Use of GA_3 and Boron to Improve Physico-chemical Quality of Dragon Fruit [*Hylocereus costaricensis* (Web.) Britton and Rose]

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ABSTRACT

Dragon fruit (*Hylocereus spp.*) is a perennial climbing cactus (2n=22), belongs to the family Cactaceae. However, one of its species *Hylocereus costaricensis* exhibiting excellent nutritional quality and attractive pulp colour with pleasant taste is having minimum fruit weight compared to other dragon fruit species. Fruit quality plays a major role for its overall acceptability. The present investigation was planned to investigate the effect of fruit treatment of GA_3 and Boron on physico-chemical quality improvement of dragon fruit [*Hylocereus costaricensis* (Web.) Britton and Rose] grown under Lucknow sub-tropical climatic condition. There were 9 treatments (T_1- Control, T_2 -GA_3@60 ppm, T_3-GA_3@80 ppm, T_4-Boron@100 ppm, T_5-Boron@120 ppm, T_6-GA_3@60 ppm + Boron@100 ppm, T_7- GA_3@ 60 ppm+ Boron@ 120 ppm, T_8- GA_3@ 80 ppm +Boron@ 100 ppm and T_9-GA_3@ 80 ppm + Boron @ 120 ppm) with three replications laid out following Randomized Block Design. There were 4 plants per pole and poles were planted at 4m x 2m spacing. Findings of the present investigation revealed that both GA_3 and Boron had positive effect on physico- chemical quality improvement of dragon fruit. It may be suggested for combined foliar application of GA_3 @ 80 ppm + Boron @ 120 ppm thrice at 5, 15 and 25 days after anthesis which improved the chemical qualities of red fleshed dragon fruit.

Keywords: Dragon fruit, Fruit quality, GA_3, Boron

Introduction

Dragon fruit is one of the newly introduced exotic fruit crops in India. It is commonly called as *Pitaya*, *Strawberry pear*, *Night blooming cereus*, *Queen of night*, *Honorable queen, Jesus in the cradle and Belle of the night* (Martin *et al.*, 1987; Maji, 2019). The origin of Dragon fruit is tropical and subtropical forest regions of Mexico and Central South America (mo and Nerd, 1996). There are four popular species of dragon fruit: 1) *Hylocereus undatus* (Haworth) Britton and Rose having red-coloured rind with white flesh; 2) *H. polyrhizus* (F. A. C. Weber) Britton and Rose has red-coloured rind with red flesh; 3) *H. costaricensis* (Web.) Britton and Rose red-

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coloured rind with purple red flesh and 4) *Selinecereus megalanthus* having yellow-coloured rind with white flesh (Mirzahi and Nerd, 1999).

Purple Red Fleshed dragon fruit [*Hylocereus costaricensis* (Web.) Britton and Rose], renowned for its striking appearance and nutritional value, has emerged as a lucrative crop in tropical and subtropical regions worldwide. It is characterised by vigorous vines, perhaps the stoutest of this genus. Despite its growing popularity, challenges persist in optimizing fruit yield and quality in comparison to other dragon fruit species, prompting investigations into novel approaches to cultivation enhancement. However, fruit size and some quality parameters are inferior to other species and need improvement for consumer attraction. Among the various approaches, plant hormones and micronutrients, such as Gibberellic acid (GA_3) and Boron (B), have garnered attention for their pivotal roles in regulating fruit development across various crop species. Application of exogenous GA_3 has been shown to enhance fruit size, promote parthenocarpy, and improve fruit quality in several fruit crops (Smith, 2018; Garcia, 2020). Similarly, Boron (B), an essential micronutrient, plays pivotal roles in various physiological processes crucial for plant growth and development such as influencing pollen germination, fruit set, and seed development (Khan, 2017; Rodriguez, 2019). Therefore, the present investigation was conducted with objective to elucidate the synergistic or antagonistic interactions of GA_3 and boron on fruit development and their implications for dragon fruit production.

