Research Article

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Enhancing performance and profitability of bottle gourd (*Lagenaria siceraria*) through growing methods and bio-regulators in semi-arid region

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ABSTRACT

The study revealed the different treatment combination of growing methods (vertical and horizontal) and foliar application of bio-regulators (control, NAA at 200 ppm, GA_3 at 150 ppm, ethrel at 200 ppm, and salicylic acid at 150 ppm) in bottle gourd significantly influenced the yield, quality and profitability of bottle gourd in semi-arid conditions. The results indicated that the vertical trailing system registered significantly higher vine length (70.12 cm), number of nodes (25.86), number of leaves (24.73), leaf area (518.18 cm^2), fruit length (17.70 cm), number of fruits/ vine (4.08), fruit weight (0.78 kg), fruit yield/ vine (3.19 kg), TSS (3.96 %), total sugar (3.07 g/100 g), crude protein (0.51%) and Ascorbic acid (11.72 mg/100g). Similarly, foliar application of GA_3 at 50 ppm registered maximum vine length (67.83 cm), number of nodes (25.76), number of leaves (24.30), leaf area (523.14 cm^2), fruit length (17.92 cm), number of fruits/ vine (4.13), fruit weight (0.77 kg), fruit yield/ vine (3.16 kg), TSS (3.91%), total sugar (3.08 g/100 g), crude protein (0.52 %) and Ascorbic acid (11.44 mg/100g) and greater net returns as compared to control.

Introduction

Bottle gourd [*Lagenaria siceraria* (Mol.) Stand L.] is a commonly grown and used vegetable in India. It belongs to the family Cucurbitaceae. Besides being an important vegetable crop, it also has good medicinal as well as nutritional value. The fruits are also used as a vegetable or for making sweets (*halwa, kheer, petha, barfi*, and pickles). It is economically found growing in Ethiopia, Africa, and Central America. In India, bottle gourd is grown on an area of 200,000 hectares with an annual production of 3274,000 metric tonnes (Anonymous, 2023). It occupies 5200 hectares of land in Rajasthan, producing 26982 metric tonnes (Anonymous, 2023).

The traditional method of planting bottle gourd tends to restrict light penetration to lower leaves and thus reduce the photosynthetic efficiency. The dense vine canopy also hampers proper air circulation and enhances high humidity, which can promote the occurrence and spread of diseases. As vining plant, bottle gourd grows best with support, which keeps them off the ground and encourages straight fruit growth. Since trailing allows vertical growth instead of sprawling all over the plot, it not only keeps the produce off the ground, but it also allows for the growth of more plants

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in a smaller area.

The yield of cucurbit depends to a great extent on sex expression and sex ratio. Early nodes bear male flowers and higher amounts, whereas hermaphrodites and pistillate flowers are found in later nodes. These results in delaying harvesting as well as yield reduction. The problem can be overcome by the exogenous application of plant growth regulators as well as bio-regulators. The host of physiological processes involved in crop development, such as blooming and fruiting, are controlled by plant growth regulators. Additionally, they are employed in the germination, inhibition of growth and post-harvest ripening of assimilates. Bio-regulators are employed in very tiny amounts to control plant development. They also govern the development of the shoot and the root. Bio-regulators directly affect male and female flower ratio, fruit set, fruit drop, and ultimately yield (Bose *et al.,* 1999). Therefore, the use of bio-regulators like NAA, ethrel, and GA_3 in bottle gourd may become an important tool for yield enhancement as well as timely harvest. Thus, the study was undertaken to investigate the effect of vertical trailing system and bio-regulators on yield and quality of bottle gourd.

Material and Methods

The field experiment was conducted during the *summer* seasons of 2022 and 2023 on bottle gourd cv. Pusa Santushti at the Horticulture Farm, Rajasthan Agricultural Research Institute, Jaipur, Rajasthan, India. The experimental site is situated at 26.50° North latitude and 75.47° East longitude at an altitude of 390 meters above mean sea level. In Rajasthan, this region falls under agro-climatic zone-IIIA (Semi-Arid Eastern Plains). The region has a typically semi-arid climate characterized by dry atmosphere.

