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Studies on exogenous application of plant growth regulators on storage changes in kiwifruit cv. Hayward

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Abstract
Effect of four different plant growth regulators *viz*., GA3 (25 and 50 mg/litre), BA (10 and 20 mg/litre), 2,4-D (10 and 25 mg/litre), TRIA (10 and 20 mg/litre) and a natural extract (4gm/litre) on storage changes in kiwifruit cv. Hayward were studied for two consecutive years. 11-year-old vines of kiwifruit cv. Hayward grown on a T-bar trellis system for two years were sprayed four weeks after full bloom. All the growth regulators proved effective in reducing physiological loss in weight. Application of 25 mg/litre GA3 sprayed four weeks after full bloom proved effective in maintaining higher firmness, TSS and vitamin C content after 20 days of ambient storage. Sensory evaluation reading after 20 days of ambient storage was also higher under this treatment. The study showed that the application of plant growth regulators *viz*., GA3 (25 and 50 mgL-1), BA (10 and 20 mgL-1), 2,4-D (10 and 25 mgL-1), TRIA (10 and 20 mgL-1) and a natural extract (4gmL-1) four weeks after full bloom influences the storage changes after 20 days of ambient storage.

Keywords: Hayward, GA3, 2, 4-D, triacontanol, BA, storage changes

Introduction
Kiwifruit (*Actinidia deliciosa* Chev.) has emerged as a success story in temperate fruit growing areas in India. The fruit is very much acclaimed for its nutritive and medicinal value. It is rich is ascorbic acid, vitamin E and minerals like K, P and Ca. The important advantage of cultivation of this fruit is that it is available for marketing during October to December when other fruits are rarely available and therefore fetches good price. Among few cultivars of kiwifruit, Hayward is the most commercial due to its internal green colour and superior flavour. Firmness, TSS, and ascorbic acid content are the important quality characters of kiwifruit. Among various practices, application of plant growth regulators are the most important factor for quality kiwifruit production. Triacontanol (TRIA), a primary alcohol, is reported to cause increased uptake of water and nutrients and results in improved growth and CO2 exchange (Mishra and Srivastava, [8]. Gibberellic acid plays a major role in stimulating cell division and cell elongation (Xin *et al*.,) [15]. BA, a cytokinin play an important role in cell division whereas 2, 4-D an organic component is known to promote size in fruit crops. The effect of plant growth regulators depends upon climate, cultivar, stage and rate of application. So there was need to study the influence of these chemicals on storage changes in kiwifruit cv. Hayward under ambient conditions under temperate conditions of Kashmir valley.

Materials and Methods
The present investigation was carried out on 11 -year-old Hayward kiwifruit vines planted at a spacing of 6m x 5m. Canopies of the vines were trained on T-bar system. The vines were irrigated using drip irrigation system. All the vines were managed according to uniform agronomic practices. There were ten treatments *viz*. Gibberellic acid @50 mg/litre (T_1), Gibberellic acid @25 mg/litre (T_2), Benzylaminopurine (6-BA) @ 20 mg/litre (T_3), Benzylaminopurine (6-BA) @ 10 mg/litre (T_4), 2, 4-Dicholorophenoxyacetic acid @25 mg/litre (T_5), 2, 4-Dicholorophenoxyacetic acid @10 mg/litre (T_6), Triacontanol (TRIA) @ 20 mg/litre (T_7), Triacontanol (TRIA) @ 10 mg/litre (T_8), Natural extract (Auxin + Cytokinin +

GA_3) (T_9) and control (water spray) (T_{10}). The treatments were applied foliarly 4-weeks after full bloom for two consecutive years. Treatments were replicated thrice with a plot size of 2 plants/treatment. For measuring physiological loss in weight, a total of 30 fruits with 10 fruits in each replication were kept separately in 3 boxes where each box represented a replication. The weight of the fruit after 20 days of storage under ambient conditions was recorded and per cent physiological loss in weight (PLW) was calculated by subtracting the final weight of fruit from initial weight as per the following equation:

$$\text{PLW (\%)} = \frac{\text{Initial weight} - \text{Final weight}}{\text{Initial weight}} \text{ x } 100$$

The pressure required to force an 8 mm plunger into the kiwifruit flesh was recorded as a measure of fruit firmness using 53205 digital fruit pressure tester (Toshiba-India). Observation were taken on diagonal sides of each fruit after peeling flesh of one square inch at harvest and after 20 days of storage under ambient conditions and results were expressed in Newton. Fruit TSS was measured with a hand refractometer (Tanco-0 to 50% range) by placing few drops of juice from stem and stylar end of each fruit on the prism and taking the readings at harvest and after 20 days of storage under ambient conditions. The readings were corrected at 20°C with the help of temperature correction chart (Ranganna) [13]. Quantitative determination of ascorbic acid was done by 2, 6-dichlorophenol-indophenol visual titration method at harvest and after 20 days of storage under ambient conditions (Ranganna) [13]. Sensory evaluation was performed by using a 4 point scale (Ranganna) [13]. The fruits for organoleptic evaluation were presented to the panel of five judges in coded form and they were requested to note their sensory response on the basis of colour, taste, flavor, texture and overall acceptability on the basis of 4 point numerical scale as; very good: 4, good: 3, fair: 2 and poor: 1. The data generated were subjected to statistical analysis as per the procedures described by Gomez and Gomez [4].

