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The effect of different concentrations of pre-harvest gibberellic acid on the quality and durability of 'Obilnaja' and 'Black Star' plum varieties

Yunus HARMAN[1], Fatih SEN[1*]

Abstract

The research work aimed at investigating the effect of pre-harvest gibberellic acid (GA_3) treatment on the quality of 'Obilnaja' and 'Black Star' Japanese plum varieties. GA_3 was sprayed onto the trees during the fruit color break at 0, 25, 50, 75, and 100 ppm concentrations. After pre-cooling, the plums were placed in modified atmosphere packages and exposed to the following conditions as follows: short storage-transportation (ST) [20 days at 2 °C and 90% relative humidity (RH)]; distribution center (DC) (5 days at 6 °C and 80% RH), and shelf life conditions (SL) (2 days at 20 °C and 70% RH). Pre-harvest GA_3 treatments increased the fruit weight and size. Treatment of GA_3 at 50, 75, and 100 ppm increased the fruit flesh firmness and total soluble substances (TSS) values in both the plum varieties during storage, transport, and marketing; it also limited the weight loss during the marketing process. Treatment of GA_3 had no significant effects on the color, titratable acidity (TA), and the total phenolic and antioxidant activity values of plums. Pre-harvest GA_3 treatment at 50 ppm GA_3 can be thus recommended for both the plum varieties due to its effect on the fruit quality.

Keywords: *Prunus salicina*; GA_3 treatments; marketing; flesh firmness; chemical composition.

Practical Application: The production and marketing of Japanese plums is increasing world-wide. Extending the post-harvest durability without reduction in quality is of utmost importance for all stakes in plum business. The results presented in the paper showed that 50 ppm treatment of GA_3 will reduce losses during post-harvest handling of plums and contribute to marketing through firmer fruit as demanded by consumers.

1 Introduction

Japanese plums are produced for fresh consumption, and their varieties differ significantly in shape, size, taste, appearance, and postharvest durability (Venter et al., 2013). Earlier studies on the quality and storage of Japanese plums were focused on the 'Angelina' variety (Erkan et al., 2005; Ozkaya et al., 2005; Kaynas et al., 2010; Erogul & Sen, 2015). Enhancing the quality and postharvest durability of other Japanese plums is of great importance for increasing their consumption. One of the negative postharvest developments in these plum varieties is the softening of the fruit flesh (Abdi et al., 1998), which limits the enjoyment of consumption of the plum fruit and shortens its postharvest life. Delaying and slowing of the softening of fruit flesh is particularly important in extending the storage and shelf life (SL) of plum fruit.

The increase in the production of midseason Japanese plum varieties suitable for short-term storage and transport requires the protection of fruit quality during short-term storage and marketing process. The quality of storage and marketing of plum fruits differs significantly with the varieties, growth conditions, care, harvesting, and postharvest conditions (Crisosto & Mitchell, 2002). Pre-harvest treatments can directly affect the fruit quality and postharvest durability, including treatment of gibberellic acid (GA_3) in stone fruits during the cultivation period. GA_3 treatments, which are performed on several orchard products during pre-harvest cultivation periods, can directly affect the fruit quality and postharvest durability. Moreover, it is believed that GA_3 may also affect the SL of fruits (Krisha et al., 2012). It is important to determine the effect of GA_3 treatments on the quality and physical, chemical, and biochemical properties of fruits during storage and marketing.

It has been reported that 50 and 100 ppm GA_3 treatments performed over 106 days after anthesis increased the fruit diameter and average weight (González-Rossia et al., 2006). GA_3 applied after flowering was found to increase the fruit firmness (Webster & Spencer, 2000; Webster et al., 2006; Lenahan et al., 2006) and total soluble substances (TSS) content (Lenahan et al., 2006). Pre-harvest GA_3 treatments increased the weight of apricot fruit (Southwick et al., 1997) and the diameter, coloring, TSS content, and flesh firmness of peaches and nectarines (González-Rossia et al., 2007; García-Pallas et al., 2001; Coneva & Cline, 2006; Cetinbas & Koyuncu, 2013). It was reported that GA_3 treatments in several citrus species led to a delay in peel aging, softening, and deterioration as well as a decrease in the risk of disease (El-Otmani & Coggins, 1991; Garcia-Luis et al., 1992; Pozo et al., 2000; El-Otmani et al., 2000; Tumminelli et al., 2005; Sen et al., 2009, 2013).

In this study, we investigated the effect of pre-harvest GA_3 treatment on the fruit quality of 'Obilnaja' and 'Black Star' plum varieties during storage, transport, and marketing processes.

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[1] Department of Horticulture, Faculty of Agriculture, Ege University, Bornova, İzmir, Turkey
*Corresponding author: fsenmacar@gmail.com

2 Materials and methods

2.1 Material

The experiment was conducted in 2014 on fruits harvested from 6-year-old 'Obilnaja' and 'Black Star' plum trees (*Prunus salicina* Lindl.) grafted onto 'Myrobalan 29 C' rootstock in Salihli (Manisa Province, Turkey). These trees were pollinator varieties in the orchard, which was established in a planting density of 4.5 × 4.5 m.

