

Effect of Pre-Harvest Application of Gibberellic Acid on Fruit Quality and Shelf Life of Mandarin (*Citrus reticulata* Blanco)

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Abstract

Mandarin (*Citrus reticulata* Blanco) is a promising fruit crop gaining popularity for its human nutrition and economic importance in Nepal. The qualitative losses during pre-harvest stage hinder the productivity and subsequently shorten the on-tree storability. An experiment was conducted to assess the effect of gibberellic acid on quality and shelf life of the mandarin fruit. GA₃ at 10, 20, and 30 ppm as against of control were evaluated. Observations on fruit weight (g), fruit firmness (kg/cm²), rind colour (1 - 5 index), juice recovery (%), TSS/acid ratio, PLW (%), decay loss (%), and ascorbic acid (mg/100 ml) were recorded at three harvesting dates *i.e.* 20 Nov, 5 Dec, and 20 Dec and storage condition. It has been revealed that the fruits treated with GA₃ at 20 ppm retained higher fruit weight (128.6 g), more firmness (3.54 kg/cm²), better juice recovery (57.75%), and greater TSS/acid ratio (21.24) at the end of study (20 December). The PLW was found less with GA₃ at 30 ppm in both ambient (5.17%) and cellar (6.69%) condition as against untreated fruits (9.52% and 11.76%). Similarly, the decay loss was minimum in the fruits treated with GA₃ at 30 ppm both with ambient (1.02%) and cellar condition (8.21%) as against control with ambient (5.54%) and cellar (21.58%).

Keywords

Fruit Quality, Gibberellic Acid, Peel Puncture Resistance, Physiological Loss in Weight, Postharvest Shelf Life

1. Introduction

Mandarin (*Citrus reticulata* Blanco) is a promising fruit crop regarding its positive influence on human nutrition and economic importance in Nepal. Farmers in the mid hills of Nepal produce large amount of mandarin during its peak season *i.e.* November-December [1]. In the peak season, growers fetch lower price due to seasonal glutting, and in lean season, fruits are not available in the market. The consumers suffer due to unavailability of fruits beyond the peak harvesting and have to pay high price for cold stored coming all the way from India [2]. The fluctuation in the fruit supply and price can be minimized either by extending the harvesting period or by holding the fruits in storage [3]. Mandarin is a perishable fruit that cannot be kept on tree storage without any treatments.

Pre-harvest application of GA₃ has been reported to delay softening, delay rind colour, and minimize the fruits drops and puffiness [4]-[6]. Pre-harvest spray of GA₃ in mandarin delayed ripening and decay loss of fruits [7]. Kher *et al.* [8] found that GA₃ was the most effective chemicals in increasing the weight, specific gravity and decreasing the total acid content in guava fruits. Brahmachari and Rani [9] suggested that GA₃ and kinetin are beneficial in prolonging the shelf life and retaining the quality of guava fruits. Bhattacharya [10] reported that the fruits treated with GA₃ extended the storage life of lime fruits over control by delaying in ripening. Maturity and colour break stage were delayed with GA₃ 50 ppm treatment in Satluj Purple plum [11]. There was a decrease in TA, increase in total juice volume, TSS/acid ratio, and along with delayed rind colour by GA₃ [12]. In citrus fruit, GA₃ application delayed the loss of chlorophyll [13]. Exogenous application of growth regulators significantly decreased fruit drop leading to increase in total number of fruits per plants, fruit weight, juice percentage, total soluble solids, acidity, and vitamin C [14]. Fruit skin colour advanced in GA₃ applied trees [15]. GA₃ delayed the maturity and reduced the postharvest losses in kinnow mandarin [16]. Considering perishability and market glut in peak season, this study was undertaken to minimize the pre-harvest losses and to get high price beyond peak season through increase in harvest span. Therefore, pre-harvest application of GA₃ was investigated to evaluate its efficacy during on-tree storage and the consequent postharvest storage of mandarin.