Materials and Methods

The investigation was conducted at dragon fruit orchard Department of Horticulture, Babasaheb Bhimrao Ambedkar University, Lucknow, U.P, India (26°55′ N latitude, 80°54′ E longitude and 123 metres above mean sea level) during 2023-2024 in the subtropical climate of central Uttar Pradesh. The distinct climate which includes cool winters and sweltering summer is influenced by the presence of dry, continental- type air throughout most of the year. During winter the average temperature goes down low to 2°C, while in summer high temperature often reaches 45°C. A total of 700 mm of precipitation falls in the area each year, with majority of occurring between June and September. During the winter, the north-east monsoon also occasionally brings rain. There were 9 treatments (T_1 - Control, T_2- GA_3@60 ppm, T_3-GA_3@80 ppm, T_4- Boron@100 ppm, T_5-Boron@120 ppm, T_6-GA_3@60 ppm + Boron@100 ppm, T_7-GA_3@ 60 ppm+ Boron@ 120 ppm, T_8-GA_3@ 80 ppm +Boron@ 100 ppm, T_9-GA_3@ 80 ppm + Boron @ 120 ppm) with three replications laid out following Randomized Block Design. There were 4 plants per pole and poles were planted at 4m x 2m spacing and age of plants was about 5 years.

For preparing a solution of GA_3 and Boron of desired concentration as per the treatment firstly stock solution (10X) of both chemicals was prepared. For GA_3 the highest concentration to be sprayed was 80 ppm hence the stock solution prepared for this was 10x *i.e.* 800 ppm (800 mg in 1 Liter distilled water). From this prepared stock solution required concentration of GA_3 (60 ppm or 80 ppm) and Boron stock solution of 1200 ppm was taken by applying formula $V_1S_1=V_2S_2$.The treatment solution was applied 3 times at an interval of 5, 15 and 25 days after anthesis (DAA). Observations for fruit physical parameters such as fruit weight, fruit length (both longitudinal and transverse), pulp weight, peel weight, pulp %, peel %, scale count, scale length, fruit volume, specific gravity, pulp thickness, peel thickness, scale width, number of seed and chemical parameters such as total soluble solids (T.S.S), ascorbic acid, titratable acidity, reducing sugar, non reducing sugar and total sugar were recorded following standard methods (Thimmaiah, 2009).

To test the significance of variance in the data obtained from the various physicochemical characters, the technique of analysis of variance was adopted as suggested by Fisher (1950) for Randomized Block Design (RBD). Significance of difference in the treatment effect was tested through 'F' test at 5% level of significance and critical difference (CD) was calculated to compare the mean effects of treatments.

Results and Discussion

Effect on fruit morphological characters (fruit weight, fruit length, fruit diameter, volume and specific gravity) of purple red fleshed dragon fruit

Maximum fruit weight (210.00 g) was recorded from the plants which were treated with GA_3 @ 60 ppm (T_2) (Table 1). It was followed by T_6 (190.67g), T_9 (190.33g), T_3 (190.00g) which were statistically *at par*. Results are analogous with the earlier findings of Nor *et al.* (2014) who observed that dragon fruit (*Hylocereus polyrhizus*) treated with 50 ppm of GA_3 produced the best quality fruits in comparison to control in terms of fruit weight.

Fruit length as shown in Table 1 was also significantly influenced by the application of both GA_3 and boron. The maximum fruit length (93.4 mm) was recorded from the treatment T_2, followed by T_8 (91.6 mm), T_5 (88.3 mm) and T_6 (86.9 mm). The minimum fruit length (69.3 mm) was recorded from Boron@100 ppm (T_4). Similar results have been obtained by Hossain (2012) in strawberry plant when treated with GA_3 @ 75 ppm.

Similarly, fruit diameter was significantly influenced by the application of both GA_3 and boron. The maximum fruit diameter (70.97 mm) was recorded in treatment T_9 followed by T_2, T_7 and T_3. The minimum fruit diameter was recorded from the control plants (T_1). Results of fruit diameter are in line with the finding of Hossain (2012) in strawberry plant treated with GA_3 @ 75 ppm and Lal and Ahmed (2012) in pomegranate cv. G-137 with application of GA_3 @ 80 ppm.

Result of fruit volume showed a significant influence by the application of both GA_3 and boron. The maximum fruit volume (201.00 ml) was recorded from the treatment (T_2). It was followed by T_4 (196.00 ml), T_6 (189.33 ml) and T_7 (185.33ml). But statistical analysis showed that there was no significant difference between T_2 (201 ml) and T_4 (196 ml), so they were statistically *at par*. While, treatment T_6 (189.33 ml) and T_7 (185.33 ml) were also statistically *at par*. The minimum fruit volume (104 ml) was recorded from the control plants (T_1). Garasiya *et al.* (2013) obtained similar results in winter-season guava cv. L-49 with application of GA_3 @ 50 ppm.

The maximum specific gravity (1.30 g/cc) was recorded from the plants which were treated with GA_3 80 ppm + Boron 120 ppm (T_9). It was followed by T_8 (1.13 g/cc), T_1 (1.10 g/cc), T_3 (1.07 g/cc) and T_5 (1.07 g/cc).

