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Influence of spacing and foliar application of boron and calcium on fruit quality of bitter gourd (*Momordica charantia*) grown under protected structures

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Bitter gourd (*Momordica charantia* L.) is an important vegetable crop of the Cucurbitaceae family. Bitter gourd is specifically used as a folk medicine for diabetes because it is designated as 'plant insulin' which has been found highly beneficial in lowering the blood and urine sugar level (Jat *et al.* 2024). Because of several medicinal properties, it is highly preferred by the consumers either in the form of culinary preparation, juice, or value-added products (Jat *et al.* 2024).

The bitter gourd crop grown under open field condition during *kharif* season produces low yield with poor quality of fruits due to the viral diseases, fruit fly, and low temperature (Maragal *et al*. 2018). The excellent quality produce could be obtained by increasing photosynthetic rate and better growth under protected environment (Jat *et al*. 2016). It also leads to the production of more fruits per unit area with superior quality which fetches higher market price.

The essential nutrients required in large quantities are supplied through soil application (Fageria *et al*. 2009) but some nutrients are required in lower quantities can be better absorbed through foliar spray (Fageria *et al*. 2009). Calcium is an important secondary macronutrient for plants but its deficiency is common in soils which may be either due to low level of calcium in the soil or low calcium availability due to high soil *p*H. Hence, a regular supply of calcium is essential for leaf development, plant canopy and vigourous root growth. Boron (B) is one of the eight essential micronutrients required for the normal growth of plants. It enhances the growth and yield of plants because it stimulates division and elongation of the cell and the development of its walls. The boron requirement of plants can be fulfilled by both foliar and soil application during growing season, especially during reproductive growth stage.

The experiment was conducted during rainy (*kharif*) seasons of 2017 and 2018 at Centre for Protected Cultivation Technology, ICAR-Indian Agricultural Research Institute (28°63′N, 77°08′E; at an elevation of 228.61 m amsl), New Delhi under insect-proof nethouse and naturally ventilated polyhouse. Two bitter gourd varieties/genotypes namely Pusa Rasdar (V_1) and Selection-32 (V_2) were grown during *kharif* (August to November) in 2017 and 2018. Three different spacings, viz. 20 cm × 50 cm (S_1), 25 cm × 50 cm (S_2) and 30 cm × 50 cm (S_3) were maintained along with 4 micronutrients levels i.e. boron @0.2% (M_1) and 0.4% (M_2) and calcium chloride @0.3% (M_3) and 0.6% (M_4). The foliar spray was done at 30 and 45 days after transplanting. The experimental design was factorial randomised complete block design with 24 treatments and 3 replications. All the female flowers were hand pollinated and fruits were harvested at marketable stage. Five plants were selected randomly in each treatment per replication for measurement of juice content (mL/500 g), DPPH (2,2-diphenyl-1-picrylhydrazyl) (mg/100 g), chlorophyll (mg/100 g), pulp content (g/100 g), vitamin C (mg/100 g) and carotenoid content (mg/100 g). The mean values of these quality parameters were subjected to statistical analysis. Data were analysed using the SAS package (9.3 SAS Institute, Inc, USA). The F values and p values ≤ 0.05 were calculated and considered as significant.

The mean data for fruit quality parameters are presented in Table 1, Fig. 1 and 2. Maximum fruit juice content (71.43 mL/500 g) was measured in variety Pusa Rasdar followed by Selection-32 (49.13 mL/500 g) under nethouse. Application of optimum dose of boron (0.2%) and the highest dose of calcium (0.6%) enhanced fruit juice content (61.80 and 60.83 mL, respectively) under nethouse, however, 46.17 mL and 46.86 mL fruit juice content was measured under polyhouse condition, respectively. The foliar spray of micronutrients enhances earliness, yield and quality parameters of bitter gourd fruits (Meenakshi *et al*. 2007, Maragal *et al*. 2018).

