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Response of Strawberry (*Fragaria ananassa*) cv. Chandler to Different Doses of Gibberellic Acid

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Abstract: Effects of doses of gibberellic acid (GA_3) were studied on the growth and performance of strawberry cultivar 'Chandler'. GA_3 was applied as foliar spray at three leaf stages @ 50, 75, 100 and 150 ppm. The applied GA_3 @ 150 ppm significantly increased the plant height, leaf area index (LAI), crown size and fruit yield. However, this dose of GA_3 (150 ppm) significantly decreased the shelf life and spoilage of fruit. Foliar application of GA_3 @ 75 ppm significantly increased the fruit ascorbic acid content. It is inferred that exogenous application of GA_3 @ 150 ppm could improve the yield and quality of strawberry fruits for better economic returns.

Key words: Strawberry, Vegetative, Floral, Fruit quality, Gibbrellic acid.

INTRODUCTION

Strawberry (*Fragaria ananassa*) is known as the most delicious, refreshing fruit with high nutritive value (Cordenunsi *et al*., 2003) and high hexose/sucrose ratio (Nishizawa *et al.*, 2005) to millions of people of the world. It is one of the most perishable fruits with short shelf life due to the susceptibility of berries to mechanical injury, water loss, decay and physiological deterioration (Nunes *et al*., 1995). More research has been conducted, and there were efforts of manipulating preharvest (Mukkun *et al*., 2001) and post harvest factors (Cordenunsi *et al*., 2005) that affect fruit quality in order to enhance strawberry shelf life. Superficial colour of berries determines the time of harvest, while fruit firmness is associated with shelf life. Recently, the determination of ascorbic acid has been of major interest **(**Aaby *et al*., 2005: Scalzo *et al*., 2005).

GA_3 is a growth promoting or retardant hormone that appears to have been explored most extensively in relation to its influence on dormancy. Use of GA_3 to various plants has produced growth responses, which are analogous to those, which are affected by certain natural environmental aspects, such as, long days and chilling. It has prompted flowering on non-chilled biennial plants (Lang, 1957) and broken the dormancy of seeds and buds thereby substituting for chilling.

In strawberry, the influence of GA_3 has been considered more as a substitute of long days and some effects similar to chilling, such as, increasing heights of the trusses, inhibition of flower formation and increased number of flowers (Ozgüven and Yilmaz, 2002; Tafazoli and Vince-Prue, 1978). Chilling requirements of different strawberry cultivars differ greatly, such as, "Nyoho" requires short chilling (Asrey and Jain, 2005) "Hokwase" and "Morioka 16" require long chilling period. Like many other fruit trees pistachio also requires cold weather in their annual cycle for the buds to bloom naturally afterwards and right conditions are prepared for their growth (Erez, 2000). Trees go into the rest mode (also called dormancy), at the time they receive chilling. This mechanism serves to protect the buds against the winter cold. Buds, that are dormant, do not wake up due to unusual heats of the winter (George *et al.*, 2002). Temperature, less than 0 ºC or higher than 7 °C, is not valuable in this respect (Javanshah *et al.*, 2006). In mild winter regions, chilling inadequacy prolongs dormancy and causes anomalous patterns in bud break and development resulting in a lower commercial production (Mohamed, 2008).

The aim of the present investigation was to determine the impact of exogenously applied GA_3 on growth, yield, quality and shelf life of strawberry cultivar 'Chandler'.

MATERIALS AND METHODS

The experiment was carried out during 2006-2007, at Fruit Crops Research Program, National Agricultural Research Center, Islamabad, Pakistan (Latitude: 33.42 °N; Longitude: 73.08 ^{o}E; Elevation: 683 msl). The present investigation was undertaken to determine the response of strawberry cultivar

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'Chandler' to different doses of gibberellic acid. The field was ploughed up three times with disc harrow and levelled for better drainage. Farmyard manure was applied @ 20 t ha^{-1}, Ammonium sulfate @ 500 kg ha^{-1}, super phosphate @ 300 kg ha^{-1} and potassium sulfate @ 150 kg ha^{-1}, prior to ploughing the soil. Raised beds of width 70 cm with a height of 30 cm were prepared.

