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Effect of bio-regulators on storage life of plum (*Prunus salicina*) var. Santa Rosa at different conditions

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ABSTRACT

The effect of plant bio-regulators, viz. salicylic acid (200ppm), Ca-EDTA (0.4%), thyme oil (100 ppm) and control (distilled water dip) on the postharvest shelf life of plum (*Prunus salicina* L.) var. Santa Rosa was studied at ambient (18-20^{o}C and 85-90% RH) and low temperature (2^{o}C and 90% RH) conditions for 20 and 55 days respectively. The fruits treated with Ca-EDTA had better retention of firmness followed by salicylic acid and control at ambient and low temperature storage conditions. The highest (22.19%) physiological loss in weight (PLW) was observed in the plum fruits dipped in distilled water as compared to 14.97% in salicylic acid and 15.74% in thyme oil at ambient conditions after 20 days of storage. The maximum and minimum PLW of 3.95 and 2.60% was recorded in the above treatments at low temperature after 55 days of storage. The TSS of the fruits dipped in water and stored at ambient conditions were found to increase for 14 days followed by reduction as compared to other treatments where the TSS increased for 20 days. The maximum reduction in ascorbic acid from 13.64 mg/100g to 8.64 mg/100g was recorded in the water dipped plum fruits stored at ambient conditions for 20 days as compared to the same treatment under low temperature where the reduction was observed from 13.65 to 12.38 after 55 days of storage. The total sugars in the water dipped (control) fruits was found to increase for 6 days followed by decrease at ambient conditions. The fruits treated with salicylic acid showed increase in sugars at the slowest rate compared to Ca-EDTA and thyme oil in both the storage conditions. At both the storage conditions the retention of the antioxidants was better in the SA treated fruits followed by Ca-EDTA and thyme oil.

Key words: Antioxidants, Bio-regulators, Plum, Storage, Temperature

Although, the production of plum (*Prunus salicina* L.) is increasing due to improved horticultural practices and production technologies, the improper handling, storage, transportation and marketing pose a serious problem during glut resulting in huge postharvest losses restricting the farmers to fetch good prices. The fruit is generally, harvested manually or by shaking the trees which renders most of the fruits unfit because of injury. As the fruit is climacteric in nature and highly perishable, its availability is restricted for a short period and during transport the produce is likely to be spoiled. Among the different cultivars being grown, the fruits of Santa Rosa are comparatively bigger and juicy with thick skin making it possible to send the produce to the distant markets. Harvesting of fruits in a short period used to create glut in the market because of which the growers don't get remunerative returns for their produce. The plum matures at a time when both temperature and humidity in the air are quite high because of which the harvested fruits ripen very fast. Use of plant bio-regulators like salicylic acid as well as calcium present in fruits play a significant role in enhancing the postharvest shelf life of a number of fruits. Salicylic acid, which is also known as 2-hydroxybenzenecarboxcylic acid, is an organic acid which functions as plant hormone enhancing fruit postharvest life by controlling their firmness. Calcium is thought to be the most important mineral element determining the fruit quality. It helps maintaining fruit firmness and decreases the incidence of physiological disorders (Conway *et al*. 1998). Calcium is one of the most significant fruit tree nutrients but it is very difficult to accumulate enough in the fruit because of its less mobility in the plant. Its accumulation is more during the fruit development but tends to decrease in the latter phase (Cline and Hanson 1991). It is an essential component for plant cell function and plant tissue integrity. Conway and Sams (1987) suggested that calcium treatment significantly reduced the rate of ripening as a result of enhanced endogenous levels of auxin and cytokinin. It alters

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intra-cellular and extra-cellular processes which retard ripening exemplified by lower rates of colour change, softening, CO_2 and ethylene production, increase in sugar and a reduction in total acid content. Similarly, thyme oil is also known to increase the shelf life of the fruit by restricting the physiological process. To study the effect of salicylic acid (SA), Calcium-Ethylene diamene tetra acetic acid (Ca-EDTA) and thyme oil on the physico-chemical characters of Santa Rosa cultivar of plum during storage at ambient and low temperature the present investigations were undertaken.

MATERIALS AND METHODS

The present study was undertaken during 2010-11 at Central Institute of Temperate Horticulture - Regional Station, Mukteshwar which is situated at 2 200 m above mean sea level in Nainital district of Uttarakhand.