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Table 1 Effect of spacing and micronutrients on fruit quality traits of bitter gourd (Pooled mean of 2017–18 and 2018–19)

Treatments	Polyhouse condition						Insect proof nethouse condition					
	Juice content (mL/500 g)	DPPH (mg/100 g)	Chlorophyll (mg/100 g)	Pulp content (g/100 g)	Vitamin C (mg/100 g)	Carotenoid content (mg/100 g)	Juice content (mL/500 g)	DPPH (mg/100 g)	Chlorophyll (mg/100 g)	Pulp content (g/100 g)	Vitamin C (mg/100 g)	Carotenoid content (mg/100g)
V_1	49.56	64.07	3.28	50.44	64.14	61.34	71.43	73.02	5.34	28.57	74.78	66.83
V_2	42.33	24.98	4.58	57.67	53.00	54.65	49.13	33.50	6.39	50.87	64.45	56.56
CD (p=0.05)	0.37	0.36	0.04	0.35	0.43	0.41	0.50	0.41	0.05	0.27	0.48	0.54
SEM	0.13	0.12	0.01	0.12	0.15	0.23	0.17	0.14	0.02	0.09	0.17	0.21
S_1	44.21	40.75	3.80	55.79	59.24	30.43	57.33	52.40	5.61	42.67	70.19	32.45
S_2	45.54	45.16	3.89	54.46	58.44	33.12	59.84	53.57	5.90	40.16	70.05	34.87
S_3	48.08	47.66	4.09	51.93	58.03	34.75	63.67	53.81	6.07	36.33	68.58	36.94
CD (p=0.05)	0.46	0.42	0.04	0.43	0.52	0.34	0.61	NS	0.06	0.33	0.58	0.31
SEM	0.16	0.15	0.02	0.15	0.18	0.09	0.21	0.18	0.02	0.12	0.20	0.36
M_1	46.17	43.83	4.01	53.84	59.21	34.21	61.8	53.67	6.07	38.20	70.14	36.13
M_2	45.19	44.24	3.93	54.31	58.29	31.59	59.72	52.58	5.57	40.28	68.94	33.41
M_3	45.07	44.05	3.86	54.89	58.20	30.41	58.76	52.92	5.59	41.24	69.45	32.54
M_4	46.86	45.98	3.92	53.20	59.51	35.54	60.83	54.48	6.24	39.17	70.09	36.13
CD (p=0.05)	NS	0.49	0.05	NS	NS	NS	NS	NS	0.07	NS	NS	NS
SEM	0.19	0.17	0.02	0.17	0.21	0.16	0.25	0.20	0.03	0.13	0.24	0.21
Mean of V_1 and V_2	45.94	44.52	3.93	54.05	58.57	57.99	60.28	53.26	5.865	39.72	69.61	61.69

NS, Non-significant. Refer to methodology for treatment details.