The experiment consisted of 10 treatment combinations with two growing methods and five levels of bio-regulators in a factorial randomized block design with three replications. In growing method, vertical trailing system (G_1) and horizontal/ traditional system (G_2) were used to raise the crop. The five levels of bio-regulators viz., control (B_1), NAA at 200 ppm (B_2), GA_3 at 50 ppm (B_3), ethrel at 200 ppm (B_4), and salicylic acid at 150 ppm (B_5) were applied as a foliar spray at 2-true leaf stage. Appropriate standard and uniform agronomical and cultural practices and plant protection measures were adopted for raising a healthy crop. The observations on growth and yield parameters were recorded during the investigation on five plants, which were randomly selected from each treatment.

Total soluble solids (TSS) per cent of randomly selected fruits was determined with the help of a digital refractometer at the time of harvesting fruits. The total sugar content, protein content, and ascorbic acid content of the fruit were determined following the procedures outlined by A.O.A.C. (1980).

In calculating the benefit:cost, only fruit yield has been considered as the product. The total cost of cultivation and gross income were estimated on the basis of the average fruit yield per hectare for each treatment. The cost of cultivation included money spent on preparatory tillage, seed costs, plant growth regulators (NAA, GA_3, ethrel, and salicylic acid), manures and fertilizers, irrigation, weeding, interculture operations, plant protection, harvesting, and various labour charges, etc. The gross income was estimated by calculating returns from the sale of fruits. The net income was calculated by deducting the total cost of cultivation from the gross income.

Results and Discussion

The growing method and foliar spray of bio-regulators had a significant impact on the growth parameters of bottle gourd (Table 1). The vertical trailing system registered higher vine length (70.12 cm), number of nodes (25.86), number of leaves (24.73), leaf area (518.18 cm^2) and number of secondary branches (4.04) at 45 DAS over the traditional method of growing. However, it did not affect the number of primary branches, which remained consistent at 5.34, showing no significant difference. The trailing system provided better scope for plants to exploit sunlight, which resulted in higher photosynthetic activity, assimilation of carbohydrates and increased plant growth. The results corroborate the findings of Kalyanrao *et al.* (2012), Sharma *et al.* (2016) and Singh *et al.* (2023) in bottle gourd.

The results clearly demonstrate that foliar application of GA_3 at 50 ppm significantly increased the vine length (67.83 cm), number of nodes (25.76), number of leaves (24.30), leaf area (523.14 cm^2) and number of primary branches (5.52) as compared to other treatments in pooled analysis. However, the number of secondary branches were recorded higher with the foliar application of ethrel at 200 ppm, followed by GA_3 at 50 ppm. The results are in agreement with Soni *et al.* (2015) and Ansari and Chowdhary (2018).

The pooled data on yield and yield-attributing characters presented in Table 2 indicate a significant difference in the effect of growing methods and bio-regulators on bottle gourd. It indicated that significantly higher fruit length (17.70 cm), number of fruits/ vine (4.08), average fruit weight (0.78 kg), fruit yield/ vine (3.19 kg) and marketable fruit yield/ ha (255.06 q) were recorded with the trailing method as compared to the traditional method. The better fruit length in trailing may be due to the gravitational force and the better fruit weight may result from the translocation of more dry matter from the source to these components, which have significant growth characteristics. These results are in conformation with the results of Kalyanrao *et al.* (2012) in bottle gourd, Ahmed *et al.* (2021) in ridge gourd, and Khan *et al.* (2021) in bitter gourd.

