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EFFECTS OF PREHARVEST BIOREGULATOR APPLICATION ON SHELF-LIFE AND DISEASE INCIDENCE DURING STORAGE OF KINNOW MANDARIN

ARTI DEVI, NIRMAL SHARMA*, VK WALI, PARSHANT BAKSHI, MAHITAL JAMWAL AND RAJESH KUMAR

Division of Fruit Science, SKUAST-J, Chatha, Jammu and Kashmir-180009, India

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Abstract

Shelf-life and disease incidence of Kinnow mandarin treated with bio-regulators at pre-harvest stage were studied wherein results revealed that fruit weight, length, volume, rind weight, rind thickness, juice percentage, acidity and ascorbic acid decreased with the increase in storage period. During first two weeks least stained/shriveled/wrinkled fruits were observed in the fruits treated with 75 ppm GA_3 and 20 ppm 2,4-D and maximum losses were found in fruits treated with 15 ppm NAA. Maximum PDI was recorded in the fruits treated with 15 ppm NAA, however, maximum PLW was recorded with 75 ppm NAA. Better shelf-life of Kinnow mandarin up to one week was observed with 75 ppm GA_3.

Introduction

Citrus is the third largest fruit industry of India, grown on 987.00 thousand hectare with annual production of about 12181.00 thousand metric ton (Anonymous 2016). Kinnow, (*Citrus reticulata* Blanco.), a mandarin, is commercially cultivated for its good yield, high processing quality, fresh consumption, aromatic flavor and better adaptation to agro-environmental conditions (Ahmed *et al.* 2006), however, preharvest fruit drop is one of the major reasons of low productivity in India. Fruit drops at various stages of fruit development due to malnutrition, water stress, excessive insect pest attack and most important among them is the hormonal imbalance. Fruit drop is triggered when the auxin concentration decreases and abscissic acid (ABA) concentration increases as the endogenous hormones and their balance plays a modulating role in the mobilization of nutrients to the developing fruits. Use of plant bioregulators has become an important component of modern agro-technique in most of the cultivated plants and especially in fruit plants. In order to check the preharvest fruit drop of citrus, use of plant bioregulators is recommended at preharvest stage.

Auxins and gibberellins are used to control the fruit drop and to improve the fruit quality in citrus (Almeida *et al.* 2004). Spraying of auxin controls the dropping of fruit by maintaining the cells at the zone of abscission, preventing the synthesis of hydrolytic enzymes, such as cellulase, which decompose the cell walls. Combined application of GA_3 and 2,4-D has been said to reduce the precocious drop of citrus fruit, besides, retarding the softening and senescence of the peel (El-Otamani 1992). In India, 2,4-D is recommended to control the preharvest fruit drop of citrus particularly Kinnow. However, it is evident that application of plant bioregulators at prehravest stage would surely affect the shelf-life of the fruits. Longer shelf-life of the fruits leads to lowering the post-harvest losses. So attempt was made to study the shelf-life and per cent disease index of Kinnow mandarin given preharvest plant bio-regulator treatment.

*Author for correspondence: <nirmalsharma.77@rediffmail.com>.