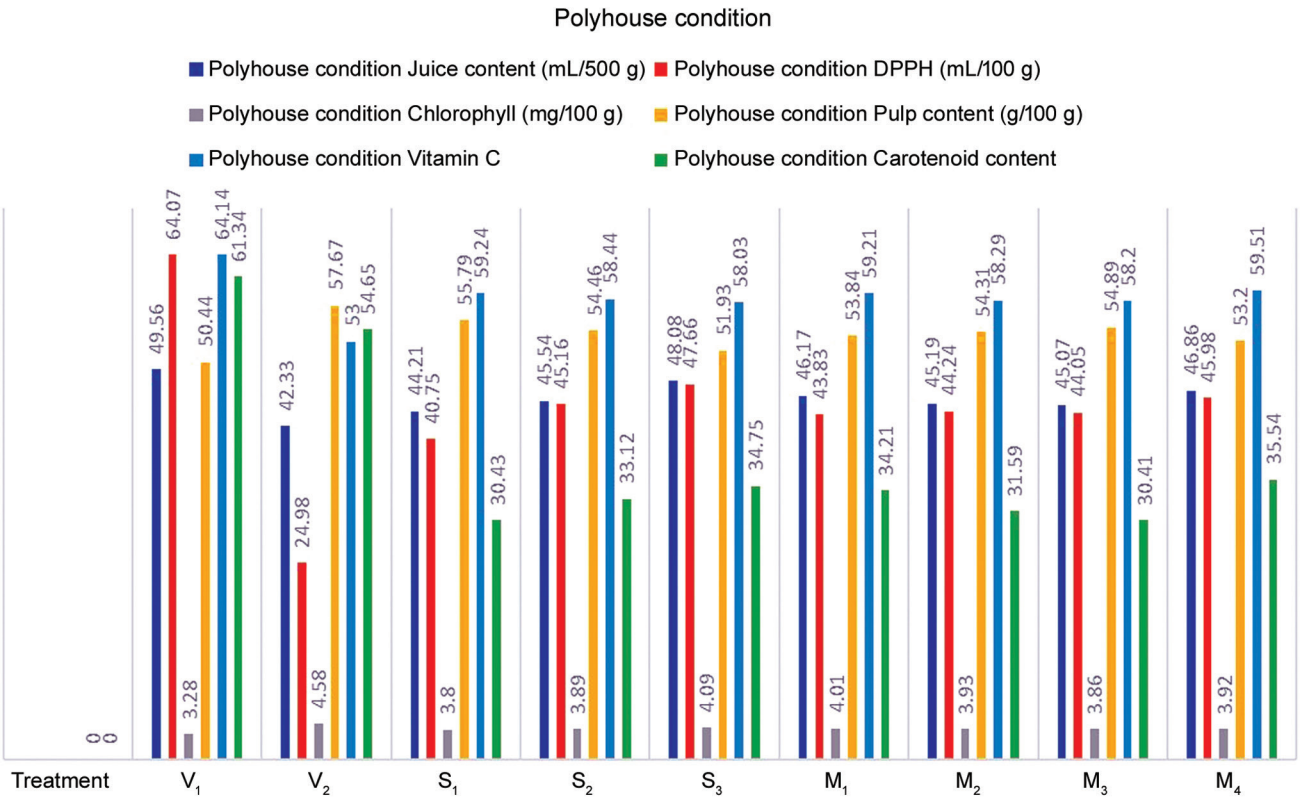

Fig. 1 Effect of different treatment combinations on fruit quality traits in polyhouse grown bitter gourd crop. Refer to methodology for treatment details.