The matured and uniform fruits of Santa Rosa plum were procured from local area of Mukteshwar. After sorting out the uniform and matured fruits were selected on the basis of water dip method.

The total treatments were 4 (F_1) which included each with salicylic acid (200ppm), Ca-EDTA (0.4%), thyme oil (100 ppm) and control (distilled water dip). The concentration of the bio-regulators was selected on the basis of earlier work carried out in other temperate fruits as the higher concentration spoiled the fruits, whereas lower had insignificant effect. The selected fruits in each treatment were dipped for 30 minutes in aqueous solutions of bio-regulators. The treated fruits were subjected to air drying in shade at room temperature followed by storage in the corrugated fibreboard boxes (CFB) at ambient temperature (18-20^{o}C as F_2) having relative humidity of 85-90% and low temperature (2^{o}C and 90% RH as F_2). The storage study was conducted for 20 days at ambient conditions, whereas it continued for 55 days at low temperature as stored the fruits remained marketable till that period.

The physiological loss in weight (%PLW) of the marked fruits in each treatment was recorded at regular interval on initial weight basis. The firmness of the fruits was observed with fruit pressure tester model FT 327 and the results were expressed as lb/in^2. The fruits as well as extracted juice was subjected to physical characters analysis, viz. weight (g), length (cm), breadth (cm), pulp (%), and peel (%), stone (%) by following standard methods (Ranganna 2000). Similarly, the total soluble solids (TSS) of the pulp were recorded with hand refractometer (Erma, Japan) corrected at 20^{o}C, acidity (%) by titrating a known volume of aliquot against N/10 NaOH using phenolphthalein as indicator as described by Ranganna (2000). The reducing and total sugars (%) of the juice were estimated as per the methods of AOAC (1990). The ascorbic acid contents (mg/100g) were recorded by titrating a known volume of juice with metaphosphoric acid against 2,6 dicholophenol indophenol dye (Ranganna 2000) and were expressed as mg/100g juice.

The total antioxidants in the plum fruits stored at ambient and low temperature were measured as per the method of Apak *et al*. (2004) and expressed as m mol Trolox® per litre, or mM TE.

The experiment was undertaken in completely randomized block design replicated four times. Data on physico-chemical characteristics of Santa Rosa plum during storage both at ambient and low temperature were analysed by completely randomized design (CRD) factorial as described by Mahony (1985).

RESULTS AND DISCUSSION

Physico-chemical characters

The physico-chemical characters of Santa Rosa plum revealed an average weight of 48.45g having a length of 4.87cm and breadth 4.53cm. The fruit had 91.50, 5.60 and 2.90% pulp, peel and stone respectively. The TSS of the pulp was recorded 12.4^o B and acidity 1.657%. The ascorbic acid was observed as 13.64mg/100g, whereas the reducing and total sugars were found 3.34 and 9.09% respectively. In Santa Rosa plum fruit, size of 3.44 cm as length and diameter, weight 28.20 g and stone to pulp ratio of 17.73 have been recorded by Mehta and Jindal (1984). Similarly, Raj *et al*. (2012) recorded TSS of 14.17% along with acidity of 2.01%, whereas Sahani *et al*. (1994) have observed 14.10 and 4.32% total and reducing sugars with 10.40 mg/100 g ascorbic acid in Santa Rosa plum.

Fruit firmness

Among the different treatments, storage period and interaction between treatments and storage period a significant reduction in the firmness of the fruits was recorded both at ambient and low temperature with a faster rate in the former than latter. The fruits treated with Ca-EDTA had better retention of firmness followed by salicylic acid and control at ambient and low temperature storage conditions for 20 and 55 days respectively (Table 1). The maximum retention of the firmness in the fruits treated with Ca may be due to checking the breakdown of insoluble protopectin thereby maintaining the firmness better as compared to other treatments. The exogenous application of salicylic acid inhibited the respiration rate and delayed the ethylene production peak of ripening peaches at ambient storage conditions (Han *et al*. 2003). The plum fruits treated with Ca $(NO_3)_2$ (0.5, 1.0 and 2.0%) and stored at low temperature revealed that the fruits treated with 2% Ca $(NO_3)_2$ recorded the highest firmness throughout the storage as compared to control signifying the utility of calcium nitrate during transit and marketing (Mahajan *et al*. 2008). In peach 200 ppm salicylic acid had a significant effect on firmness and quality during five weeks of storage (Tareen *et al*. 2012).

