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Effect of Growth Regulators on the Shelf-life of Sweet Orange cv.Sathgudi (Citrus sinensis Osbeck.)

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ABSTRACT

An experiment was conducted to study the effect of growth regulators in combination with wax on shelf life of sweet orange. Sathgudi fruits were treated with the 2,4-D (500ppm) + wax (6%), GA_3 (500ppm) + wax (6%), Benzyl Adenine (50ppm) -+ wax (6%) and wax (6%). The results from the experiment clearly indicated that the BA (50ppm) -+ wax (6%) was better in maintaining the fruit quality during storage followed by 2,4-D (500ppm) + wax (6%). The efficacy of BA (50ppm) + wax (6%) in prolonging the shelf life of sweet orange fruits was attributed to the reduction of weight loss, spoilage, retention of more juice and peel content and maintenance of fruit firmness. Quality changes in sweet orange were also good in the BA (50ppm) + wax (6%) due to the optimum sugar content. The quality of treated fruits was better maintained as compared to those treated with wax alone. The slow buildup of sugars in growth regulator treated fruits was attributed to their increased shelf life. The ascorbic acid content and overall acceptability was also high for the fruits treated with the BA (50ppm) + wax (6%).

Key words : Benzyl adenine (BA), 2,4-Dichloro phenoxy acetic acid (2,4-D), Gibberellic acid (GA_3), Growth Regulators, Wax, Shelf-life, Sweet orange.

Sweet orange cv. Sathgudi (*Citrus sinensis* Osbeck.) is one of the most important citrus fruits grown in Andhra Pradesh. In A.P. it is grown in an area of 1,94,395 ha with an annual production of 26,24,333 tonnes (Annonymous, 2008). Sweet orange from the Andhra Pradesh is exported to the marketing centers of other states namely Bangalore, Trivandrum, Madras, Nagpur, Bombay, New Delhi and Calcutta etc. However, considerable quantity of the exported oranges gets spoiled (25 - 30 %) during transit due to bulk transportation (Biswas, 1989). Postharvest losses can be reduced and the storage life can be increased by using wax coatings and growth regulators (Gupta *et al.,* 1980).

Plant growth regulators (PGRs) control the physiological processes at extremely low concentrations. Most of these compounds occur naturally and hence their use in the postharvest treatments is expected. Auxins, gibberellins (GA), cytokinins are used to extend the vitality of fruit tissues. PGRs along with the wax have been very effective in extending the storage life of various citrus fruits. Understanding the mechanism of action and key processes regulated by the PGRs may lead to generate strategies for modifying the fruit characteristics to improve the fruit quality and to delay senescence (Ladaniya, 2008).

MATERIAL AND METHODS

The mature uniform size sweet orange fruits used for investigation were obtained from the farmers field located at Tipparthi village, Nalgonda district and the experiment was carried out in the Postharvest technology laboratory, College of Horticulture, Rajendranagar in the year 2010. The fruits were washed, air-dried, immersed in the respective growth regulator solution for about two minutes and then in the wax emulsion (6%) for about a minute. The fruits arranged in the corrugated fibre board (CFB) boxes were stored at room temperature. The four treatments were 2,4-D (500ppm) + wax (6%), GA_3 (500ppm) + wax (6%), BA (50ppm) + wax (6%) and wax (6%) and each treatment was replicated 4 times. The experimental design was factorial completely randomised design (CRD). The fruits were analysed to observe the physico-chemical changes for every 5 days.

The physiological loss in weight (in grams) in relation to the initial weight on five marked fruits was calculated and expressed as percentage. The visible symptoms of rotting/spoilage on the number of fruits over total fruits were recorded at periodical intervals and the cumulative spoilage was determined in terms of percent fruits. The juice extracted from the sample fruits with the help of juice extractor was strained through single mesh filter to remove the rag, seeds and left over waste. The percent juice content per fruit was worked out on weight basis. Weight of the peel in relation to its total fruit weight expressed as percent was recorded as peel content. The fruit firmness (kg cm^{-2}) was recorded using a pocket penetrometer while colour index was determined by the visual observation. Colour score (Green – 1, Yellowish green – 2, Greenish yellow – 3, Yellow - 4, Orange - 5).