Four different concentrations of GA_3 (50 ppm, 75 ppm, 100 ppm and 150 ppm) were compared with control plants. Cultivar 'Chandler' was used as an experimental material. Bare rooted plants were obtained from Agriculture Research Institute, Mingora, Swat (Pakistan) and potted in 3 L plastic pots, using a growing medium consisting of a mixture of medium coarse soil, coarse sand and farm yard manure in the ratio 1: 1: 1, respectively, under natural environmental conditions and evaluated for their subsequent vegetative and reproductive response to GA_3 doses. GA_3 was applied as foliar spray at 3 leaf stages by utilizing common insecticidal plastic sprayer. Measurements were made after 48, 96 and 192 h. The design of the experiment was completely randomized design (CRD) with 3 replications (ten plants were treated as a replicate). Statistical analysis was carried out with MSTAT-C to construct ANOVA, using Duncan's Multiple Range Test (DMRT) to determine significance of the results.

Parameters studied: In this study, the following parameters, namely, Endogenous GA_3, Plant height, Leaf area index (LAI), Crown size, Leaf nutrient status (NPK), Growth parameters, Fruit yield and post-harvest parameters, Fruit quality, Shelf life, were studied.

Preparation of GA_3 solution: The solution of GA_3 was prepared by dissolving the requisite amount of GA_3 in 1-2 ml ethanol. Finally, the volume of this solution was made up to 100 ml with distilled water. From this stock solution, further dilutions were made as required.

Application of GA_3: The GA_3 was applied as foliar spray @ 50, 75, 100 and 150 ppm, at 3 leaf stages by utilizing common insecticidal plastic sprayer. Measurements were made after 48, 96 and 192 hours.

Determination of GA_3 contents of plant leaves: The leaves of strawberry plant were collected for the extraction of endogenous GA_3 before and after 48 h of foliar application and 15 days after foliar application of GA_3. The extraction and purification was made, following the method of Kettner and Dörffling (1995). The wavelength, used for the detection of GA_3 analysis, was set at 254 nm (Li *et al.*, 1994).

RESULTS AND DISCUSSION

Plant height: The exogenous application of GA_3 significantly increased the plant height as compared to control (untreated) at P<0.01 (Table 1). Plants treated with GA_3 @ 75 ppm exhibited 35% increase in the plant height than control. Similarly, the plants treated with 100 ppm GA_3 showed 34% increase in the plant height, whereas, the plants treated with 150 ppm GA_3 exhibited 33% increase in plant height as compared to control. Minimum increase (27%) in the plant height was recorded in 50 ppm GA_3 treatment as compared to control. The result of our experiment is supported by the previous work of Ouzounidou *et al*. (2010), who stated that pre-flowering foliar spray of GA_3 increased the plant height in horticultural crops.

Table 1: DMRT of treatment means showing the effect of foliar spray of GA_3 on vegetative growth of strawberry cv. Chandler.

Treatment (ppm)	Plant height (cm)			Leaf area index (LAI)			Crown size (cm)		
	2006	2007	Mean	2006	2007	Mean	2006	2007	Mean
0	16.33 e	16.57 e	16.45 c	11.3	10.89	11.09 e	0.96	0.91	0.94 d
50	21.30 c	20.50 d	20.90 b	13.07	12.14	12.60 d	1.09	1.08	1.09 c
75	22.63 a	21.73 b,c	22.18 a	14.53	13.3	13.91 c	1.37	1.32	1.35 b
100	22.50 a	21.73 b,c	22.12 a	15.53	14.4	14.97 b	1.39	1.37	1.39 a,b
150	22.14 a,b	21.70 b,c	21.92 a	16.53	15.42	15.98 a	1.42	1.44	1.43 a
LSD	0.5609		0.3966	0.6523		0.4612	0.1224		0.08654
Mean of years	20.98 a	20.45 b		14.19	13.23		1.25	1.23	
Source	**F value**			**F value**			**F value**		
Years	12.7807*			7.6447 NS			1.1824 NS		
Treatments	341.5174**			157.1567**			53.4947**		
Interaction	3.0757*			1.1404 NS			0.2363 NS		

Leaf area index (LAI): The average of two years showed that leaf area index was significantly increased by GA_3 application (Table 1). GA_3 at higher concentration (150 ppm) resulted in 44% higher LAI as compared to control. The application of GA_3 @ 100 ppm resulted in 35% increase in LAI. An increase of 25% in LAI was observed by exogenous application of 75 ppm GA_3. As compared to other treatments, the GA_3 application @ 50 ppm exhibited significantly lower LAI. However, it increased the

LAI by 14% as compared to the control. Minimum leaf area index (LAI) was recorded in control plants. These findings are in line with the work of Sharma and Singh (2009), Kumar and Manimegalai. (2008), who reported increased leaf petiole, leaf area and leaf number appreciably in strawberry.