Physiological loss in weight

The highest (22.19%) physiological loss in weight (PLW) was observed in the plum fruits dipped in distilled water as compared to 14.97% in salicylic acid and 15.74 in thyme oil at ambient conditions after 20 days. The maximum and minimum PLW of 3.95 and 2.60% was recorded in the above treatments at low temperature after 55 days (Table 2).

Table 1 Effect of salicylic acid, calcium and thyme oil on firmness (lb/in²) of plum during storage at different conditions

Treatment (F_1)	Ambient temperature							Low temperature										
	Storage period (F_2)							Storage period (F_2)										
	0	3	6	9	14	20	Mean (F_1)	0	3	6	9	14	20	29	34	46	55	Mean (F_1)
1	7.5	7	6.8	5.8	4.9	3.5	5.92	7.5	7.4	7	6.9	6.7	6.2	6	5.6	5.3	5	6.36
2	7.4	7.2	7	6.4	5.6	4.2	6.30	7.4	7.4	7.2	7	6.8	6.4	6.2	5.8	5.4	5.2	6.48
3	7.5	6.5	5.2	4	3	2.2	4.74	7.5	7.4	7	6.8	6.5	6	5.7	5.4	5.1	4.8	6.22
4	7.4	5.8	4.2	3	2	1	3.90	7.4	7.2	6.8	6.4	6	5.7	5.3	5.1	4.6	4.2	5.87
Mean (F_2)	7.45	6.63	5.8	4.8	3.87	2.73		7.45	7.35	7	6.775	6.5	6.075	5.8	5.475	5.1	4.8	
CD (P=0.05)	F_1=0.067, F_2= 0.082, F_1×F-$_2$=0.164							F_1= 0.054, F_2=0.085, F_1 × F-$_2$=0.171										

Table 2 Physiological loss in weight (%PLW) in plum during storage at ambient and low temperature conditions

Treatment (F_1)	Ambient temperature							Low temperature										
	Storage period (F_2)							Storage period (F_2)										
	0	3	6	9	14	20	Mean (F_1)	0	3	6	9	14	20	29	34	46	55	Mean (F_1)
1	0	4.21	11.5	15.77	18.12	25.25	14.97	0	0.74	1.12	1.5	1.76	2.27	3.18	3.42	4.39	5.02	2.6
2	0	5.01	12.16	16.79	19.22	26.4	15.92	0	0.82	1.45	1.83	2.07	2.85	3.36	3.84	4.82	5.24	2.92
3	0	4.52	11.44	16.46	19.11	27.17	15.74	0	0.9	1.67	2.09	2.64	3.18	3.69	4.14	4.97	5.77	3.23
4	0	7.83	15.87	23.06	29.37	34.81	22.19	0	1.41	1.89	2.85	3.47	3.98	4.67	4.96	5.63	6.68	3.95
Mean (F_2)	0	5.39	12.74	18.02	21.45	28.41		0	0.9675	1.5325	2.0675	2.485	3.07	3.725	4.09	4.9525	5.6775	
CD P=(0.05)	F_1=0.021, F_2= 0.026, F_1 × F-$_2$=0.052							F_1= 0.013, F_2= 0.020, F_1 × F-$_2$= 0.040										

At both the conditions the results were found significant for treatments, storage period and their interaction. The lower rate of transpiration, hence, less moisture loss at low temperature was probably responsible for lower mean weight loss in the fruits treated with bio-regulators and stored at low temperature compared to those at ambient conditions. Lower weight loss in fruits of plum stored in ZECC as compared to fruits stored at ambient conditions has also been reported by Sharma *et al*. (2010).

Total soluble solids

A significant difference among the different treatments, storage period and their interaction at ambient and low storage conditions was recorded in the TSS of the fruits. The TSS of the fruits dipped in water and stored at ambient conditions were found to increase for 14 days followed by reduction as compared to other treatments where the TSS increased for 20 days. Under low temperature similar trend was observed but the increase in the TSS was at slower rate (Table 3). The minimum increase in the TSS in the fruits treated with salicylic acid and Ca-EDTA may be due to the restriction in the physiological process and respiration during storage thereby maintaining the total soluble solids better as compared to the fruits under control. As the respiration rate in the untreated fruits was high, the conversion of the un-dissolved compounds to dissolved particles may be high resulting in higher TSS. On the other hand, in the treated fruits, as the respiration rate was checked, the conversion was also delayed with better firmness of the fruits. The results are in conformity with those reported by Mahajan *et al*. (2004) in Asian pear.