Effect on peel and pulp characters (peel thickness, peel weight, peel content, pulp thickness, pulp weight, pulp content and pulp: peel ratio) of purple red fleshed dragon fruit

The maximum peel thickness (4.95 mm) was recorded from the treatment GA_3 60 ppm + boron 100 ppm (T_6). It was followed by T_1 (4.93 mm), T_2 (4.71 mm) and T_5 (4.20 mm). But statistical analysis showed that there was no significant difference between T_6 (4.95 mm) and T_1 (4.93 mm), T_2 (4.71 mm), T_5 (4.20 mm) so they were statistically *at par*. The minimum peel thickness (3.40 mm) was recorded from treatment T_3.

Fruit peel weight was significantly influenced by the application of both GA_3 and boron. The maximum fruit peel weight (82.00 g) was recorded from the treatment T_6 followed by T_2 (81.33 g), T_5 (73.00g) and T_9 (73.00 g). However, T_6 (82.00 g) was statistically *at par* with T_2 (81.33 g) and there was no statistical difference between T_5 (73.00 g) and T_9 (73.00 g). The minimum fruit weight (40.33 g) was recorded from the control plants (T_1).

Percentage of peel content of the dragon fruit was significantly influenced by the application of both GA_3 and boron. The maximum peel (43.00%) was recorded from the treatment T_6. It was followed by T_5 (42.4%) and T_8 (41.0%) i.e. by application of Boron @120ppm and GA_3@80ppm + B@100ppm, respectively but these were statistically *at par* with T_6 (43.0%). The minimum peel content (31.9%) was recorded due to application of GA_3 @80 ppm (T_3).

However, maximum pulp thickness (66.74 mm) was recorded from the treatment T_9, followed by T_7 (63.87 mm), T_3 (61.39 mm) and T_2 (57.60mm). But statistical analysis showed that there was no significant difference between T_9 (66.74 mm) and T_7 (63.87 mm). While, minimum pulp thickness (48.29 mm) was recorded from the control plants (T_1).

In terms of edible part of fruit i.e. fruit pulp weight was recorded maximum (120.67 g) from the treatment T_2 (GA_3 @60 ppm) which was followed by T_3 (119.00 g), T_7 (118.00 g) and T_9 (111.33 g), but were statistically *at par*. The minimum fruit weight (68.33 g) was recorded from the control plants (T_1). Similar results were obtained by Nor *et al.* (2014) in dragon fruit (*Hylocereus polyrhizus*) and Garasiya *et al.* (2013) in winter-season guava cv. L-49 and Mohamed (2004) in pomegranate cv. Manfalouty.

Pulp content of the fruit was significantly influenced by the application of both GA_3 and boron. The maximum pulp (65.48%) was recorded from the treatment T_4 followed by T_3 (62.80%), T_7 (62.65%) and T_1 (59.02%), but statistical analysis showed that they were statistically *at par*. The minimum pulp content (52.23%) was recorded from GA_3@60ppm + B@100ppm (T_6).

The maximum pulp: peel ratio (01.97) was recorded from the treatment T_3, followed by T_7 (01.89), T_1 (01.68) and T_9 (1.53). But statistical analysis showed that there was no significant difference between T_3 (1.97) and T_7 (1.89), so they were statistically *at par.* The minimum pulp: peel ratio (01.21) was recorded from treatment T_6.

Scale number per fruit, scale length and scale base width of purplish red fleshed dragon fruit

Scale count was significantly influenced by the application of both GA_3 and boron. The maximum scale count (27.33) was recorded from the treatment T_2, followed by T_3 (27.00), T_7 (25.00) and T_4 (24.00) and minimum scale count (19.67) was recorded from the control plants (T_1).

The maximum scale length (2.83 cm) was recorded from the treatment T_8 but, scale base width was found maximum (2.47 cm) under T_9 treatment. Statistical analysis showed that there was no significant difference between T_8 (2.83 cm) and T_2 (2.82 cm), T_4 (2.58 cm) and T_7 (2.51 cm) for scale length and T_8 (2.46 cm), T_6 (2.42 cm) and T_7 (2.37 cm) for scale base width.

Effect of GA_3 and boron on chemical quality parameters of purplish red fleshed dragon fruit

T.S.S. content in fruits was significantly influenced by the application of both GA_3 and boron. The maximum T.S.S. (15.48°B) was recorded from the treatment T_4 and minimum T.S.S. (12.87°B) was recorded from the control plants (T_1).These findings are in agreement with those of several scientists (Pandey *et al.*, 1988; Chaitanya *et al.*, 1997; Kumar *et al.,* 2013) worked in guava, Shukla *et al.* (2011) in Aonla, Rachna and Singh (2013) in Ber fruit and Kaur *et al.* (2016) in Cape gooseberry.