Crown size: The mean values of two years showed that crown size of plants was improved by GA_3 application (Table 1). The application of GA_3 @ 150 ppm enhanced the crown size by 52% as compared to the control. The 100 ppm GA_3 treatment exhibited 48% higher crown size than the control. The application of GA_3 @ 50 ppm also significantly promoted (16%) of the crown size than the control. However, its impact on crown size was significantly lower as compared to other treatments. The present findings are in line with the work of Hytönen *et al.* (2009), who suggested that GA_3 significantly increase the vegetative parameters, especially canopy spread, number of leaves, runners and number of lateral branches. Another study by Ragab (1996), reported that GA_3 improved significantly total carbohydrates content in roots and crowns of strawberry transplants.

Leaf nutrient status (NPK): Mean values showed significant differences among GA_3 treatments for leaf nitrogen. The GA_3 treated plants showed high concentration of leaf nitrogen. The plants treated with 150 ppm had maximum (7%) concentration of leaf nitrogen followed by 100 ppm (6%), 75 ppm (5%) and 50 ppm (3%), respectively, as compared to the control (Table 2). The plants treated with 50 ppm GA_3 exhibited significantly lower leaf nitrogen content than other treatments.

The plants, treated with GA_3, showed higher leaf phosphorus (P). Maximum leaf P was found in plants treated with 150 ppm, 100 ppm, and 75 ppm. The treatment with 50 ppm had also at par results with the rest of treatments and control, which had minimum value of leaf P (Table 2).

There was no significant effect of GA_3 treatment on leaf potassium contents (Table 2).

Table 2: DMRT of treatment means showing the effect of foliar spray of GA_3 on leaf nutrients level of strawberry cv. Chandler.

Treatment (ppm)	Leaf nitrogen (%)			Leaf phosphorus (%)			Leaf potassium (%)		
	2006	**2007**	**Mean**	**2006**	**2007**	**Mean**	**2006**	**2007**	**Mean**
0	2.97	2.97	2.97 d	0.28	0.28	0.280 b	1.43	1.45	1.44
50	3.04	3.08	3.06 c	0.29	0.29	0.292 a,b	1.46	1.45	1.46
75	3.11	3.12	3.12 b	0.29	0.3	0.293 a	1.46	1.46	1.46
100	3.13	3.14	3.14 a,b	0.29	0.31	0.300 a	1.46	1.45	1.46
150	3.19	3.15	3.17 a	0.29	0.31	0.303 a	1.47	1.46	1.46
LSD	0.05474		0.0387	0.01731		0.01224	NS		0.00387
Mean of years	3.09	3.09		0.29 b	0.30 a		1.46	1.45	
Source	**F value**			**F value**			**F value**		
Years	0.0052 NS			8.8947*			2.4500 NS		
Treatments	58.0920**			14.2439**			2.8936 NS		
Interaction	2.0102 NS			2.8293 NS			1.1745 NS		

Growth parameters: The GA_3 treatment had increased shoot dry weight. Maximum increase in shoot dry weight was observed in plants treated with 75 ppm (12%), followed by 100 ppm (11%), GA_3 application than control. The 150 ppm and 50 ppm GA_3 application also significantly increased the shoot dry weight as compared to control. Minimum shoot dry weight was recorded in control plants (Table 3a). The results of our findings are in contradiction with the findings of Kasim *et al.*, 2007, Sharma and Singh, 2009, Ouzounidou *et al*., 2010, stated that gibberellic acid significantly improved dry weight of shoots in strawberry.

A maximum of 2% increase in root dry weight was found in plants treated with GA_3 @ 75 ppm. Non-significant variations were recorded among the rest of the treatments (Table 3a).

Maximum root shoot ratio was found in control. All the treatments showed low root shoot ratio than the control (Table 3a).