The total soluble solids (TSS) were measured by the Hand refractometer (0-32°Brix). Titrable acidity, reducing sugars, total sugars and ascorbic acid were determined as per the procedure described by Ranganna (1986). Overall acceptability was determined by the panel of 10 members using a score card developed for the purpose.

RESULTS AND DISCUSSION

The initial average fruit weight of sweet orange cv. sathgudi was 210.00 g, horizontal and vertical diameter of the fruit was 63.75 and 66.10 mm respectively. The number of segments per fruit was 10.60 and average segment weight was 9.98 g, juice content and peel content were 47.90 % and 28.72 % respectively. The firmness of the fruit was 7.69 $kgcm^{-2}$. The fruit juice had total soluble solids of 8.60° Brix, titrable acidity of 0.98 %, reducing sugars and total sugars of 1.99 % and 4.00 % respectively. The ascorbic acid content was 64.10 mg/100 ml juice (Table 1).

Physical changes

Physiological loss in weight (PLW) :

The lowest PLW was observed in the fruits treated with BA (50ppm) (8.88 %) followed by those treated with the 2,4-D (500ppm) (9.08 %) and GA_3 (500ppm) (9.24 %). The highest PLW was observed in the fruits treated with wax (6%) alone (9.85 %) (Table 2). The lowest PLW in BA (50ppm) treated fruits may be due to the fact that BA reduces the rate of respiration and the results are in conformity with those of Bhardwaj *et al*. (2005) in Nagpur Santra.

There was a significant increase in the PLW from 5th day (4.30 %) to 25th day (15.86 %) of storage (Table 2). The highest PLW was observed between 15th and 20th days of storage. This physiological loss in weight was essentially due to the respiration as opined by Lotha *et al.* (1994) in kinnow mandarin.

Spoilage :

There was no spoilage of fruits upto 15 days of storage (Table 2). But from the 20th to 25th day, it was noticed that the BA (50ppm) (2.78 %) has recorded the lowest spoilage preceded by the 2,4-D (500ppm) (3.89 %) and highest was observed in the wax (6%) (7.78 %). Similar results were observed by Ladaniya (2008) in citrus fruits.

Juice and peel content :

The mean juice content (44.39 %) and peel content (25.80 %) were highest in the fruits treated with BA (50ppm) and lowest in those treated with wax (40.77 % and 24.50 % respectively). There was no significant difference between the BA (50ppm) (25.80 %) and 2,4-D (500ppm) (25.48 %) and GA_3 (500ppm) (25.08 %) (Table 3). The higher juice and peel content observed in BA (50ppm) treated fruits might be due to less respiration rate there by less moisture loss during the respiration as proposed by the Bhardwaj *et al*. (2005) in Nagpur Santra.

With increase in the duration of storage period, the juice content and peel content decreased significantly from the 5th day to 25th day. The reduction in juice and peel content was directly correlated with the reduction in moisture content of the fruit. These results are in confirmation with those reported by Jain and Chauhan (1995) in Kinnow mandarin.

Firmness :

Higher firmness was observed in the BA (50ppm) treated fruits (6.67 kg cm^{-2}) which were on par with those treated with 2,4-D (500ppm) (6.53 kg cm^{-2}) and lower in the wax (6%) treated fruits (6.25 kg cm^{-2}) (Table 4). Significant difference in the firmness was not observed between the 2,4-D (500ppm) (6.53 kg cm^{-2}) and GA_3 (500ppm) (6.40 kg cm^{-2}). The firmness of the fruits maintained for a longer period by BA (50ppm) reflecting the retarded ripening thereby maintenance of the fruit texture for longer period. The results are inline with the findings of Jayachandran *et al.* (2007) in guava.

Significant decrease in the firmness was observed from 5th (7.28 kg cm^{-2}) to 25th day (5.63

Table 1. Initial fruit characteristics.

Average fruit weight (g)	210.00
Horizontal diameter (mm)	63.75
Vertical diameter (mm)	66.10
Number of segments/fruit	10.60
Segment weight (g)	9.98
Juice content (%)	47.90
Peel content (%)	28.72
Firmness (kgcm^{-2})	7.69
TSS (°Brix)	8.60
Titrable acidity (%)	0.98
Reducing sugars (%)	1.99
Total sugars (%)	4.00
Ascorbic acid (mg per 100ml)	64.10

kg cm^{-2}). The firmness levels were always higher at initial days which decrease gradually, due to the degradation of cell wall components as reported by Ladaniya and Sonkar (1997) in Nagpur mandarin.