Materials and Methods

Studies on effect of plant bioregulators on shelf-life of Kinnow mandarin (*Citrus reticulata* Blanco.) were conducted at Division of Fruit Science, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, Jammu & Kashmir, India during 2013 - 2014. Seven year old plants of Kinnow mandarin (*Citrus reticulata* Blanco.) were selected for this experiment. Experiment consisted of preharvest application of 11 growth regulator treatments i.e. T1: 25 ppm GA_3, T2: 50 ppm GA_3, T3: 75 ppm GA_3, T4: 100 ppm GA_3, T5: 10 ppm NAA, T6: 15 ppm NAA, T7: 20 ppm NAA, T8: 10 ppm 2,4-D, T9: 20 ppm 2,4-D, T10: 30 ppm 2,4-D and T11: untreated control, replicated thrice were applied during the third week of November. Fruits from the treated plants were collected to check the effect of pre-harvest bioregulator application on shelf life of Kinnow mandarin. Stained/shriveled/wrinkled fruits were visually counted at weekly interval up to 28 days of storage and expressed as per cent. Fruit weight, fruit length, fruit diameter, rind weight, rind thickness and juice percentage were measured as per standard procedure at weekly intervals up to 28 days of storage. Total soluble solids (^oB), titratable acidity (%), total sugars, reducing sugars and non-reducing sugars were measured as per standard procedures (Ranganna 1986) at weekly interval up to 28 days of storage. The per cent loss in weight for each date of observation was calculated by dividing the difference of initial and final weight of the fruit with initial weight multiplied with 100. Disease severity was estimated on the basis of fruit area covered by disease either single or in combination using 1 - 5 rating scale as described by Naik and Lakkund (1997) and was worked out using below formula described by Wheeler (1969).

$$\text{PDI} = \frac{(n1 \times 1 + n2 \times 2 + n3 \times 3 + n4 \times 4 + n5 \times 5)}{\text{Total number of fruits observed} \times \text{maximum classes of disease}} \times 100$$

where, n1 to n5 represent total number of fruits falling under 1 - 5 scales of disease severity.

For assessing the quality attributes of taste, texture, flavour and colour of Kinnow mandarin fruits, evaluation was carried by panel of judges. The score card of such an organoleptic valuation carried total of 40 points with 10 points for each characteristic. For assessment, composite samples of fruit for each treatment and replication was drawn and average score was calculated for final assessment. The statistical analysis of the data generated during the course of study was analyzed as per the method suggested by Panse and Sukhatme (1967).

Results and Discussion

The data presented in Table 1 indicate that the maximum number of stained/shriveled/ wrinkled fruits were observed in T_6 (75 ppm GA_3) i.e. 39.22 and 75.50 per cent on and 14th day of storage, respectively followed by T_2 (20 ppm 2,4-D) and minimum number of stained/shriveled/wrinkled fruits were observed in T_{11} (control) i.e. 23.85 per cent on 7th day of storage and 56.77 per cent on 14th day of storage, while on and 28th 28^{th} day of storage all the fruits under different treatments had stained/shriveled/wrinkled fruits. Loss of fruit weight and moisture content of the peel are mainly caused by respiration and transpiration resulting in wilted rind and shriveled appearance. In orange and mandarin, 5.0 - 6.0 per cent water loss results in changes in appearance and firmness of the fruit that could be detrimental to its marketability (Ladaniya, 2008). Maximum per cent disease index (Table 1) was recorded in T_9 (15 ppm NAA) on 7, 14 and 21st day of storage i.e. 21.0, 55.0 and 80.0 per cent, respectively and minimum per cent disease index was recorded under T_{11} (control) i.e 12.0 per cent on 7th day, 38.0 per cent on 14th day and 68.0 per cent on 21st day of storage while on 28st day of storage all the treatments showed non-significant result. Marpudi *et al.* (2011) found 40 and 100 per cent disease index in