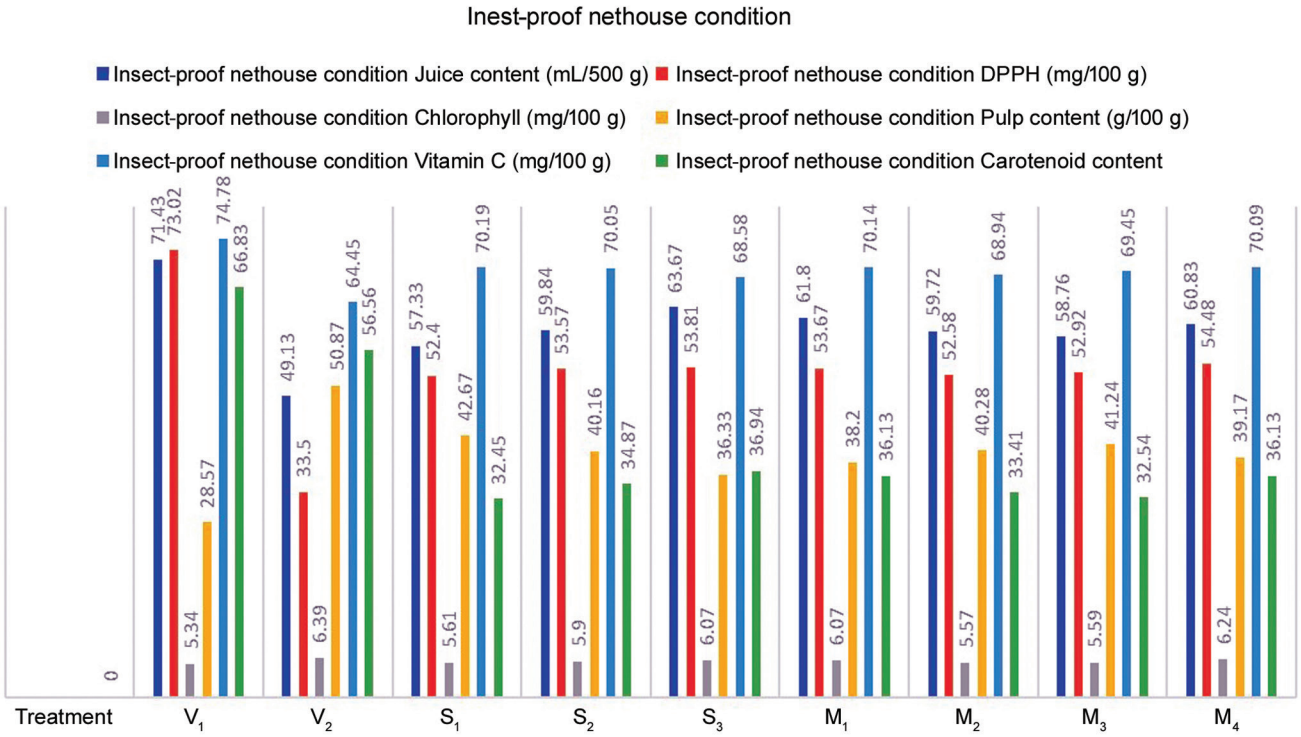

Fig. 2 Effect of different treatment combinations on fruit quality traits in insect-proof nethouse grown bitter gourd crop. Refer to methodology for treatment details.

Among the three different spacing, wider spacing (30 cm × 50 cm) increased fruit juice content (63.67 mL) followed by 25 cm × 50 cm spacing (59.84 mL) under nethouse condition. In polyhouse condition, fruit juice content (48.08 mL) was highest at the wider spacing and 45.54 mL at the closer spacing, respectively.

The highest DPPH content (73.02 mg) was recorded in Pusa Rasdar, whereas Selection-32 recorded 33.50 g under nethouse. Application of boron @0.2% and calcium @0.6% increased DPPH content (53.67 and 54.48 mg/100 g, respectively), under nethouse. Similar quantity of boron (0.2%) and calcium (0.6%) showed a significant effect on DPPH content (44.24 and 45.98 mg, respectively) under polyhouse. The foliar spray of mixture of different micro-nutrients in combination with fertigation enhanced quality parameters of bitter gourd (Meenakshi *et al*. 2007). Application of recommended dose of fertilisers and foliar spray of calcium and boron might have increased the DPPH content in bitter gourd fruits. The wider spacing (30 cm × 50 cm) increased DPPH content (53.81 and 47.66 mg) followed by 25 cm × 50 cm spacing, resulting in 53.57 and 45.16 mg DPPH under nethouse and polyhouse conditions, respectively.

The maximum chlorophyll content (6.39 and 5.34 mg) was observed under nethouse in Selection-32 and Pusa Rasdar, respectively, whereas it was slightly lower under polyhouse (4.58 and 3.28 mg) in Selection-32 and Pusa Rasdar, respectively. Application of boron @0.2% and calcium @0.6% increasesd chlorophyll content (6.07 and 6.24 mg) under nethouse condition, whereas low chlorophyll content (4.01 and 3.92 mg) was observed under polyhouse condition, respectively. The wider spacing of 30 × 50 cm increased the chlorophyll content (6.07 and 4.09 mg) followed by 25 cm × 50 cm spacing (5.90 and 3.89 mg) under nethouse and polyhouse condition, respectively.

The maximum fruit pulp content (57.67 g) was measured in Selection-32 whereas 50.44 g fruit pulp content in Pusa Rasdar under polyhouse condition. The application of higher dose of boron (0.4%) and the lower dose of calcium (0.3%) had enhanced fruits pulp content (54.31 and 54.89 g) under polyhouse condition. However, fruits pulp content was 40.28 and 41.24 g recorded under nethouse condition, respectively. The yield traits were increased with the increase in micronutrient concentration in bitter gourd cv. Pusa Rasdar under polyhouse condition (Maragal *et al*. 2018). Among the three different spacings, closer spacing of 20 cm × 50 cm resulted in increased fruit pulp content (55.79 and 42.67 g) followed by 25 cm × 50 cm spacing (54.46 and 40.16 g) under polyhouse and nethouse conditions, respectively. The superior performance of growth, flowering, fruit traits and quality parameters were recorded in bitter gourd (Jat 2011, Jat *et al*. 2016, Jat *et al*. 2024).