Results and Discussion

The effect of plant growth regulators on physiological loss in weight and fruit firmness is given in Table 1. The results shown in Table 1 reveal that per cent weight loss of Hayward fruit during storage was significantly influenced by different growth hormones during both the years of study. There was a gradual increase in per cent physiological loss in weight of Hayward fruits during storage period of 20 days irrespective of treatments.

All the treatments had great influence in reducing the physiological loss in weight during storage as compared to control. Physiological loss in weight was significantly lowest with the application of (T_2) 25mg/litre GA_3 (3.13 and 3.17%) followed by (T_1) 50 mg/litre GA_3 (3.34 and 3.49%) and (T_6) 10mg/litre 2, 4-D (3.41 and 3.99%) than all other treatments. The control recorded significantly higher physiological loss in weight (5.24 and 6.02%) during both the years. Physiological loss in weight of fruit is mainly due to evaporation, respiration and degradation process occurring during post-harvest handling of fruits (Haard and Salunkhe, [6]. It has been suggested that GA_3 influences cuticle thickness and dimensions of the epidermal cells (Mohamed *et al.*,) [9]. The results are inconformity with the findings of Marzouk and Kassem [7].

At harvest, fruit firmness was highest (7.76 and 7.55 N) in fruits treated with (T_2) 25 mg/litre GA_3 and lowest under control (water spray). Fruits lost its firmness with the advancement of ripening period during ambient storage although treated fruits were firmer than the untreated ones in both the years. Highest fruit firmness after 20 days of ambient storage was recorded in fruits treated with (T_2) 25 mg/litre GA_3 (5.85 and 6.54N) followed by (T_5) 25 mg/litre 2, 4-D (5.73 and 6.42N). The lowest fruit firmness after 20 days of ambient storage was obtained in untreated fruits (4.98 and 5.79 N) in both seasons, respectively. Spraying with GA_3 significantly increased the average fruit firmness. Decreased loss of fruit firmness with GA_3, application was also observed by Okan *et al.* [12].

At harvest, total soluble solids were highest (12.91 and 13.32 °Brix) in fruits treated with (T_2) 25mg/litre GA_3 during both the years of study. With the advancement of storage period, there was increase in the total soluble solids of fruits (Table 2). During first year maximum total soluble solids after 20 days of ambient storage was recorded in fruits treated with (T_2) 25mg/litre GA_3 (14.32 °Brix) which was statistically at par with (T_1) 50 mg/litre GA_3 (14.01 ^{0}brix). Lowest total soluble solids (11.26 °Brix) after 20 days of ambient storage were recorded in control. During second year (T_2) 25mg/litre GA_3 recorded highest total soluble solids (14.91 °Brix) after 20 days of ambient storage. Treatment (T_1) 50 mg/litre GA_3 (14.78 °Brix) and (T_6) 10 mg/litre 2,4-D (14.66 °Brix) were statistically at par with (T_2) 25mg/litre GA_3 (14.91°Brix). The increase in TSS after storage may be attributed partly to the conversion of organic acids to sugars through gluconeogenesis (Echeverria and Ismail,) [2]. Moreover, the degradation of cellulose, hemicellulose and pectin from cell walls within fruit segments might release soluble components which could have a direct effect on TSS (Echeverria *et al.*,) [3]. These results coincide with the findings of Singh *et al.* [14].

Fruit vitamin C content at harvest was higher (92.75 and 92.76 mg/100 g) with (T_2) 25 mg/litre GA_3 during both the years of study. However maximum vitamin C content after 20 days of ambient storage was observed in (T_2) 25 mg/litre GA_3 (83.59 and 84.63 mg/100g) followed by (T_1) 50 mg/litre GA_3 (80.98 and 83.64 mg/100 g) and (T_6) 10 mg/litre 2,4-D (82.36 and 83.77 mg/100g), respectively during both the years of study (Table 2). The lowest vitamin C content after 20 days of ambient storage was recorded in control (65.84 and 69.79 mg/100g) during both the years. As regards the Hayward fruits, its ascorbic acid content and its retention during storage period is of commercial importance. The continuous decrease in ascorbic acid content with the advancement of storage period was observed in all the treatments and this decrease was significantly more in untreated fruits than the treated fruits. However maximum decrease in vitamin C content was observed in control and minimum in GA_3 treated fruits. This pattern of retention of ascorbic acid, might be due to the lowering of respiration or oxidation of ascorbic acid in the treated fruits. These results are in conformity with the findings of Gupta and Mukherjee [5] and Nath *et al.* [11].