papaya fruits after 5 and 10 days of storage at room conditions. Per cent physiological loss in weight of Kinnow mandarin revealed (Table 1) that with the advancement of storage life, the per cent weight loss was highly significant. The maximum physiological loss in weight was registered in T_6 (75 ppm GA_3) during 7, 14, 21 and 28th day of storage i.e. 8.70, 14.45, 18.40 and 12.40 per cent, respectively and minimum was registered in T_{11} (control) i.e. 5.10 percent on 7th day of storage, 13.30 per cent on 14th day of storage, 17.00 per cent on 21st day of storage and 11.10 per cent on 28th day of storage. In general physiological loss in weight increased with the advancement of storage period. This has also been confirmed by Singh (1988) in Guava. The possible reason for reduced weight loss by growth regulators may be that growth regulators cause some chemical changes within the fruits resulting in retention of more water against the force of evaporation. Alteration of proteinaceous constitutes in the cells can also cause increased affinity for water. Rizk-Alla *et al.* (2011) reported that 20 ppm GA_3 + 75 ppm NAA at preharvest stage resulted in lowest weight loss percentage i.e. 5.63 and 6.57 per cent after four weeks of cold storage. Tecchio *et al.* (2009) also found that NAA significantly reduced the increase in weight loss (per cent) during storage of grapes. Among different treatments, the maximum fruit weight was observed in T_6 (75 ppm GA_3) i.e. 109.30 gm on first day, 99.79 gm on 7th day, 84.00 gm on 14th day, 63.89 gm on 21st day and 50.33 gm on 28th day of storage and minimum was found in T_{11} (control) (Table 2). The data further revealed that treatment T_6 maintained maximum fruit weight on each day of observation during storage period. Kaseem *et al.* (2011) reported that the percentage of fruit weight loss decreases with the application GA_3 and NAA. Preharvest application of growth regulators like GA_3 along with mechanical treatments like girdling and thinning have been found to reduce weight loss of grapes during storage (Saini *et al.* 2011).

During storage period the maximum juice percentage was registered in T_6 (75 ppm GA_3) and minimum was 25.35 percent in T_{11} (Table 2). Use of plant growth regulators in improving citrus fruit quality including juice percentage is well documented. Khalid *et al.* (2012) reported that GA_3 and higher concentrations of BA and kinetin significantly increased juice mass (%) and decreased the rag mass (%) as compared to control. Increased juice percentage may be due to the increased vasculization in the pedicel and/or due to the increased sink strength and/or reduced senescence and respiration from the fruit (Dhillion *et al.* 1985) induced with the application of growth regulators. The data depicted in table 2 indicates that there was a significant increase in total soluble solids from initial day of storage to day of storage, however, thereafter it decreased significantly till 28th day of storage. The maximum total soluble solids was recorded in T_9 (15 ppm NAA) i.e. 12.70°B on first day, 12.80°B on 7th day, 12.70°B on 14th day, 12.50°B on 21st day and 12.25°B on 28th day and minimum was found in T_{11} (control). The results reveal that there was increase in total soluble solids content up to 7th day of storage in all the treatments including control and it continued to decrease on further storage. The initial increase of TSS during storage may be due to the breakdown of complex polymers into simple molecules by hydrolytic enzymes that may have been further metabolized during respiration and the level got decreased during subsequent storage period. Garg and Ram (1974) in guava and Bassily (1968) in peach reported similar trend of increase and decrease in TSS during storage. The treatments were helpful in retaining higher TSS contents in storage over control. The more retention of TSS during storage with pre-harvest sprays of plant growth regulators might be due to increase in firmness and decrease in decay loss which resulted into slow degradation of soluble contents of the fruits. Similar improvement and retention of TSS has also been reported in guava with NAA and GA_3 by Singh (1988). A significant decrease in the acidity was observed in all the treatments during storage period as presented in Table 3. The maximum acidity was found in T_9 (15 ppm NAA) i.e. 1.38 per cent on first day of storage, 1.36 per cent on 7th day of storage, 1.34 per cent on 14th

Table 1. Effect of plant bioregulators on stained/shriveled/wrinkled fruits (%), percent disease index (%) and physiological loss of weight (%) of Kinnow mandarin during storage.