Colour index :

The lowest colour index value was noticed in BA (50ppm) (1.82) preceded by 2,4-D (500ppm) (1.86) followed by GA_3 (500ppm) (1.93). The highest colour index value was observed in wax (6%) (2.19) (Table 4). The lowest colour index recorded by BA (50ppm) might be due to the fact that BA reduces the senescence and ethylene production thereby delays ripening of the fruits as stated by Sukumar Reddy (2009) in guava.

There was a gradual increase in the colour index value from 5th day (1.30) to 25th day (2.60) which may due to the breakdown of chlorophyll followed by a subsequent increase in orange and yellow pigments in the peel. The changes in peel colour may be due to development of carotenoids during ripening as stated by Ladaniya (2008).

Chemical changes in fruit juice

Total soluble solids (TSS) :

The TSS content of fruits was not significantly influenced by treatments. However, the higher TSS was observed in GA_3 (500ppm) (9.51°B) followed by BA (50ppm) (9.46°B) and the lower in 2,4-D (500ppm) (9.39°B) (Table 5). The results obtained are in confirmation with the findings of Sandhu *et al.* (1983) in Kinnow.

Significant increase in the TSS was observed from 5th (8.79°B) to 25th (10.36°B) day of storage. This was because of the concentration of the juice due to the dehydration as stated by Jain and Chauhan (1995) in Kinnow mandarin.

Titrable acidity :

Significantly, the higher titrable acidity was recorded in the BA (50ppm) (0.90 %) followed by the 2,4-D (500ppm) (0.88 %) and lowest in the wax (6%) treated fruits (0.86 %). (Table 5). There was no significant difference in the fruits treated with 2,4-D (500ppm) (0.88 %) and GA_3 (500ppm) (0.87 %). The higher titrable acidity in the benzyl adenine treated fruits could be due to the delay in physiological ageing and alteration in metabolism, which ultimately resulted in the higher retention of acidity. Similar results were observed by the Bhardwaj *et al*. (2005) in Nagpur Santra.

There was a significant decline in titrable acidity from the 5th day (0.92 %) to the 25th day (0.84 %) of storage due to the utilisation of acids in respiration process as reported by the Bhullar *et al.* (1981) in Kinnow mandarin.

Reducing sugars and total sugars :

The reducing sugars were highest in BA (50ppm) treated fruits (2.85 %) followed by those treated with 2,4-D (500ppm) (2.79 %). The highest total sugars were noticed in 2,4-D (500ppm) (5.66 %) and BA (50ppm) (5.60 %) treated fruits while the lowest total sugars were recorded in wax (6%) treated fruits (5.26 %) (Table 6). BA (50ppm) recorded optimum sugar content in the juice and the results are similar to those reported by Bhardwaj *et al*. (2005) in mandarin cv. Nagpur Santra.

There was a significant increase in the reducing and total sugars from 5th to 25th day of storage due to the conversion of acids to sugars as reported by Bhullar *et al.* (1981) in Kinnow mandarin ; Sharma and Dashora (2001) in guava.

Ascorbic acid :

Lower ascorbic acid content was noticed in the wax (6%) (51.20 mg) and higher in the BA (50ppm) treated fruits (54.00 mg) (Table 7). The delayed ripening by Benzyl adenine might have reduced the degradation of ascorbic acid as stated by Bhardwaj *et al*. (2005) in Nagpur mandarin.

A significant declining trend in the ascorbic acid content was noticed from 5th day (58.37 mg) to 25th day (44.94 mg) of storage (Table 7). This was due to the conversion of dehydroascorbic acid

Table 2. Effect of growth regulators on physiological loss in weight (PLW %) and spoilage (%) of sweet orange.

