.22
M_2- $ZnSO_4$ @ 0.5%	8.29	375.94	45.85	8.22	83.87	29.33
M_3- $FeSO_4$ @ 0.5%	8.59	374.80	44.77	8.40	83.26	32.17
'F' test	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.
SE (m)±	0.06	0.30	0.33	0.06	0.89	0.19
CD at 5%	0.18	0.92	0.98	0.19	2.62	0.61
Treatment combinations	**Interaction (FXM)**					
F_1M_0	9.95	369.22	41.12	8.98	84.30	28.88
F_1M_1	7.37	382.33	50.17	7.62	87.06	33.78
F_1M_2	7.62	380.56	48.43	7.86	86.79	31.13
F_1M_3	8.05	377.65	47.10	8.02	85.77	34.70
F_2M_0	10.07	371.64	40.95	9.08	78.22	26.30
F_2M_1	8.00	376.51	47.05	8.00	85.28	30.73
F_2M_2	8.40	374.53	46.10	8.13	84.44	28.94
F_2M_3	8.60	376.16	45.12	8.34	83.98	30.69

F_3M_0	10.30	368.53	40.09	9.19	75.98	24.62
F_3M_1	8.60	373.63	43.30	8.63	82.24	29.17
F_3M_2	8.87	372.74	43.02	8.67	80.38	27.62
F_3M_3	9.13	370.59	42.09	8.83	80.02	31.14
'F' test	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.
SE (m) ±	0.10	0.58	0.58	0.12	1.54	0.32
CD at 5%	0.30	1.70	1.69	0.38	4.54	0.95

Table 3: Effect of fertigation levels and foliar application of micronutrients on yield parameters.

Treatments	Number of pickings	Number of fruits per vine	Fruit length (cm)	Fruit diameter (cm)	Fruit weight (g)	Fruit yield vine^{-1} (kg)	Fruit yield plot^{-1} (kg)	Fruit yield ha^{-1} (q)
Fertigation levels (F)								
F_1- 125% NPK	12.04	40.19	17.55	4.36	116.78	4.70	56.46	209.11
F_2- 100% NPK	11.54	37.24	16.77	4.00	113.18	4.23	50.74	187.94
F_3- 75% NPK	10.91	33.54	15.61	3.71	106.99	3.60	43.18	159.94
'F' test	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.
SE (m)±	0.09	0.23	0.17	0.03	0.38	0.02	0.34	1.26
CD at 5%	0.28	0.70	0.51	0.11	1.11	0.08	0.99	3.71
Foliar spray (M)								
M_0- Water spray	9.08	32.37	13.83	3.46	105.23	3.42	40.99	151.83
M_1- Boric acid @ 0.1%	12.85	39.80	18.33	4.39	116.62	4.65	55.83	206.79
M_2- $ZnSO_4$ @ 0.5%	12.19	38.51	17.78	4.18	114.41	4.42	53.01	196.34
M_3- $FeSO_4$ @ 0.5%	11.87	37.28	16.63	4.06	113.02	4.22	50.68	187.69
'F' test	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.
SE (m)±	0.11	0.27	0.20	0.04	0.43	0.03	0.55	1.46
CD at 5%	0.32	0.80	0.59	0.13	1.28	0.09	1.15	4.29
Treatment combinations	**Interaction (FXM)**							
F_1M_0	9.21	34.67	14.04	3.73	111.99	3.88	46.59	172.54
F_1M_1	13.44	43.68	19.44	4.91	120.67	5.27	63.24	234.22
F_1M_2	12.97	42.03	18.81	4.49	118.54	4.98	59.80	221.48
F_1M_3	12.54	40.40	17.89	4.30	115.94	4.68	56.21	208.18
F_2M_0	9.07	32.03	13.82	3.56	105.57	3.38	40.57	150.27
F_2M_1	12.81	40.12	18.26	4.22	117.07	4.70	56.36	208.74
F_2M_2	12.24	38.92	17.94	4.13	115.23	4.48	53.82	199.32
F_2M_3	12.04	37.89	17.05	4.09	114.86	4.35	52.22	193.42
F_3M_0	8.95	30.42	13.62	3.08	98.12	2.99	35.82	132.67
F_3M_1	12.31	35.06	17.29	4.05	112.13	3.99	47.09	177.40
F_3M_2	11.35	34.58	16.58	3.92	109.46	3.78	45.42	168.22
F_3M_3	11.02	33.56	14.94	3.80	108.25	3.63	43.59	161.46
'F' test	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.
SE (m) ±	0.19	0.48	0.35	0.07	0.75	0.06	0.69	2.56
CD at 5%	0.56	1.39	1.02	0.23	2.22	0.17	2.01	8.02

Conclusion

Based on the findings of the current experiment, it was determined that the foliar application of micronutrients to bitter gourd significantly increased its growth, yield, and quality indices. Micronutrients are essential for increasing growth, flowering, fruit set percent, and quality of fruits.

The growth parameters *viz.*, vine length, number of branches, leaf area (cm^2), number of male flowers, number of female flowers and fruit set were maximum in 125% of RDF (250:125:125 kg/ha NPK) through fertigation and foliar application of boric acid (0.1%). And the interaction effect of 125% of RDF (250:125:125 kg/ha NPK) through fertigation with foliar application of boric acid (0.1%) showed significantly minimum days required for first male flower appears, days to first female flower appears, lowest node at which first female flower appears and narrow male : female (sex) ratio.

The maximum yield was obtained in 125% of RDF (250:125:125 kg/ha NPK) through fertigation and foliar application of boric acid (0.1%). The yield-contributing characteristics included pickings, fruits per vine, average fruit weight, length and diameter, as well as yield per vine (kg), yield per plot (kg), and yield per hectare (q).

The qualitative parameter chlorophyll index was recorded maximum in treatment combination of 125% of RDF (250:125:125 kg/ha NPK) through fertigation with foliar application of $FeSO_4$ (0.5%).

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