Acidity

Unlike the total soluble solids, the acidity (%) of the fruits was found to decrease significantly in the treatments, storage period and their interaction. The acidity in the fruits under control irrespective of the storage conditions was found to decrease faster as compared to the fruits treated with SA, Ca-EDTA and thyme oil (Table 4). As the respiration was checked due to exogenous application of bio-regulators, the acidity was found to remain under control. These results are in line with those reported by Banik *et al*. (1988) where it has been mentioned that retention of high acidity means slow ripening. Low temperature inside the refrigerator slowed down the physiological process leading to minimal non-enzymatic browning thus

Table 3 TSS (°B) of plum affected by bio-regulators at different storage conditions

Treatment (F_1)	Ambient temperature							Low temperature										
	Storage period (F_2)							Storage period (F_2)										
	0	3	6	9	14	20	Mean (F_1)	0	3	6	9	14	20	29	34	46	55	Mean (F_1)
1	12.4	12.8	13	13.2	13.6	13.8	13.13	12.4	12.6	12.8	13	13	13.1	13.2	13.3	13.4	13.6	13.04
2	12.6	13	13.2	13.6	13.8	14	13.37	12.6	12.8	12.8	13	13	13.2	13.2	13.4	13.5	13.8	13.13
3	12.6	13	13.4	13.8	13.4	12.6	13.13	12.6	12.8	12.8	13	13.1	13.3	13.4	13.5	13.7	13.8	13.2
4	12.4	13.2	13.8	13	12.6	10.4	12.57	12.4	13	13.2	13.2	13.3	13.4	13.5	13.6	13.8	14	13.34
Mean (F_2)	12.5	13	13.35	13.4	13.35	12.7		12.5	12.8	12.9	13.05	13.1	13.25	13.325	13.45	13.6	13.8	
CD P=(0.05)	F_1= 0.067, F_2= 0.083, F_1×F_2=0.165							F_1= 0.418, F_2= 0.660, F_1 × F_2= 0.321										

Table 4 Effect of salicylic acid, calcium and thyme oil on acidity (%) in Santa Rosa plum at different storage conditions

Treatment (F_1)	Ambient temperature							Low temperature										
	Storage period (F_2)							Storage period (F_2)										
	0	3	6	9	14	20	Mean (F_1)	0	3	6	9	14	20	29	34	46	55	Mean (F_1)
1	1.675	1.641	1.507	1.407	1.273	1.072	1.430	1.675	1.675	1.668	1.664	1.66	1.657	1.652	1.645	1.632	1.608	1.654
2	1.67	1.608	1.407	1.34	1.173	1.005	1.370	1.67	1.668	1.66	1.655	1.65	1.646	1.64	1.634	1.623	1.59	1.644
3	1.705	1.624	1.44	1.374	1.206	1.038	1.400	1.682	1.65	1.648	1.64	1.632	1.622	1.615	1.604	1.598	1.575	1.627
4	1.641	1.541	1.34	1.273	1.005	0.837	1.273	1.667	1.662	1.645	1.635	1.626	1.617	1.608	1.592	1.565	1.54	1.616
Mean (F_2)	1.673	1.604	1.424	1.349	1.165	0.988		1.6735	1.664	1.655	1.648	1.642	1.6355	1.629	1.619	1.604	1.578	
CD (P=0.05)	F_1= 0.005, F_2= 0.006, F_1×F_2=0.013							F_1= 0.001, F_2= 0.002, F_1xF_2= 0.003										

preventing the utilization of acids (Sagar *et al.* 1999).