Treatments	PLW (%)						Spoilage (%)					
	Day						Day					
	5	10	15	20	25	Mean	5	10	15	20	25	Mean
T_1 - 2,4-D (500 ppm) + Wax (6%)	4.35	5.61	7.74	12.14	15.54	9.08^{b}	—	—	—	3.33	4.44	3.89^{c}
T_2 - GA_3 (500 ppm) + Wax (6%)	4.38	5.72	7.95	12.30	15.87	9.24^{b}	—	—	—	3.33	5.56	4.44^{b}
T_3 - BA (50 ppm) + Wax (6%)	4.04	6.31	7.41	11.27	15.38	8.88^{b}	—	—	—	2.22	3.33	2.78^{d}
T_4 -Wax (6%)	4.34	6.04	8.90	13.33	16.64	9.85^{a}	—	—	—	5.56	10.00	7.78^{a}
Mean	4.30^{t}	5.92^{s}	8.00^{r}	12.26^{q}	15.86^{p}					3.61^{q}	5.83^{p}	

C.D : significant at p = 0.05 level Means followed by the same letter are statistically not significant

Table 3. Effect of growth regulators on juice content (%) and peel content (%) of sweet orange.

Treatments	Juice content (%)						Peel content (%)					
	Day						Day					
	5	10	15	20	25	Mean	5	10	15	20	25	Mean
T_1 - 2,4-D (500 ppm) + Wax (6%)	46.38	45.00	44.67	41.11	38.67	43.17^{b}	27.51	27.12	26.37	23.46	22.95	25.48^{ab}
T_2 - GA_3 (500 ppm) + Wax (6%)	45.85	45.19	43.46	39.17	36.10	41.96^{c}	27.45	26.47	25.75	23.19	22.54	25.08^{b}
T_3 - BA (50 ppm) + Wax (6%)	46.73	46.01	45.04	43.53	40.61	44.39^{a}	27.96	27.31	26.67	23.68	23.39	25.80^{a}
T_4 -Wax (6%)	45.51	43.94	42.16	37.33	34.88	40.77^{d}	27.12	26.26	25.54	22.23	21.63	24.56^{c}
Mean	46.12^{p}	45.04^{q}	43.83^{r}	40.29^{s}	37.57^{t}		27.51^{p}	26.79^{q}	26.08^{r}	23.14^{s}	22.63^{t}	

C.D : significant at p = 0.05 level Means followed by the same letter are statistically not significant

Table 4. Effect of growth regulators on firmness ($kgcm^{-2}$) and colour index of sweet orange.

Treatments	Firmness ($kg\ cm^{-2}$)						Colour index					
	Day						Day					
	5	10	15	20	25	Mean	5	10	15	20	25	Mean
T_1 - 2,4-D (500 ppm)+ Wax (6%)	7.30	6.87	6.47	6.23	5.80	6.53^{ab}	1.28	1.45	1.73	2.38	2.43	1.86^{c}
T_2 - GA_3 (500 ppm) + Wax (6%)	7.27	6.80	6.60	6.07	5.27	6.40^{bc}	1.31	1.53	1.78	2.44	2.61	1.93^{b}
T_3 - BA (50 ppm) + Wax (6%)	7.33	7.03	6.60	6.30	6.10	6.67^{a}	1.28	1.44	1.72	2.27	2.41	1.82^{c}
T_4 -Wax (6%)	7.23	6.77	6.33	5.60	5.33	6.25^{c}	1.35	1.71	2.23	2.76	2.93	2.19^{a}
Mean	7.28^{p}	6.87^{q}	6.50^{r}	6.05^{s}	5.63^{t}		1.30^{t}	1.53^{s}	1.86^{r}	2.46^{q}	2.60^{p}	

C.D : significant at p = 0.05 level Means followed by the same letter are statistically not significant

Colour score : Green - 1, Yellowish green - 2, Greenish yellow - 3, Yellow – 4, Orange

Table 5. Effect of growth regulators on TSS (°B) and titrable acidity (%) of sweet orange.