Leaf chlorophyll content of GA_3 treated plants was higher than control plants. GA_3 treatments 150, 100 and 75 ppm showed maximum leaf chlorophyll contents, followed by 50 ppm. The exogenous application of GA_3 @ 100 ppm enhanced the chlorophyll content by 10% as compared to the control. The effects of 50 ppm GA_3 application on leaf chlorophyll contents were significantly lower than the rest of the treatments (Table 3b). The present results are in agreement with the work of Kalir and Poljakoff-Mayber (1976), and Khan *et al*., 1996, who reported an increase in chlorophyll content by gibberellic acid, as it is well known that gibberellic acid is a multipurpose growth regulator that also improves plant coloration (Kappel and McDonald, 2007).

Non-significant differences were observed among different treatments for root length. Plants treated with GA_3 @ 75 ppm showed higher (8%) root length closely followed by 100 ppm and 150 ppm (6%), respectively, than the control. Treatment with 50 ppm showed a 4% higher root length than the control (Table 3b).

Table 3(a): DMRT of treatment means showing the effect of foliar spray of GA_3 on growth parameters of strawberry cv. Chandler.

Treatment (ppm)	Shoot dry weight (g)			Root dry weight (g)			Root shoot ratio		
	2006	2007	Mean	2006	2007	Mean	2006	2007	Mean
0	5.9	6.07	5.99 c	2.10 c	2.37 a	2.23 a,b	0.36 b	0.39 a	0.37 a
50	6.33	6.63	6.48 b	2.10 c	2.27 b	2.18 b	0.33 c,d	0.34 b,c	0.34 b
75	6.67	6.77	6.72 a	2.30 a,b	2.27 b	2.28 a	0.34 b,c	0.33 c,d	0.34 b
100	6.63	6.67	6.65 a,b	2.10 c	2.27 b	2.18 b	0.32 d	0.34 b,c	0.33 b
150	6.27	6.7	6.48 b	2.10 c	2.27 b	2.18 b	0.33 c,d	0.34 c	0.34 b
LSD	NS		0.1774	0.07741		0.05474	0.01731		0.01224
Mean of years	6.36 b	6.57 a		2.14 b	2.29 a		0.34	0.35	
Source	**F value**			**F value**			**F value**		
Years	10.8177*			30.2500**			5.4000 NS		
Treatments	23.6951**			6.0000**			51.2000**		
Interaction	1.8540 NS			9.0000**			11.4667**		

Table 3(b): DMRT of treatment means showing the effect of foliar spray of GA_3 on leaf chlorophyll, root length and fruit yield of strawberry cv. Chandler.

Treatment (ppm)	Leaf chlorophyll			Root length (cm)			Fruit yield plant $^{-1}$ (g)		
	2006	2007	Mean	2006	2007	Mean	2006	2007	Mean
0	44.06	43.07	43.57 c	5.33	5.27	5.30 c	188.7	198	193.3 d
50	46.59	46.94	46.76 b	5.53	5.47	5.50 b	224	232.3	228.2 c
75	48.49	47.18	47.74 a	5.8	5.67	5.73 a	237.3	249	243.2 b
100	48.52	47.33	47.93 a	5.63	5.6	5.62 a,b	244	259	251.5 a
150	48.44	47.01	47.72 a	5.7	5.5	5.60 a,b	243	260	251.5 a
LSD	NS		0.6988	0.2448		0.1731	7.744		5.476
Mean of years	47.22	46.31		5.6	5.5		227.4 b	239.7 a	
Source	**F value**			**F value**			**F value**		
Years	2.9175 NS			5.7692 NS			80.9952**		
Treatments	62.8605**			7.7236**			178.5945**		
Interaction	2.4198 NS			0.3252 NS			1.0175 NS		

Fruit yield parameters: The mean values of two years showed that the yield of strawberry plants was affected by GA_3 application. The maximum increase in fruit weight (30%) was obtained with 150 and 100 ppm GA_3 treatments, as compared to control. The 75 ppm concentration of GA_3 increased the fruit weight by 7%, as compared to 50 ppm GA_3 (Table 3b).

The maximum increase in single fruit weight per plant was obtained from plants treated with GA_3 @ 150 ppm (33%) and 100 ppm (26%), followed by 75 ppm (18%) and 50 ppm (12%), respectively, than control (Table 4).