Total sugar of fruit was significantly improved by the application of both GA_3 and boron and treatment T_9 showed maximum total sugars (11.32%) followed by T_8 (11.17%), T_7 (10.80%) and T_6 (10.63%). Similar result was also obtained by Kumar *et al.* (2013) who reported that the combined foliar spray of GA_3 100 ppm + borax 0.4% + NAA 50 ppm + $ZnSO_4$ 0.8% increased the total sugar content, reducing sugar content and T.S.S. of guava fruit.

Similarly, maximum reducing sugar (9.34%) was recorded in the treatment T_9. It was followed by T_8 (9.25%), T_7 (8.93%) and T_6 (8.88%), but closely related. The result corroborated with the findings of Kumar *et al.* (2013) and Brahmachari *et al.* (2005) in guava fruit where combination treatment results in highest reducing sugar content. Same pattern was found in case of non-reducing sugar content recording maximum amount under T_9.

The maximum ascorbic acid (vitamin-c) (22.23 mg/100 g FW) was recorded from the treatment T_9, followed by T_8 (21.47 mg/100 g FW), T_7 (20.70 mg/100 g FW) and T_6 (20.20 mg/100 g FW) i.e. by application of GA_3@80ppm + Boron@100ppm, GA_3@60ppm + Boron@120ppm, GA_3@60ppm + Boron@100ppm, respectively. The minimum Ascorbic acid (18.23 mg/100 g FW) was recorded from the control plants (T_1). Shukla *et al.* (2011) reported similar results in aonla with combined application of GA_3 and borax which resulted in increasing ascorbic acid content of the fruit. Brahmachari *et al.* (2005) also reported significant increase in ascorbic acid (vitamin-C) content in guava cv. Sardar even after 9 days in storage on combination application of NAA (25 and 50 ppm), 2, 4, 5-T (25 and 50 ppm), GA_3 (50 and 100 ppm), Kinetin (20 and 40 ppm) and CCC [chlormequat] (250 and 500 ppm).

Titratable acidity (in terms of citric acid) of fruit was significantly influenced by the application of both GA_3 and boron. Interestingly, it was seen that T_9 also caused an increase in acidity in fruits and it recorded maximum titratable acidity of 0.142%. The minimum titratable acidity (citric acid) (0.129 %) was recorded from the control plants (T_1). GA_3 can enhance the metabolic activity within the fruit, leading to increased synthesis of organic acids. This could result in higher level of acids such as citric and malic acid, contributing to overall fruit acidity, whereas boron can influence the balance between sugar and acid in the fruit. While sugars generally contribute to sweetness, an optimal boron level can ensure that acid production is not suppressed maintaining or even increasing the fruit's acidity. This phenomenon also influenced T.S.S.: Acid ratio as well as Total sugars: acid ratio of fruits. The maximum T.S.S.: Acid ratio (115.16) was recorded from the treatment T_4 whereas, maximum Total sugar: acid ratio (79.51) was recorded from the treatment T_9. Similar results were obtained by Chaitanya *et al.* (1997) in L-49 guava where combined application of zinc sulphate and borax thrice resulted in higher sugar: acid ratio (18.08) than control.

Conclusion

Results of the present investigation showed that both GA_3 and Boron had positive effect on physico-chemical quality improvement of dragon fruit. Among the various treatments under study, it may be suggested to foliar application of GA_3 @ 80 ppm along with boron @ 120 ppm thrice at 5, 15 and 25 days after anthesis for good quality reddish purple fleshed dragon fruit production under subtropical climate of Lucknow.

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Conflict of Interest Statement

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Table 1 (a). Effect of GA_3 and Boron on fruit morphology of dragon fruit.