Treatments	TSS (°B)						Titrable acidity (%)					
	Day						Day					
	5	10	15	20	25	Mean	5	10	15	20	25	Mean
T_1 - 2,4-D (500 ppm) +Wax (6%)	8.77	8.94	9.21	9.79	10.24	9.39	0.93	0.89	0.87	0.85	0.84	0.88^{b}
T_2 - GA_3 (500 ppm) + Wax (6%)	8.81	9.01	9.35	9.78	10.57	9.51	0.92	0.89	0.86	0.850	0.84	0.87^{bc}
T_3 - BA (50 ppm) + Wax (6%)	8.82	8.97	9.32	9.84	10.38	9.46	0.94	0.92	0.89	0.87	0.86	0.90^{a}
T_4 -Wax (6%)	8.74	9.02	9.45	9.70	10.23	9.43	0.91	0.89	0.85	0.83	0.81	0.86^{c}
Mean	8.79^{t}	8.99^{s}	9.33^{r}	9.80^{q}	10.36^{p}		0.92^{p}	0.90^{q}	0.87^{r}	0.85^{s}	0.84^{s}	

C.D : significant at p = 0.05 level Means followed by the same letter are statistically not significant

Table 6. Effect of growth regulators on reducing sugars (%) and total sugars (%) of sweet orange.

Treatments	Reducing sugars (%)						Total sugars (%)					
	Day						Day					
	5	10	15	20	25	Mean	5	10	15	20	25	Mean
T_1 - 2,4-D (500 ppm)+ Wax (6%)	2.24	2.45	2.83	3.14	3.26	2.79[ab]	4.10	4.69	5.99	6.53	6.99	5.66[a]
T_2 - GA_3 (500 ppm) + Wax (6%)	2.20	2.44	2.62	3.07	3.18	2.69[c]	4.14	4.59	5.73	6.26	6.88	5.52[b]
T_3 - BA (50 ppm) + Wax (6%)	2.35	2.52	2.90	3.18	3.30	2.85[a]	4.05	4.66	5.86	6.50	6.92	5.60[ab]
T_4 -Wax (6%)	2.15	2.35	2.76	2.96	3.07	2.70[bc]	3.84	4.44	5.42	6.14	6.45	5.26[c]
Mean	2.24[s]	2.44[r]	2.78[q]	3.09[p]	3.19[p]		4.03[t]	4.60[s]	5.75[r]	6.36[q]	6.81[p]	

C.D : significant at $p = 0.05$ level Means followed by the same letter are statistically not significant

Table 7. Effect of growth regulators on ascorbic acid content (mg per 100ml) and overall acceptability of sweet orange.

Treatments	Ascorbic acid (mg per 100ml)						Overall acceptability					
	Day						Day					
	5	10	15	20	25	Mean	5	10	15	20	25	Mean
T_1 - 2,4-D (500 ppm)+ Wax (6%)	58.67	57.96	55.51	50.48	44.03	53.33[a]	4.62	4.45	3.54	2.65	1.83	3.42[b]
T_2 - GA_3 (500 ppm) + Wax (6%)	58.88	55.51	53.05	50.74	46.61	52.96[a]	4.57	4.26	3.37	2.54	1.64	3.28[c]
T_3 - BA (50 ppm) + Wax (6%)	59.49	57.96	56.12	50.76	45.36	54.00[a]	4.76	4.57	3.76	2.83	2.01	3.59[a]
T_4 -Wax (6%)	56.43	54.59	52.75	48.48	43.77	51.20[b]	4.38	4.12	3.03	2.36	1.35	3.05[d]
Mean	58.37[p]	56.50[q]	54.36[r]	50.12[s]	44.94[t]		4.58[p]	4.35[q]	3.43[r]	2.60[s]	1.71[t]	

C.D : significant at $p = 0.05$ level Means followed by the same letter are statistically not significant

Overall acceptability score : Highly acceptable - 5, Acceptable - 4, Moderately acceptable - 3 , Slightly acceptable - 2, Not acceptable - 1 furfural by oxidation to hydroxyl furfural as reported by Dhatt *et al.* (1995) in Kinnow.

Overall acceptability :

Significantly highest overall acceptability was observed for the fruits treated with BA (50ppm) (3.59) followed by those treated with 2,4-D (500ppm) (3.42) (Table 7). This may be due to slow buildup of sugars and acids which reflect the flavour and taste component of the fruit. Favourable effects of BA were earlier reported by Prasanna lakshmi *et al.* (2005) in mango fruits.

The overall acceptability scores decreased significantly during storage with highest on 5^{th} day (4.58) and lowest on 25^{th} day (1.71). Similar results have been reported by Prasanna lakshmi *et al.* (2005) in mango fruits.

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