Table 1. Effect of growing methods and bio-regulators on growth parameters of bottle gourd

Treatments	Vine length (cm) (45 DAS)			No. of nodes			No. of leaves			Leaf area (cm^2)			No. of primary branches			No. of secondary branches		
	2021-22	2022-23	Pooled	2021-22	2022-23	Pooled	2021-22	2022-23	Pooled	2021-22	2022-23	Pooled	2021-22	2022-23	Pooled	2021-22	2022-23	Pooled
(A.) Growing methods																		
Trailing method (G_1)	70.25	70	70.12	25.71	26.02	25.86	24.66	24.80	24.73	513.60	522.77	518.18	5.25	5.43	5.34	4.07	4.02	4.04
Traditional method (G_2)	57.78	59.46	58.62	23.00	23.15	23.07	21.73	22.29	22.01	467.44	477.59	472.51	5.03	5.19	5.11	3.66	3.95	3.81
SEm±	1.06	1.01	0.73	0.37	0.38	0.26	0.33	0.51	0.30	6.93	7.81	5.22	0.07	0.08	0.05	0.05	0.06	0.04
CD (P=0.05)	3.14	2.99	2.09	1.09	1.12	0.76	0.99	1.51	0.87	20.60	23.22	14.98	NS	NS	NS	0.16	0.17	0.11
(B.) Bio-regulators																		
Control (water spray) B_1	57.65	58.44	58.05	22.15	22.69	22.42	20.92	21.12	21.02	442.14	453.48	447.81	4.61	4.75	4.68	3.43	3.55	3.49
NAA @ 200 ppm (B_2)	66.76	67.19	66.98	25.26	25.35	25.31	23.81	24.21	24.01	512.42	515.62	514.02	5.32	5.49	5.41	3.98	4.16	4.07
GA_3 @ 50 ppm (B_3)	67.56	68.1	67.83	25.69	25.82	25.76	24.10	24.49	24.30	516.81	529.46	523.14	5.42	5.61	5.52	4.10	4.18	4.14
Ethrel @ 200 ppm (B_4)	67.1	67.82	67.46	25.46	25.51	25.49	23.92	24.35	24.14	515.69	523.85	519.77	5.39	5.56	5.48	4.12	4.21	4.17
Salicylic acid @ 150 ppm (B_5)	61.01	62.1	61.56	23.20	23.54	23.37	22.23	22.54	22.39	465.52	478.49	472.01	4.96	5.12	5.04	3.69	3.82	3.76
SEm±	1.67	1.59	1.15	0.58	0.60	0.42	0.52	0.80	0.48	10.96	12.36	8.26	0.12	0.12	0.08	0.08	0.09	0.06
CD (P=0.05)	4.97	4.73	3.31	1.72	1.78	1.19	1.56	2.38	1.37	32.57	36.71	23.69	0.34	0.36	0.24	0.25	0.26	0.18

Table 2. Effect of growing methods and bio-regulators on yield attributes and yield of bottle gourd

Treatments	Fruit length (cm)			No. of fruits/ vine			Fruit weight (kg)			Fruit yield/ vine (kg)			Fruit yield (q/ ha)		
	2021-22	2022-23	Pooled	2021-22	2022-23	Pooled	2021-22	2022-23	Pooled	2021-22	2022-23	Pooled	2021-22	2022-23	Pooled
Growing methods															
Trailing method (G_1)	17.62	17.78	17.70	4.06	4.11	4.08	0.77	0.79	0.78	3.12	3.26	3.19	249.39	260.73	255.06
Traditional method (G_2)	16.93	17.06	17.00	3.98	4.03	4.01	0.68	0.69	0.68	2.69	2.76	2.73	214.95	221.19	218.07
SEm±	0.19	0.2	0.14	0.02	0.02	0.02	0.01	0.01	0.01	0.04	0.05	0.03	3.25	3.42	2.38
CD (P=0.05)	0.57	0.58	0.39	0.06	0.07	0.04	0.02	0.03	0.02	0.11	0.16	0.09	9.67	10.17	6.83
(B.) Bio-regulators															
Control (water spray) B_1	16.25	16.42	16.34	3.88	3.93	3.91	0.68	0.69	0.68	2.62	2.69	2.65	209.32	215.21	212.26
NAA @ 200 ppm (B_2)	17.45	17.64	17.55	4.05	4.10	4.08	0.73	0.75	0.74	2.94	3.06	3.00	235.14	244.63	239.89
GA_3 @ 50 ppm (B_3)	17.88	17.96	17.92	4.1	4.15	4.13	0.76	0.78	0.77	3.10	3.22	3.16	247.95	257.6	252.78
Ethrel @ 200 ppm (B_4)	17.65	17.72	17.69	4.08	4.13	4.11	0.73	0.76	0.74	2.96	3.12	3.04	237.02	249.78	243.4
Salicylic acid @ 150 ppm (B_5)	17.16	17.35	17.26	3.99	4.04	4.02	0.73	0.74	0.73	2.89	2.97	2.93	231.44	237.57	234.5
SEm±	0.3	0.31	0.22	0.03	0.04	0.02	0.01	0.02	0.01	0.06	0.08	0.05	5.15	5.41	3.76
CD (P=0.05)	0.9	0.92	0.62	0.1	0.11	0.07	0.04	0.05	0.03	0.17	0.25	0.15	15.29	16.09	10.79