2. Materials and Methods

This investigation was undertaken on 15 years old uniform and healthy tree with spacing of 5m × 5m in the Lamjung district of Nepal in the year 2012 and 2013. On 16 October *i.e.* five weeks before normal harvesting (with fruits at colour break), tree were treated with GA₃ (10, 20, and 30 ppm) as a whole tree spray containing Tween-80 surfactant (0.02% v/v). The spray of surfactant served as control. The second spray was applied two weeks later. The experiment was laid out in randomized complete block design (RCBD) including four treatments with four replications. The fruits were harvested in November 20, December 5, and December 20 and analysis was done with the respective date of harvesting. 20 fruits in each replication were sampled for analysis. Fruit weight was taken in gram by top balance, fruit firmness in terms of peel puncture resistance by Effigy tester for citrus (model 011). The rind colour was evaluated as in index where colours were given numerical value: full green = 1, yellowish green = 2, greenish yellow = 3, yellowish orange = 4 and full orange = 5. Total Soluble Solids in juice were determined by hand refractometer in °Brix, acidity by titrating against 0.1 N titration and vitamin C as mentioned by AOAC [17]. Data were tabulated in excel and analysed by using standard procedures as proposed Gomez and Gomez [18].

3. Results and Discussion

3.1. Fruit Weight

Data presented in the **Table 1** show that fruit weight was increased significantly in all the treatments of GA₃ with the advancement of the maturity as compared to control. Perusal on observations of fruit weight indicates that fruits treated with GA₃ was able to increase in weight. Maximum fruit weight was recorded with GA₃ at 20 ppm (128.6 g) against control (95.51 g) at the end of experiment (20 December). It was noted that GA₃ treated fruit had maximum increase on 5 December and beyond this date it was observed slow, stagnant and declined where as sharp decline in control fruits. Based on the findings, GA₃ with the concentration at 10 - 20 ppm was the most effective effect treatment for fruit growth in mandarin. The higher fruit growth with GA₃ treated fruits might be due to mediating process for faster translocation and mobilization of photosynthates from source. These findings are in agreement with the reports of Singh *et al.* [19] in pear, and Pal *et al.* [20] in kinnow man-

Table 1. Periodical changes on fruit weight, rind colour, and peel puncture resistance in mandarin fruit during on-tree storage in 2012 and 2013.

Treatments (ppm)	Fruit weight (gram)			Rind colour index (1 - 5 scale)			Peel puncture resistance (kg/cm ²)		
	A	B	C	A	B	C	A	B	C
GA ₃ 10	110.58	125.04	125.01	2.05	2.93	3.42	4.36	4.21	3.24
GA ₃ 20	113.50	127.46	128.60	1.92	2.84	3.16	4.19	3.80	3.54
GA ₃ 30	113.16	123.80	124.66	1.83	2.69	2.97	4.19	3.71	3.45
Control	98.75	98.26	95.51	3.37	4.63	5.00	3.75	2.80	2.73
LSD (0.05)	6.07	9.36	7.88	0.26	0.39	0.40	NS	0.27	NS

A = 20.11, B = 05.12, and C = 20.12.

darin who had observed GA₃ (10 ppm) has resulted in an increase in fruit diameter and Kumar *et al.* [21] in the fruit of strawberry who stated that gibberellic acid at 12.5 ppm resulted in the highest fruit length, breadth, and weight. Kaur *et al.* [11] has also reported that GA₃ at 25 and 50 ppm increased the fruit weight in plum and in consonance with the observation of Bose *et al.* [22] who recorded three times increment on fruit weight in mandarin. The increment in fruit weight might be due to hormone directed to transportation and accumulation of phytosynthates which resulted in better fruit development and also acceleration of cell division, elongation, and enlargement. Similar observation was recorded by Daulta and Veniwal [23] in sweet orange who claimed maximum weight with GA₃ sprayed tree fruits.

3.2. Rind Colour

Rind colour is the perhaps most important and reliable index of mandarin fruit. GA₃ treated fruits resulted in delaying the rind colour development as well delay in the maturity of the mandarin fruits. Perusal from the observations in the **Table 1** shows that GA₃ treated fruits resulted in significant delay in the rind colour development. On 20 November, the index value of 3.37 indicated orange colour in control as against index of less than 2.0 indicating greener fruits with GA₃ treatments. Likewise at the end of the study (20 December), the colour index of GA₃ treated fruits was 2 - 3.5 indicating orange colour as against of 5.0 indicating orange yellow with over ripe fruits in control. These findings are in consonance with the findings of the Ladaniya [5] in mandarin who stated that GA₃ treatments significantly delayed the rind colour development in Nagpur mandarin. Kaur *et al.* [11] also observed that colour development of the fruits was delayed by gibberellin treatments in plum. Gibberellin has been reported to delay chlorophyll degradation and the senescence in the fruits [24]. Colour development is associated with a loss of texture, increasing sugar content and decreasing acidity [25].