A significant higher fruit length was obtained from control, whereas, the treated plants had a reduced fruit length (Table 4). Minimum decrease in fruit length (10%) was recorded in fruits obtained from lower concentration of GA_3 application (50 ppm), as compared to the control, whereas, maximum decrease (4%) in fruit length was recorded in 100 ppm GA_3 treatment.

GA_3 application increased fruit width in cv. Chandler of strawberry as shown by mean of two years for different treatments. Maximum increase in fruit width (14 and 12%) was obtained with GA_3 foliar spray @ 150 and 75 ppm, respectively, than the control (Table 4).

Table 4: DMRT of treatment means showing the effect of foliar spray of GA_3 on single fruit weight and fruit size of strawberry cv. Chandler.

Treatment (ppm)	Single fruit weight (g)			Fruit length (cm)			Fruit width (cm)		
	2006	2007	Mean	2006	2007	Mean	2006	2007	Mean
0	12.5	13.07	12.78 d	3.91 a	3.94 a	3.93 a	2.57	2.63	2.60 c
50	14.27	14.3	14.28 c	3.52 c	3.59 c	3.56 d	2.8	2.87	2.83 b
75	15.2	15	15.10 b,c	3.76 b	3.78 b	3.77 b	2.87	2.97	2.92 a
100	16.07	16.1	16.08 a,b	3.79 b	3.79 b	3.79 b	2.83	2.97	2.90 a,b
150	17.1	16.97	17.03 a	3.78 b	3.52 c	3.65 c	2.9	3.03	2.97 a
LSD	1.398		0.9883	0.1224		0.08654	0.09481		0.06704
Mean of years	15.03	15.09		3.75	3.73		2.79 b	2.89 a	
Source	**F value**			**F value**			**F value**		
Years	0.1961NS			0.5477 NS			9.7826*		
Treatments	24.6743**			25.9763**			46.7500**		
Interaction	0.2088 NS			5.6982**			0.6250 NS		

Fruit quality: Fruits of GA_3 treated plants (except 50 and 100 ppm) had higher ascorbic acid content than the control. Higher ascorbic acid contents were recorded at 75 ppm, followed by 150 ppm, as compared to all treated and control plants (Table 5a). Strawberries are the vital source of ascorbic acid (vitamin C) contents for the human diet (Food and Nutrition Board, 1989) and they contain more vitamin C, as compared to oranges. Ascorbic acid is the main nutrient quality parameter and is very sensitive to degradation, due to its oxidation, as compared to the rest of the nutrients, during food processing and storage. Our results revealed the increasing effect of GA_3 application on vitamin C and these findings are in parallel with that of other scientists, including Sharma and Singh, (2009) and Ouzounidou *et al.* (2010), who worked on strawberry and capsicum.

Non-significant differences were found among treatments, regarding fruit acidity (Table 5a).

Significant differences were found among treatment means, total soluble solids (TSS) of fruits. Plants treated with GA_3 accumulated more TSS in fruits, whereas the control showed significantly lower TSS values for fruits. There were non-significant variations among the different treatments of GA_3 application (Table 5a). Titratable acidity is associated with the levels of organic acids present in the fruits; these are important parameters in maintaining the quality of fruits. In strawberries, citric acid is the chief acid contributing 90% of the total organic acid content. Current study revealed that Gibbellins had a positive effect on elevation of titratable acidity which is undesirable with respect to consumption, which coincides with the findings of Ouzounidou *et al.* (2010), who worked on the effect of gibberellic acid in capsicum plant and found non-significant results regarding titratable acidity. Similar results were reported by Kappel and MacDonald, 2007.

Although, the interaction of treatments and year were highly significant regarding pH of fruit, there was not any consistency among treatments in both years (Table 5b).

Non-significant differences among treatments were recorded regarding fruit firmness (Table 5b).

Table 5(a): DMRT of treatment means showing the effect of foliar spray of GA_3 on quality aspects of strawberry cv. Chandler.