Ascorbic acid

There was a significant reduction in the ascorbic acid in all the treatments irrespective of storage conditions. The reduction was observed at a faster rate in the fruits dipped in water as compared to those treated with SA, Ca-EDTA and thyme oil. The maximum reduction from 13.64 mg/100g to 8.64 mg/100g was recorded in the water dipped plum fruits stored at ambient conditions for 20 days as compared to the same treatment under low temperature where the reduction was observed from 13.65 to 12.38 after 55 days of storage (Table 5). In the other treatments in both the conditions the reduction rate was very slow. As SA and Ca-EDTA had restricted the process of ripening, the retention of the ascorbic acid was attributed due to slow rate of ripening. The postharvest dip of calcium chloride, calcium lactate and calcium propionate helped to increase the shelf life significantly with reduced ethylene production of peach stored in cold storage for 4 weeks (Manganarisa *et al.* 2007). The loss of ascorbic acid during storage could be attributed to its oxidation and enzymatic degradation (Kumar *et al.* 2012).

Sugars

Increase in reducing and total sugars during storage in all the treatments, storage period and interaction between them irrespective of the storage conditions was observed with a faster increase in the water dipped fruits both at ambient and low temperature conditions. The total sugars in the water dipped (control) fruits was found to increase for 6 days followed by decrease at ambient conditions. The fruits treated with salicylic acid showed increase at the slowest rate compared to Ca-EDTA and thyme oil in both the storage conditions (Table 6 and 7). The increase in the reducing and total sugars was probably due to the hydrolysis of starch as well as other complex carbohydrates to simpler sugars. Increase in reducing and total sugars during storage might be attributed to the inversion of non-reducing sugars and other polysaccharides into reducing sugars. The results are in conformity with those reported by Knee and Smith (1989) in apple fruits. On complete hydrolysis of starch, no further increase in TSS and sugars occurs and consequently a decline in these parameters is predictable as they are the primary substrates in respiration (Wills *et al.* 1980). The PLW,

Table 5 Ascorbic acid (mg/100g) of plum affected by salicylic acid, calcium and thyme oil during storage

Treatment (F_1)	Ambient temperature							Low temperature										
	Storage period (F_2)							Storage period (F_2)										
	0	3	6	9	14	20	Mean (F_1)	0	3	6	9	14	20	29	34	46	55	Mean (F_1)
1	13.64	12.73	11.82	9.09	9.09	7.27	10.61	13.64	13.64	13.6	13.58	13.5	13.24	13.1	12.8	12.1	11.4	13.06
2	13.64	11.82	9.99	9.09	8.18	5.45	9.70	13.6	13.58	13.55	13.48	13.4	13.12	12.9	12.5	11.7	11.1	12.89
3	13.64	12.27	10.91	9.09	8.18	6.36	10.08	13.68	13.6	13.5	13.36	13.18	12.95	12.72	12.25	11.2	10.6	12.70
4	13.64	10.91	9.09	7.27	6.36	4.55	8.64	13.65	13.5	13.42	13.2	13.04	12.6	12.2	11.8	10.9	9.5	12.38
Mean (F_2)	13.64	11.94	10.46	8.64	7.96	5.91		13.65	13.58	13.52	13.41	13.28	12.98	12.73	12.34	11.47	10.65	
CD (P=0.05)	F_1= 0.021, F_2= 0.026, $F_1 \times F_2$=0.052							F_1= 0.013, F_2 = 0.020, $F_1 \times F_2$ = 0.040										

Table 6 Effect of salicylic acid, calcium and thyme oil on reducing sugars (%) of plum during storage at different conditions

Treatment (F_1)	Ambient temperature							Low temperature										
	Storage period (F_2)							Storage period (F_2)										
	0	3	6	9	14	20	Mean (F_1)	0	3	6	9	14	20	29	34	46	55	Mean (F_1)
1	3.34	3.57	4.0	4.13	4.23	4.54	3.97	3.34	3.35	3.36	3.4	3.48	3.56	3.62	3.7	3.88	3.94	3.563
2	3.34	3.7	4.18	4.23	4.38	4.71	4.09	3.36	3.38	3.4	3.44	3.54	3.65	3.74	3.84	3.96	4.08	3.639
3	3.34	3.62	4.06	4.2	4.31	4.67	4.03	3.36	3.38	3.4	3.44	3.54	3.65	3.74	3.84	3.96	4.08	3.639
4	3.34	4.18	4.54	4.46	4.16	3.96	4.11	3.34	3.42	3.45	3.58	3.66	3.75	3.88	4.06	4.16	4.26	3.756
Mean (F_2)	3.34	3.77	4.20	4.26	4.27	4.47		3.34	3.39	3.41	3.48	3.56	3.67	3.76	3.89	4.02	4.12	
CD (P=0.05)	F_1= 0.019, F_2= 0.024, $F_1 \times F_2$=0.048							F_1= 0.012, F_2= 0.019, $F_1 \times F_2$= 0.038										