Significant differences among different treatments on organoleptic qualities of fruits after 20 days of ambient storage were recorded during both the years of study (Table 3). The maximum score was recorded with the application of (T_2) 25 mg/litreGA_3 (3.25 and 3.27) followed by (T_1) 50 mg/litre GA_3 (3.24 and 3.26), respectively during both the years. The least score was observed in untreated fruits (2.02 and 2.11). Positive relationships between biochemical analysis data and taste panel results, including a correlation between the sweetness of fruits and their TSS have been identified by many researchers (Azodanlou *et al.*,) [1]. In the present study the panellists graded 25 mg/litre GA_3 treated fruits as having the best taste, aroma, and highest sweetness and were also classified among those having the lowest acidity and best flavor followed by fruits from the 50mg/litre GA_3 and 10 mg/litre BA. The control fruit had low values for taste, appearance, and sweetness. It has been suggested that plant growth regulator treated fruits accumulate the high percentage of sugar, polyphenolic compound and antioxidant substances in fruits, thus increase its taste, flavour as well as quality (Moneruzzaman *et al*.,) [10].

From the above discussion it may be concluded that application of plant growth regulators 4-weeks after full bloom improved storage parameters after 20 days of ambient storage. Among different treatments, application of 25 mg/litre GA_3 proved more effective in maintaining higher firmness, TSS and vitamin C content after 20 days of ambient storage. Sensory evaluation reading after 20 days of ambient storage was also higher under this treatment.

Table 1: Effect of exogenous application of plant growth regulators on physiological loss in weight (%) and fruit firmness (N) in kiwifruit cv. Hayward under ambient storage after 20 days

Treatments	Physiological loss in weight (%)		Firmness (N)			
			1st year		2nd year	
	1st year	2nd year	At harvest	After 20 days of storage	At harvest	After 20 days of storage
T_1	3.34	3.49	7.69	5.62	7.50	6.32
T_2	3.13	3.17	7.76	5.85	7.55	6.54
T_3	3.50	4.25	7.34	5.53	7.13	6.22
T_4	3.48	4.21	7.46	5.55	7.25	6.24
T_5	3.45	4.02	7.64	5.73	7.46	6.42
T_6	3.41	3.99	7.53	5.62	7.32	6.31
T_7	3.52	4.56	7.32	5.60	7.37	6.45
T_8	3.50	4.49	7.05	5.58	7.07	6.36
T_9	3.51	4.52	7.23	5.41	7.29	6.28
T_{10}	5.24	6.02	7.01	4.98	7.04	5.79
CD (0.05)	0.17	0.29	0.08	0.15	0.04	0.19

Table 2: Effect of exogenous application of plant growth regulators on total soluble solids and vitamin C content in kiwifruit cv. Hayward under ambient storage after 20 days

Treatments	T.S.S. (°Brix)				Vitamin C (mg/100g)			
	1st year		2nd year		1st year		2nd year	
	At harvest	After 20 days of storage	At harvest	After 20 days of storage	At harvest	After 20 days of storage	At harvest	After 20 days of storage
T_1	12.80	14.01	13.11	14.78	90.14	80.98	91.79	83.64
T_2	12.91	14.32	13.32	14.91	92.75	83.59	92.76	84.63
T_3	12.29	12.62	12.45	13.35	84.16	75.01	86.66	74.29
T_4	12.42	12.78	12.84	13.49	85.97	82.35	88.91	83.76
T_5	12.65	13.21	12.98	13.42	89.43	79.08	90.48	82.20
T_6	12.78	13.34	13.23	14.66	86.67	82.36	89.11	83.77
T_7	12.11	12.32	12.65	13.27	82.36	74.95	83.17	72.96
T_8	11.93	12.45	12.87	12.91	80.26	75.00	84.28	74.97
T_9	11.10	12.21	12.11	13.19	86.29	77.12	85.39	74.32
T_{10}	11.25	11.26	11.32	11.76	79.12	65.84	81.14	69.79
CD (0.05)	0.51	0.95	0.07	0.76	1.09	0.03	1.11	0.04

Table 3: Effect of exogenous application of plant growth regulators on sensory evaluation of kiwifruit cv. Hayward under ambient storage after 20 days

Treatments	1st year	2nd year
T_1	3.24	3.26
T_2	3.25	3.27
T_3	3.17	3.18
T_4	3.19	3.20
T_5	2.96	2.84
T_6	3.02	2.99
T_7	3.01	3.00
T_8	2.98	3.02
T_9	2.97	2.98
T_{10}	2.02	2.11
CD(0.05)	0.89	0.95

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