Table 3. Effect of growing methods and bio-regulators on quality parameters of bottle gourd

Treatments	TSS content (%)			Total sugar content (g/100g)			Crude protein (%)			Ascorbic acid (mg/100g)		
	2022	2023	Pooled	2022	2023	Pooled	2022	2023	Pooled	2022	2023	Pooled
(A.) Growing methods												
Trailing method (G_1)	3.95	3.98	3.96	3.08	3.06	3.07	0.5	0.52	0.51	11.7	11.73	11.72
Traditional method (G_2)	3.44	3.46	3.45	2.67	2.79	2.73	0.44	0.47	0.46	10.05	10.18	10.11
SEm±	0.05	0.04	0.03	0.02	0.03	0.02	0	0.01	0.00	0.12	0.12	0.09
CD (P=0.05)	0.16	0.11	0.09	0.07	0.08	0.05	0.01	0.02	0.01	0.37	0.37	0.25
(B.) Bio-regulators												

Control (water spray) B_1	3.32	3.34	3.33	2.57	2.61	2.59	0.43	0.46	0.45	9.82	9.88	9.85
NAA @ 200 ppm (B_2)	3.84	3.81	3.83	2.95	3.01	2.98	0.48	0.5	0.49	11.26	11.36	11.31
GA_3 @ 50 ppm (B_3)	3.88	3.94	3.91	3.05	3.1	3.08	0.51	0.52	0.52	11.41	11.46	11.44
Ethrel @ 200 ppm (B_4)	3.86	3.88	3.87	2.99	3.05	3.02	0.49	0.51	0.51	11.35	11.42	11.39
Salicylic acid @ 150 ppm (B_5)	3.58	3.61	3.60	2.82	2.85	2.84	0.45	0.48	0.47	10.54	10.65	10.60
SEm±	0.08	0.06	0.05	0.04	0.04	0.03	0.01	0.01	0.01	0.20	0.20	0.14
CD (P=0.05)	0.25	0.17	0.15	0.12	0.13	0.08	0.02	0.03	0.02	0.59	0.58	0.40

Table 4. Effect of growing methods and bio regulators on economics of bottle gourd