The higher vitamin C content was recorded in Pusa Rasdar (74.78 mg) followed by Selection-32 (64.45 mg) under nethouse, however, it was 64.45 and 53.00 mg under polyhouse condition in Pusa Rasdar and Selection-32, respectively. The vitamin C content increased under both nethouse (70.14 and 70.09 mg) and polyhouse (59.21 and 59.51 mg) with the application of boron @0.2% and calcium @0.6%, respectively. The effects of micronutrients were non-significant on vitamin C content under both growing conditions. The application of recommended dose of fertilisers in combination with micronutrients recorded the highest value for vitamin C content in bitter gourd (Meenakshi *et al*. 2007). The foliar application of boron @0.3% at 35 and 45 days after sowing recorded significantly maximum values for ascorbic acid, total soluble solids, and iron content in bitter gourd (Karthick *et al*. 2018) and foliar spray of boron @0.25% after 30 and 45 days after sowing also significantly influence the ascorbic acid content in bitter gourd (Bharati *et al*. 2018). In present study, the enhanced vitamin C content might be due to appropriate management practices and higher synthesis of carbohydrates at higher boron level. The vitamin C content (70.19 and 59.24 mg) was increased at closer spacing (20 cm × 50 cm) followed by 25 cm × 50 cm spacing (70.05 and 58.44 mg vitamin C) under nethouse and polyhouse condition, respectively. The increase in vitamin C content in fruits of bitter gourd at closer spacing may be due to the maximum weight of fruits and fruit yield at closer spacing under protected cultivation.

The maximum carotenoid content (66.83 and 63.10 mg) was recorded in variety Pusa Rasdar, whereas 5.90 and 5.27 mg were measured in Selection-32 under nethouse and polyhouse condition, respectively. The application of boron @0.2% and calcium @0.6% increased carotenoid content (36.13 and 36.96 mg) under nethouse condition whereas it was 33.89 and 35.30 mg under polyhouse condition, respectively. The wider spacing (30 cm × 50 cm) increased carotenoid content (36.94 and 34.75 mg) followed by 25 cm × 50 cm spacing (36.16 and 33.94 mg) under nethouse and polyhouse conditions, respectively. The quality parameters were significantly increased with the application of boron in bitter gourd (Sultana *et al*. 2017, Bharati *et al*. 2018).

SUMMARY

The experiment was conducted to examine the effect of spacing and foliar application of boron and calcium on fruit quality of bitter gourd grown in nethouse and polyhouse. The variety Pusa Rasdar was found superior for fruit juice (71.43 ml/500 g), DPPH (73.02 mg), chlorophyll (5.34 mg), vitamin C (74.78 mg) and carotenoid content (66.83 mg) per 100 g of fresh fruit weight under nethouse. Most of the quality traits were superior under nethouse grown crop except fruits pulp content. Application of boron @0.2% and calcium @0.6% in combination enhanced fruit juice content (61.80 and 60.83 mL/500 g), DPPH (53.67 and 54.48 mg/100 g), chlorophyll (6.07 and 6.24 mg/100 g), vitamin C (70.14 and 70.09 mg/100 g) and carotenoids (36.13 and 36.96 mg/100 g) under nethouse condition, respectively. High dose of boron (0.4%) and low dose of calcium (0.3%) enhanced fruit pulp content (54.31 and 54.89 g/100 g), respectively, under polyhouse condition. Among the three different spacing, wider spacing (30 cm × 50 cm) increased fruit juice content, DPPH, chlorophyll and carotenoids under nethouse and polyhouse conditions. Closer spacing (20 cm × 50 cm) increased fruit pulp and vitamin C under nethouse and polyhouse conditions. Therefore, growing of bitter gourd crop particularly cv. Pusa Rasdar and Selection-32 under polyhouse and nethouse condition is a

cost effective and sustainable strategy to fetch higher price in the market.

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