Treatments	Stained/shriveled/wrinkled fruits (%)				Per cent disease index (%)				Physiological loss of weight (%)			
	7	14	21	28	7	14	21	28	7	14	21	28
T_1 (10 ppm 2,4-D)	26.55	61.20	100	100	15.00	42.00	72.00	100	7.40	14.10	17.50	11.45
T_2 (20 ppm 2,4-D)	37.21	75.00	100	100	20.00	50.00	75.00	100	8.50	14.40	18.35	12.20
T_3 (30 ppm 2,4-D)	28.77	65.54	100	100	15.00	45.00	72.00	100	6.00	13.50	17.05	11.15
T_4 (25 ppm GA_3)	26.55	68.83	100	100	18.00	48.00	75.00	100	7.00	14.10	17.35	11.40
T_5 (50 ppm GA_3)	28.77	71.54	100	100	18.00	48.00	75.00	100	7.70	14.25	17.60	11.60
T_6 (75 ppm GA_3)	39.22	75.50	100	100	20.00	54.00	80.00	100	8.70	14.45	18.40	12.40
T_7 (100 ppm GA_3)	35.20	70.40	100	100	17.00	45.00	73.00	100	8.00	14.30	17.80	11.75
T_8 (10 ppm NAA)	28.80	70.50	100	100	20.00	50.00	78.00	100	6.40	13.70	17.10	11.20
T_9 (15 ppm NAA)	25.40	60.12	100	100	21.00	55.00	80.00	100	5.30	13.50	18.10	11.80
T_{10} (20 ppm NAA)	26.55	66.12	100	100	20.00	50.00	75.00	100	6.50	13.80	17.20	11.25
T_{11} (Control)	23.85	56.77	100	100	12.00	38.00	68.00	100	5.10	13.30	17.00	11.10
CD (p = 0.05)	**2.05**	**3.50**	**NS**	**NS**	**0.08**	**3.20**	**3.50**	**NS**	**3.05**	**2.38**	**2.75**	**2.42**

Table 2. Effect of plant bioregulators on fruit weight (g), juice percentage (%) and TSS (^{0}B) of Kinnow mandarin during storage.

Treatments	Fruit weight (g)					Juice percentage (%)					TSS (^{o}B)				
	0	7	14	21	28	0	7	14	21	28	0	7	14	21	28
T_1 (10 ppm 2,4-D)	93.60	86.67	73.48	57.10	46.38	36.20	34.20	32.42	31.11	30.04	10.80	10.90	10.70	10.55	10.40
T_2 (20 ppm 2,4-D)	106.50	97.45	82.11	62.57	49.58	52.16	49.37	47.44	45.82	44.73	12.00	12.20	11.90	11.75	11.60
T_3 (30 ppm 2,4-D)	83.20	78.96	67.89	53.75	44.51	44.50	42.65	40.38	38.31	37.52	11.00	11.20	10.90	10.60	10.40
T_4 (25 ppm GA_3)	89.90	83.61	70.93	55.33	45.08	48.60	46.00	44.20	42.70	41.00	11.70	11.80	11.65	11.40	11.25
T_5 (50 ppm GA_3)	95.70	88.33	74.69	57.85	46.75	50.04	47.96	45.51	43.96	42.25	11.80	11.95	11.70	11.55	11.40
T_6 (75 ppm GA_3)	109.30	99.79	84.00	63.89	50.33	55.80	52.81	50.75	48.02	47.85	12.60	12.75	12.65	12.45	12.20
T_7 (100 ppm GA_3)	96.20	88.50	74.75	57.62	46.32	49.40	46.76	44.93	41.40	40.36	11.30	11.50	11.30	11.20	11.00
T_8 (10 ppm NAA)	83.80	78.44	66.96	52.63	43.24	45.10	42.69	40.02	38.62	37.00	12.40	12.55	12.30	12.10	11.90
T_9 (15 ppm NAA)	97.80	92.62	79.41	61.71	50.17	45.50	43.07	41.38	39.97	38.68	12.70	12.80	12.70	12.50	12.25
T_{10} (20 ppm NAA)	86.60	80.97	69.02	54.13	44.38	39.70	37.58	35.11	33.88	32.04	12.02	12.15	11.95	11.70	11.50
T_{11} (Control)	78.00	73.32	62.79	49.49	40.79	31.10	29.96	27.31	26.09	25.35	10.05	10.20	10.00	9.80	9.55
CD (p = 0.05)	**2.82**	**3.05**	**2.38**	**2.75**	**2.42**	**3.50**	**3.46**	**3.36**	**2.23**	**3.15**	**0.09**	**0.04**	**0.04**	**0.04**	**0.04**

Table 3. Effect of plant bioregulators on titratable acidity (%), reducing sugars (%) and total sugars (%) of Kinnow mandarin during storage.