Treatments	Season	Common cost (₹/ ha)	Treatment cost (₹/ ha)	Total cost (₹/ ha)	Yield (q/ ha)	Gross return (₹/ ha)	Net returns (₹/ ha)	B:C ratio
G_1B_1	2022	81568	24800	106368	188.00	206928	100560	1.95
	2023	81568	24800	106368	196.63	235953	129585	2.22
G_1B_2	2022	81568	25008	106576	262.00	287993	181417	2.70
	2023	81568	25008	106576	277.92	333506	226930	3.13
G_1B_3	2022	81568	26000	107568	282.00	309770	202202	2.88
	2023	81568	26000	107568	294.71	353648	246080	3.29
G_1B_4	2022	81568	25248	106816	277.00	304632	197816	2.85
	2023	81568	25248	106816	289.95	347945	241129	3.26
G_1B_5	2022	81568	24998	106566	235.00	258900	152334	2.43
	2023	81568	24998	106566	241.25	289503	182937	2.72
G_2B_1	2022	81568	0	81568	224.00	246740	165172	3.02
	2023	81568	0.00	81568	227.51	273014	191446	3.35
G_2B_2	2022	81568	208	81776	208.00	229326	147550	2.80
	2023	81568	208	81776	211.34	253610	171834	3.10
G_2B_3	2022	81568	1200	82768	214.00	235729	152961	2.85
	2023	81568	1200	82768	220.50	264601	181833	3.20
G_2B_4	2022	81568	448	82016	197.00	216808	134792	2.64
	2023	81568	448	82016	209.61	251535	169519	3.07
G_2B_5	2022	81568	198	81766	218.00	239832	158066	2.93
	2023	81568	198	81766	224.27	269121	187355	3.29

Bottle gourd sold @ ₹ 11/- per kg

The yield and yield attributes were significantly enhanced by the foliar application of GA_3 at 50 ppm. The maximum fruit length (17.92 cm), number of fruits/ vine (4.13), average fruit weight (0.77 kg), fruit yield/ vine (3.16 kg), and fruit yield/ ha (252.78 q) were recorded with the application of GA_3 at 50 ppm over other treatments in pooled data. The results obtained are in agreement with Hidayatullah *et al.* (2012), Wamiq *et al.* (2020) and Rapha (2022) in bottle gourd.

It is evident from Table 3 that the growing methods and bio-regulators also had a significant effect on the quality parameters of bottle gourd. The combined data on quality measures maximum TSS (3.96%), total sugar (3.07 g/100 g), crude protein (0.51 %) and ascorbic acid (11.72 mg/100g) content showed a considerable improvement in the trailing method compared to the traditional bottle gourd-growing method (Table 3). These results are in agreement with Kartika and Karyana (2017) in Sphagetti squash and Rajalingam *et al.* (2017) in cucumber.

Among the bioregulators the highest values of the TSS (3.91%), total sugars (3.08 g/100 g), crude protein (0.52%) and ascorbic acid content (11.44 mg/100 g) in pooled analysis of bottle gourd fruit tissues were gained by foliar spray of GA_3 as compared to other treatments and control. The findings corroborate the results obtained by Shafeek *et al*. (2016) in summer squash, Kadi *et al*. (2018) in cucumber, Anayat *et al.* (2020) in bitter gourd and Pandey *et al.* (2021) in cucumber.

The data presented in Table 4 clearly indicates that the net returns and B:C ratio of bottle gourd were significantly impacted by the growing methods and bioregulators. In a pooled analysis, the maximum and significantly higher net returns (₹ 186824 per ha) were recorded using the trailing way of growing as opposed to the traditional method. With the exception of ethrel at 200 ppm, which was deemed to be at par in the pooled analysis, the application of GA_3 at 50 ppm obtained the largest and noticeably greater net returns (₹ 195919 per ha) over control.

In a pooled examination, bottle gourd grown using the traditional approach had a maximum and noticeably better B:C ratio (3.06) than those grown using the trailing method. The foliar spraying of GA_3 at 50 ppm considerably boosted the B:C ratio. During the testing, it registered the highest and noticeably better bottle gourd B:C ratio (3.06) than control in pooled analysis. Nonetheless, in the pooled analysis, the foliar application of NAA at 200 ppm, ethrel at 200 ppm and salicylic acid at 150 ppm remained comparable to one another.

Conclusion

In conclusion, the bottle gourd cultivar 'Pusa Santusthi', when grown using the trailing method (vertical system) and sprayed at 2-true leaf stage with a 50 ppm foliar spray of GA_3, produced a significantly higher marketable fruit yield and superior quality fruits, resulting in maximum net returns under semi-arid conditions.

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Conflict of Interest

The authors have no conflict of interest.

Data Sharing

All relevant data are within the manuscript.

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