Table 7 Effect of bio-regulators on total sugars (%) of plum at ambient and low temperature storage conditions

Treatment (F_1)	Ambient temperature							Low temperature										
	Storage period (F_2)							Storage period (F_2)										
	0	3	6	9	14	20	Mean (F_1)	0	3	6	9	14	20	29	34	46	55	Mean (F_1)
1	9.09	9.52	10	10.3	10.52	11.11	10.09	9.09	9.12	9.15	9.32	9.4	9.48	9.57	9.65	9.82	9.86	9.45
2	8.88	9.75	10.52	10.63	10.98	11.42	10.36	9.1	9.15	9.2	9.45	9.54	9.64	9.8	9.87	10.02	10.12	9.59
3	9.00	9.66	10.41	10.52	10.86	11.29	10.29	9.08	9.2	9.24	9.54	9.62	9.74	9.88	9.97	10.14	10.32	9.67
4	8.88	10.00	11.11	10.2	9.66	9.1	9.83	9.09	9.24	9.28	9.6	9.72	9.9	10.02	10.12	10.29	10.46	9.77
Mean (F_2)	8.97	9.74	10.51	10.42	10.51	10.73		9.09	9.18	9.22	9.48	9.57	9.69	9.82	9.90	10.07	10.19	
CD (P=0.05)	F_1=0.079, F_2= 0.096, $F_1 \times F_2$=0.193							F_1= 0.015, F_2= 0.024, $F_1 \times F_2$= 0.048										

Table 8 Total antioxidants (mMTE/L) of plum affected by salicylic acid, calcium and thyme oil during storage

Treatment (F_1)	Ambient temperature							Low temperature										
	Storage period (F_2)							Storage period (F_2)										
	0	3	6	9	14	20	Mean (F_1)	0	3	6	9	14	20	29	34	46	55	Mean (F_1)
1	14.29	14.24	10.85	9.55	8.62	5.97	10.59	14.29	14.20	14.10	14.00	13.75	13.46	13.15	12.98	12.25	11.80	13.40
2	14.34	14.16	9.84	9.12	7.83	5.65	10.16	14.34	14.26	14.05	13.90	13.50	13.32	13.00	12.82	12.08	11.20	13.25
3	14.30	14.19	10.38	9.40	8.00	5.87	10.36	14.29	14.08	14.00	13.65	13.30	12.95	12.40	11.88	11.30	10.70	12.85
4	14.34	13.50	9.08	6.01	4.98	4.32	8.71	14.34	13.92	13.80	13.30	12.85	12.45	12.04	11.70	11.05	10.20	12.56
Mean (F_2)	14.32	14.03	10.04	8.52	7.36	5.46		14.32	14.12	13.99	13.71	13.35	13.05	12.65	12.35	11.67	10.97	
CD (P=0.05)	F_1= 0.021, F_2= 0.026, $F_1 \times F_2$=0.052							F_1= 0.025, F_2= 0.039, $F_1 \times F_2$= 0.078										

firmness and acidity of the plum fruits at various conditions were found to decrease whereas TSS increased during 15 days storage (Sharma *et al*. 2010).

Total antioxidants

The total antioxidants in the plum fruits under the study exhibited a significant decrease during storage at both the conditions with a faster rate in the fruits under control compared to those treated with SA, Ca-EDTA and thyme oil. At both the storage conditions the retention of the antioxidants was better in the SA treated fruits followed by Ca-EDTA and thyme oil (Table 8). The reduction in the antioxidant contents may be attributed to the over ripening of the fruit thereby breakdown of these contents. The shelf life of different cultivars of peach was found to increase significantly by postharvest application of SA and Ca-EDTA as compared to control (Attri *et al*. 2010).

From the present study it can be concluded that the plum fruits, which are having a very short postharvest shelf life, can be increased substantially by the use of plant bio-regulators like salicylic acid, Ca-EDTA and thyme oil and storing at ambient as well as low temperature thereby increasing the availability of quality fruits for a longer duration in the market.

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