Treatments	Titratable acidity (%)					Reducing sugars (%)					Total sugars (%)				
	0	7	14	21	28	0	7	14	21	28	0	7	14	21	28
T_1 (10 ppm 2,4-D)	1.14	1.13	1.10	1.07	1.00	2.91	3.07	3.00	2.90	2.78	8.11	8.23	8.12	7.96	7.78
T_2 (20 ppm 2,4-D)	1.25	1.24	1.22	1.20	1.14	3.15	3.30	3.22	3.14	3.02	8.32	8.45	8.33	8.21	8.10
T_3 (30 ppm 2,4-D)	1.35	1.33	1.30	1.27	1.23	3.07	3.21	3.14	3.01	2.90	8.19	8.30	8.19	8.08	7.88
T_4 (25 ppm GA_3)	1.30	1.28	1.26	1.22	1.20	2.64	2.78	2.72	2.61	2.50	7.96	8.08	8.00	7.90	7.76
T_5 (50 ppm GA_3)	1.18	1.16	1.14	1.12	1.06	2.72	2.86	2.81	2.66	2.50	8.05	8.18	8.04	7.91	7.78
T_6 (75 ppm GA_3)	1.35	1.33	1.30	1.26	1.20	3.35	3.46	3.41	3.34	3.25	8.52	8.61	8.41	8.26	8.14
T_7 (100 ppm GA_3)	1.22	1.20	1.17	1.14	1.07	3.02	3.16	3.10	3.00	2.86	8.15	8.26	8.14	8.02	7.90
T_8 (10 ppm NAA)	1.29	1.27	1.25	1.22	1.16	2.67	2.80	2.74	2.58	2.40	8.00	8.14	8.05	7.89	7.72
T_9 (15 ppm NAA)	1.38	1.36	1.34	1.30	1.23	3.70	3.81	3.75	3.80	3.66	8.65	8.76	8.68	8.60	8.55
T_{10} (20 ppm NAA)	1.30	1.32	1.31	1.28	1.20	3.25	3.38	3.32	3.18	3.02	8.35	8.48	8.32	8.20	8.12
T_{11} (Control)	1.08	1.07	1.05	1.02	0.98	2.55	2.70	2.63	2.48	2.30	7.70	8.01	7.88	7.70	7.56
CD (p = 0.05)	**0.02**	**0.02**	**0.03**	**0.02**	**0.02**	**0.30**	**0.32**	**0.32**	**0.42**	**0.40**	**0.14**	**0.16**	**0.29**	**0.35**	**0.42**

day of storage and 1.30 per cent on 21st day of storage and 1.23 per cent on 28th day of storage and minimum was found in T_{11} (control). The decrease in acidity during storage could be attributed to the conversion of acids into salts and sugars by the enzymes particularly invertase. This decrease in acidity during storage has also been reported by Mann and Randhawa (1978) in Kinnow mandarin.