3.3. Peel Puncture Resistance

Peel puncture resistance serves as fruit quality determinant. Peel puncture resistance was significantly higher in the GA₃ treated fruits as compared to control. **Table 1** shows that on 20 November harvesting, the firmness of the fruits was non-significant although GA₃ treated fruits had appeared higher index value (>4.0 kg/cm²) than control (3.75 kg/cm²). On 5 December, this value was decreased in all treatments, however, GA₃ treated fruits had significantly much higher (3.71 - 4.21 kg/cm²) than control (2.8 kg/cm²). On 20 December, the resistance sharply declined and observed as non-significant among the treatments. However, fruits treated with GA₃ at 20 ppm had higher firmness (3.54 kg/cm²) than the untreated fruits (2.73 kg/cm²). These results are in conformity with the findings of the Ladaniya [5] in Nagpur mandarin who stated that GA₃ treated fruits had higher peel puncture resistance and Kaur *et al.* [11] observed the similar trends in the plum. In all the treatments the firmness was found decreasing with ripening advancement. This might be due to cell wall loosening of the fruit. The pro-pectin, which acts as a cementing material for binding the cellulose and hemicelluloses is converted to soluble pectin. As a result it loosens the cell wall's binding force during ripening [25]. Bakhshi and Chadha [13] claimed that in citrus, GA₃ application given to fruits delayed the loss of chlorophyll in limes and lemons.

3.4. Juice Recovery

Perusal on data as indicated in **Table 2** shows that the juice recovery percentage was significantly higher in

Table 2. Periodical changes on juice recovery, TSS/acid ratio, and Vitamin C in mandarin Vitamin C of GA₃ treated mandarin fruit during on-tree storage in 2012 and 2013.

Treatments (ppm)	Juice recovery (%)			TSS/acid ratio			Vitamin C (mg/100ml)		
	A	B	C	A	B	C	A	B	C
GA ₃ 10	52.68	55.08	55.68	11.86	15.00	20.04	31.03	27.5	24.75
GA ₃ 20	53.72	56.23	57.75	12.35	15.48	21.24	30.49	27.14	24.75
GA ₃ 30	53.80	54.85	55.21	12.16	15.83	17.77	29.86	28.52	23.17
Control	48.90	47.11	45.06	12.66	15.99	17.83	28.71	25.97	21.95
LSD (0.05)	NS	NS	6.77	NS	NS	2.53	NS	NS	NS

A = 20.11, B = 05.12, and C = 20.12.

fruits treated GA₃ than non-treated fruits. At normal harvesting date (20 November), the juice percentage was non-significant but higher juice was obtained from the fruit treated with GA₃. On later stage *i.e.* 20 December the juice percentage was recorded highly significant (57.75%) in the fruits treated with GA₃ at 20 ppm as against of control (45.06%) because GA₃ treated fruits remained firm and non-treated fruits were overripe in their condition. Similar observations were recorded by Haribabu *et al.* [26] in kagzi lime, Bhat *et al.* [27] in lemon and Daulta and Veniwal [23] in sweet orange who have reported that GA₃ treatments increased the percentage of juice. Increased in juice percentage may also be explained by the fact that hormones play a regulating role in the mobilization of metabolites within a plant and it is well established fact that developing fruits are extremely active metabolic “sinks” which mobilize metabolites and direct their flow from vegetative structure.

3.5. TSS/Acid Ratio

Perusal on data as indicated in **Table 2** shows that the TSS/acid ratio was not significant on 20 November and 5 December in all the treatments. However, non-treated fruits recorded higher TSS/acid ratio (12.66) than GA₃ treated fruits (11.86 - 12.16). The TSS/acid ratio was significantly higher in the GA₃ treated fruits (17.77 - 21.24) against to control (17.83). GA₃ at 20 ppm showed the highest TSS/acid ratio (21.24) followed by GA₃ at 10 ppm at the end of the study *i.e.* on 20 December whereas the lowest ratio was observed in control (17.83). These findings substantiate the earlier reports of Singh *et al.* [19] in pear and Kaur *et al.* [11] in plum and Ladaniya [5] in Nagpur mandarin who reported increase in TSS/acid ratio with GA₃ treatments. It was obvious that the TSS content increased while juice acidity decreased resulting in an increase in the TSS/acid ratio during holding of fruit on the tree. The increased TSS content could have been due to further synthesis and accumulation of photosynthates in the fruits on the tree [28]. The loss in acidity was reported to be due to normal respiration and conversion to other metabolites and loss was similar for fruit stored on the tree or in cold room [24].