Treatment (ppm)	Ascorbic acid (mg 100 g^{-1})			Acidity (%)			TSS (° Brix)		
	2006	2007	Mean	2006	2007	Mean	2006	2007	Mean
0	61.00 d	63.00 a	62.00 c	0.67	0.68	0.68	6.2	6.2	6.20 b
50	60.33 f	60.67 e	60.50 d	0.67	0.68	0.67	6.4	6.4	6.40 a
75	63.00 a	62.00 c	62.50 a	0.66	0.68	0.67	6.4	6.4	6.40 a
100	62.00 c	62.00 c	62.00 c	0.67	0.67	0.67	6.37	6.37	6.37 a
150	62.33 b	62.00 c	62.17 b	0.67	0.67	0.67	6.43	6.43	6.43 a
LSD	0.1448		0.1024	NS		NS	NS		0.1024
Mean of years	61.73	61.93		0.67 b	0.68 a		6.36	6.36	
Source	**F value**			**F value**			**F value**		
Years	0.2813 NS			15.0769*			0.0000 NS		
Treatments	10.0000**			1.5484 NS			7.7000**		
Interaction	5.2558**			1.0323 NS			0.0000 NS		

Table 5(b): DMRT of treatment means showing the effect of foliar spray of GA_3 on quality aspects of strawberry cv. Chandler.

Treatment (ppm)	pH			Fruit firmness (lbs)		
	2006	2007	Mean	2006	2007	Mean
0	3.20 b,c	3.30 a	3.25	4.46	4.52	4.49
50	3.23 a,b	3.13 c	3.18	4.43	4.52	4.48
75	3.23 a,b	3.16 b,c	3.2	4.46	4.53	4.49
100	3.30 a	3.13 c	3.22	4.43	4.52	4.48
150	3.30 a	3.17 b,c	3.23	4.47	4.52	4.5
LSD	0.09481		NS	NS		NS
Mean of years	3.25	3.18		4.45 b	4.52 a	
Source	**F value**			**F value**		
Years	3.0250 NS			686.1281**		
Treatments	1.4286 NS			1.2739 NS		
Interaction	5.5429**			1.5380 NS		

Shelf life: Significant differences for shelf life were found among treatments. GA_3 treated plants showed more weight loss, as compared to control. The maximum increase in weight loss was recorded in fruits, obtained from GA_3 treated plants @ 150 ppm (51%), followed by 100 ppm (41%), 75 ppm (25%) and 50 ppm (17%), respectively, as compared to control (Table 6).

Similar to weight loss, spoilage rate was higher in fruits obtained from GA_3 treated plants. However, maximum increase (78%) in fruit spoilage was recorded for 150 ppm GA_3 treatment as compared to control. As compared to the rest of GA_3 treatments, minimum fruit spoilage was observed in 50 ppm GA_3 treatment (Table 6).

The results revealed that exogenous application of GA_3 decreased the shelf life of fruit. Maximum shelf life was found in control plants, followed by the lowest concentration of GA_3 (50 ppm) applied. Plants, treated with 75, 100 and 150 ppm, produced fruits with minimum shelf life (Table 6).

Table 6: DMRT of treatment means showing the effect of foliar spray of GA_3 on shelf life of strawberry cv. Chandler.

Treatment (ppm)	Weight loss (%)			Spoilage (%)			Shelf life (days)		
	2006	2007	Mean	2006	2007	Mean	2006	2007	Mean
0	34.00 g	39.33 f	36.67 e	45	44.33	44.67 e	3.33	3	3.17 a
50	41.33 e,f	44.33 d,e	42.83 d	52	50.33	51.17 d	2.67	2.67	2.67 b
75	46.67 d	45.33 d	46.00 c	59.67	56.33	58.00 c	2	2	2.00 c
100	52.00 b,c	51.33 c	51.67 b	70	62.67	66.33 b	2	2	2.00 c
150	55.00 a,b	55.67 a	55.33 a	83	76	79.50 a	2	2	2.00 c
LSD	3.134		2.216	5.975		4.225	0.525		0.3712
Mean of years	45.8	47.2		61.93 a	57.93 b		2.4	2.33	
Source	**F value**			**F value**			**F value**		
Years	0.4482 NS			19.4595*			0.2500 NS		
Treatments	93.0769**			92.8294**			18.5455**		
Interaction	3.2788*			1.1678 NS			0.3636 NS		

Mean followed by dis-similar letter(s) in column differ significantly from one another and NS = Non-significant at $P \leq 0.05$.

CONCLUSION

It can be inferred from the current study that the application of exogenous GA_3@75 ppm improved the plant height, whereas, the higher concentrations of GA_3 (100 and 150 ppm) increased the ascorbic acid content of fruits. The correlation was negative between GA_3 concentrations and weight loss in strawberry fruits.

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