During storage reducing sugar content increased from initial day of storage, however, thereafter it decreased significantly till 28th day of storage. The maximum reducing sugar was recorded in T_9 (15 ppm NAA) i.e. 5.61 per cent on first day, 5.66 percent on 7th day, 5.57 percent on 14th day, 5.45 per cent on 21st day and 5.30 per cent on 28th day of storage and minimum was found in T_{11} (control) (Table 3). During storage there was initial rise in reducing sugars up to 7th day of storage and it decreased thereafter till the end of storage period. The initial increase may be due the conversion of starch into reducing sugars and their decrease later could possibly due to utilization of these sugars in respiration. Application of growth regulators retained higher reducing sugar content over control during storage. This might be due to their effect on degradation of sugars as well as on the rates of respiration. Increase in reducing sugars might be due to the effect of cytokinin (Roitsch and Gonzalez 2004) on the activity of invertase enzyme, which break down sucrose into fructose and glucose, hence increasing reducing sugars. The results depicted in Table 3 indicate that there was a significant increase in total sugar from initial day of storage to 7th day, however, thereafter it decreased significantly till 28th day. Maximum total sugar was recorded in T_9 (15 ppm NAA) i.e. 8.65 per cent on 0th first day, 8.76 per cent on 7th day, 8.68 per cent on 14th day, 8.60 per cent on 21st day of storage and 8.65 percent on 28th day and minimum was found in T_{11} (control). The initial increase in total sugars during storage may be because of increase in Fig. 1 shows the effect of foliar application of plant bioregulators on

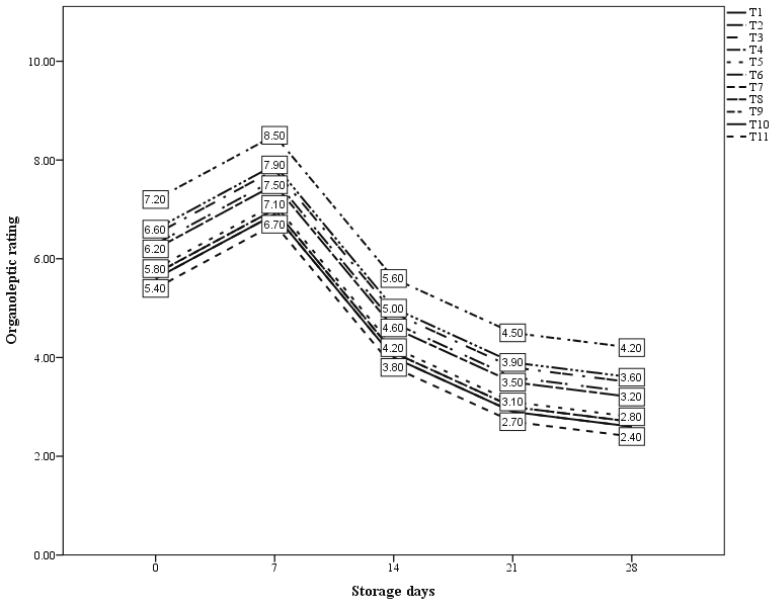

Fig. 1. Effect of plant bioregulators on the organoleptic rating of Kinnow mandarin during storage.

on organoleptic quality of reducing sugars and non-reducing sugars resulting from conversion of starch into simple sugars and their utilization in respiration may have resulted in decrease in the content. However, the treated fruits retained higher total sugars over control. Higher total sugars of

treated fruits during storage may be due to their lesser utilization in respiration as these growth regulators might have reduced the rate of respiration and delayed the onset of senescence. Data reveals that there were significant changes in organoleptic quality of fruits during storage. The rating was low (7.2) at the beginning of storage, which increased to 8.5 on 7th day of storage. Thereafter it showed a decreasing trend with the advancement of storage period and was lowest on the 28th day of storage (4.2). The maximum organoleptic rating was recorded in T_9 (15 ppm NAA) i.e. 7.2 on first day, 8.5 on 7th day, 5.6 on 14th day, 4.5 on 21st day of storage and 4.2 on 28th day and minimum was found in T_{11} (control). The decrease in organoleptic rating in all the treatments during prolonged storage might be because of the onset of senescence of tissues, which leads to decrease in firmness, rotting, discolouration of surface and dull appearance of the skin. However, the treated fruits retained higher scores over the control ones. This might be because of the fact that growth regulators might have inhibited the degradation process and delayed senescence up to 7th day of storage and maintained them in good conditions.

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