Treatments	**Fruit weight (g)**	**Fruit length (mm)**	**Fruit diameter (mm)**	**Fruit volume (ml)**	**Specific gravity (g/ml)**	**Peel thickness (mm)**	**Peel weight (g)**	**Peel content (%)**
T_1- Control	114.67	80.4	59.90	104.00	1.10	4.93	40.33	35.2
T_2- GA_3 @ 60 ppm	210.00	93.4	69.09	201.00	1.04	4.71	81.33	38.7
T_3- GA_3 @ 80 ppm	190.00	85.7	66.69	177.33	1.07	3.40	60.67	31.9
T_4- Boron @ 100 ppm	167.33	69.3	65.98	196.00	0.85	4.01	65.00	39.2
T_5- Boron @ 120 ppm	172.00	88.3	66.24	160.67	1.07	4.20	73.00	42.4
T_6- GA_3 @ 60 ppm + Boron @ 100 ppm	190.67	86.9	66.44	189.33	1.01	4.95	82.00	43.0
T_7- GA_3 @ 60 ppm + Boron @ 120 ppm	188.33	73.9	68.94	185.33	1.02	4.13	62.33	33.1
T_8- GA_3 @ 80 ppm+ Boron @ 100 ppm	175.00	91.6	58.77	155.00	1.13	4.04	71.67	41.0
T_9- GA_3 @ 80 ppm + Boron @ 120 ppm	190.33	84.1	70.97	146.33	1.30	3.96	73.00	38.4
SE(m) ±	5.361	1.958	1.187	2.335	0.027	0.266	1.245	0.887
C.D. (p=0.05)	16.210	5.921	3.589	7.062	0.081	0.804	3.764	2.684

Table 1 (b). Effect of GA_3 and Boron on fruit morphology of dragon fruit

Treatments	Pulp thickness (mm)	Pulp weight (g)	Pulp content (%)	Pulp : Peel ratio	Scale count per fruit	Scale length (mm)	Scale base width (cm)	Number of seeds/ fruit
T_1- Control	48.29	68.33	59.02	1.68	19.67	1.92	2.15	744
T_2- GA_3@ 60 ppm	57.60	120.67	57.46	1.48	27.33	2.82	2.23	2061
T_3- GA_3 @ 80 ppm	61.39	119.00	62.80	1.97	27.00	2.03	2.15	2004
T_4- Boron @ 100 ppm	54.96	109.00	65.48	1.68	24.00	2.58	2.27	1480
T_5- Boron @ 120 ppm	50.77	91.00	52.90	1.25	22.00	2.38	2.36	1338
T_6- GA_3 @ 60 ppm + Boron @ 100 ppm	54.32	99.67	52.23	1.21	21.00	2.43	2.42	1703
T_7- GA_3@ 60 ppm + Boron @ 120 ppm	63.87	118.00	62.25	1.89	25.00	2.51	2.37	1933
T_8- GA_3@ 80 ppm+ Boron @ 100 ppm	52.84	97.67	55.80	1.36	20.67	2.83	2.46	1414
T_9- GA_3 @ 80 ppm + Boron @ 120 ppm	66.74	111.33	58.49	1.53	24.33	2.23	2.47	1524
SE(m) ±	1.084	5.061	2.740	0.085	1.061	0.109	0.033	136.724
C.D. (p=0.05)	3.277	15.303	8.286	0.258	3.207	0.329	0.101	413.427

Table 2. Effect of GA_3 and Boron on chemical quality parameters of dragon fruit.

Treatments	T.S.S. (°Brix)	Total sugar (%)	Reducing sugar (%)	Non reducing sugar (%)	Ascorbic acid (mg/100g)	Titratable acidity (%)	T.S.S. : Acid ratio	Total sugar : Acid ratio
T_1- Control	12.87	9.50	8.16	1.33	18.23	0.129	99.77	73.64
T_2- GA_3 @ 60 ppm	14.13	9.60	8.23	1.37	18.67	0.135	104.67	71.11
T_3- GA_3 @ 80 ppm	13.80	9.80	8.36	1.43	18.83	0.133	103.76	73.68
T_4- Boron @ 100 ppm	15.48	10.05	8.49	1.56	19.50	0.134	115.52	75.00
T_5- Boron @ 120 ppm	14.37	10.32	8.70	1.62	19.80	0.135	106.44	76.44
T_6- GA_3 @ 60 ppm + Boron @ 100 ppm	13.90	10.63	8.88	1.75	20.20	0.136	102.21	78.16
T_7- GA_3 @ 60 ppm + Boron @ 120 ppm	14.50	10.80	8.93	1.87	20.70	0.138	105.07	78.26
T_8- GA_3 @ 80 ppm+ Boron @ 100 ppm	14.13	11.17	9.25	1.93	21.47	0.141	100.21	79.22
T_9- GA_3 @ 80 ppm + Boron @ 120 ppm	14.43	11.32	9.34	1.97	22.23	0.142	101.62	79.72
SE(m) ±	0.258	0.017	0.012	0.011	0.079	0.002	2.009	0.427
C.D. (p=0.05)	0.781	0.051	0.036	0.033	0.239	0.006	6.076	1.291