3.6. Vitamin C Content

Higher vitamin C content imparts higher nutritive value to fruits. Data in **Table 2** shows that the vitamin C content decreased with the advancement of storage of fruits on tree in all treatments. However, more pronounced decrease was found in the non-treated fruits. A decrease in ascorbic acid could be due to enzymatic loss of L-ascorbic acid where it is converted to 2-3-dioxy-L-gluconic acid [29]. Vitamin C content in the GA₃ treated and non-treated fruit was non-significant during the study (20 November to 20 December). However, the content of vitamin C was recorded higher in the GA₃ treated fruits than in non-treated. The maximum vitamin C content was obtained with GA₃ at 10 (24.75 mg/100 ml) and 20 ppm (24.75 mg/100 ml) followed by GA₃ at 30 ppm (23.17 mg/100) as against control (21.95 mg/100 ml). These results were in line with the findings of Sindhu and Sighrot [30] who reported maximum ascorbic acid content in GA₃ treated fruits.

3.7. Physiological Loss in Weight (PLW)

The perusal in **Table 3**, indicated the increase in PLW with the increase in storage period both at ambient and under cellar condition. The PLW was found significant among the treatments. The minimum loss in weight was

Table 3. Effect of GA₃ on weight loss and decay loss of mandarin fruit during storage at ambient for 15 days (14°C-18°C and 45% - 73% RH) and cellar condition for 90 days (10°C-12°C and 85% - 90% RH).

Treatments (ppm)	Ambient		Cellar	
	Weight loss (%)	Decay loss (%)	Weight loss (%)	Decay loss (%)
GA ₃ 10	6.01	2.12	8.24	13.24
GA ₃ 20	5.61	1.18	6.77	10.27
GA ₃ 30	5.17	1.02	6.69	8.21
Control	9.52	5.54	11.76	21.58
LSD (0.05)	0.59	NS	1.63	3.78

observed in the fruits treated with GA₃ at 30 ppm (5.17%) followed by GA₃ at 20 ppm (5.61%), and GA₃ at 10 ppm (6.01%) and maximum loss in weight was recorded in control (9.52%) stored at ambient condition for 15 days. Under the cellar condition, the maximum PLW was recorded with the fruit treated with GA₃ at 30 ppm (6.69%) followed by GA₃ at 20 ppm (6.77%), and GA₃ at 10 ppm (8.24%) as against control (11.76%) at the end of the 90 days. The possible reason for reduction in weight loss by GA₃ could be due to its ability to retain more water against force of evaporation. GA₃ acts an antisenescent and antirespirant, which inhibited catabolic activities and consequently reduced the weight loss during storage [9]. These findings are conformity with the reports of Sindhu and Singhrot [30] in lemon, (Brahmachari and Rani [9] in guava, Ladaniya [5] in Nagpur mandarin, and Ahlawat *et al.* [30] in kinnow mandarin who reported decrease in weight loss of fruits during storage.

3.8. Decay Loss

Table 3 shows that the decay loss increased with the increase in period of storage in all the treatments. The decay loss among the treatments was not significant at ambient condition. However, the minimum decay loss was found in the fruits with GA₃ 30 at ppm (1.02%) followed by GA₃ at 20 ppm (1.18%) and GA₃ at 10 ppm (2.12%) as against control (5.54%). On the other hand, the minimum decay loss was observed in the fruits treated with GA₃ at 30 ppm (8.21%). The lesser decay loss percentage in GA₃ treated fruits could be due to antisenescent and antirespirant properties of the gibberellins which prevent the cellular disintegration with enhancing resistant ability in the fruit. Similar results were reported by Brahmachari and Rani [9] in guava, Sindhu and Singhrot [30] in lemon, Ladaniya [5] in Nagpur mandarin and Ahlawat *et al.* [31] in kinnow mandarin.

4. Conclusion

On the basis of the above experimental findings, we concluded that GA₃ at 20 ppm was more effective to increase fruit weight and overall fruit quality whereas GA₃ at 30 ppm was the best for the prolonging the shelf life and minimising the physiological loss in weight (PLW) and decay loss of mandarin in both ambient and cellar condition. GA₃ at 20 ppm retained higher fruit weight (128.6 g), higher peel puncture resistance (3.54 kg/cm²), higher juice recovery (57.75%), and higher TSS/acid ratio (21.24) during the storage. In overall, GA₃ was proved to delay the ripening of the fruits for one month through delaying the chlorophyll development and reducing the loss of texture, decreasing sugar content and increasing acidity.

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