2.2 GA_3 treatment

GA_3 (1 g GA_3/tablet; ProGibb® G.A., Sumitomo Chemical, Japan) were applied in the color-change period at four different concentrations of 25, 50, 75, and 100 ppm. Spreader adhesive (0.04% Nu-Film-17®; Miller Chemical Corp., USA) was used in all treatments. Trees sprayed only with water containing spreader adhesive were considered as controls. All treatments were performed in the late afternoon/evenings, and the crown of each tree was soaked with 10 L of the GA_3. The study was set-up with three repetitions, according to the randomized complete block experimental design, and every three trees comprised a repetition.

2.3 Packaging and storage

'Obilnaja' and 'Black Star' plum fruits were harvested at firm-ripe stage (24 June and 21 July 2014, respectively) and pre-cooled with air (until the fruit pulp temperature reached 2 °C) on the same day. Fruits of uniform sizes that were disease-free and without other defects were selected, placed into modified atmosphere packages (MAPs; LifePack, Aypek, Bursa, Turkey), and the packages were sealed tightly. MAPs were placed into cardboard boxes and subjected to the following treatment stages: a) short storage-transportation (ST; 20 days at 2 ± 0.5 °C and 90 ± 5% relative humidity; RH) that included the pre-stage at the packing house; b) distribution center (DC; 5 days at 6 ± 0.5 °C and 80 ± 5% RH), and c) SL (2 days at 20 ± 1.0 °C and 70 ± 5% RH) to simulate the real conditions encountered during marketing. Considering the actual transportation to the distant markets (e.g., from Turkey to the United Kingdom), DCs, and the prevailing marketing conditions, the duration of the exposure and ambient conditions were defined. Fruit samples were collected at the end of each stage and subjected to physical, and chemical analyses. The research was designed as a randomized block design with 3 replications, and each MAP package (3 kg of plump fruits) was considered as a single replication.

2.4 Quality attributes

A total of 20 fruits from each of the three replications for each treatment were used to determine the mean fruit weight by precision (electronic) scale (XB 12100; Presica Instruments Ltd., Switzerland, 0.05 g accuracy) and the fruit diameter by digital compass (SC-6; Mitutoyo, Japonya).

Plum samples were weighted at the initial phase and at the end of T, DC, and SL stages on the electronic scale, and the weight loss was determined and expressed as percent loss from the initial weight.

Fruit firmness was determined on the opposite sides of 20 fruits after removing the peels using an Effegi penetrometer (FT 011; Effegi, Japan) with a 7.9-mm diameter tip; the data were calculated as the means of the measurements from each fruit sample and expressed in Newtons (N).

Fruit skin color were determined at the equatorial level on both the sides of 15 fruit using a colorimeter (CR-400; Minolta Co., Osaka, Japan), which provided CIE L*, a*, and b* values. These values were then used to calculate Chroma ($C^* = [a^{*2} + b^{*2}]^{1/2}$), which indicated the intensity or color saturation and hue angle ($h° = \tan^{-1} [b^*/a^*]$), which is expressed in degrees: 0° (red-purple), 90° (yellow), 180° (bluish–green), and 270° (blue) (McGuire, 1992).

Juice collected from 10 fruits was used for the determination of TSS and titratable acidity (TA) as previously described by Singh et al. (2009). The juice SSC was measured with a temperature-compensated digital refractometer (PR-1; Atago, Tokyo, Japan) and expressed in percent. TA was determined by titrating 10 mL of the juice with 0.1 N NaOH to an endpoint of pH 8.1 and expressed as in percent of malic acid.

2.5 Total phenolic content and antioxidant activity

Fruit extracts were prepared using the methods of Thaipong et al. (2006), with slight modifications for total phenol content and antioxidant activity (in methanol extract) analysis. Total phenol content was determined as per the Folin–Ciocalteu method (based on the methods of Swain & Hillis, 1959), with an incubation period of 120 min for color development. The absorbance was measured at 725 nm by a spectrophotometer (Carry 100 Bio; Varian, Mulgrave, Australia), and the results were expressed in milligram gallic acid equivalent (GAE)/100 g fresh weight (fw) using a gallic acid (0-0.1 mg/mL) standard curve.

The ferric reducing ability of plasma (FRAP) assay was performed as previously described by Benzie & Strain (1996). In this method, reductants (antioxidants) in the sample reduce the Fe (III)/tripyridyltriazine complex to its blue ferrous form, thereby increasing absorbance at 593 nm. The final results are expressed in mol Trolox equivalents (TE)/g fresh weight (fw) using a Trolox (25-500 mol) standard curve.

2.6 Physiological and pathological disorders

In order to determine the physiological and pathological disorders in each repetition of treatment, the fruits were examined and the deteriorated fruits were counted; the deterioration rate was expressed in percent.

Decay development was examined and their rates were expressed in percent.

2.7 Statistical analysis

All data were subjected to the analyses of variance (ANOVA) by using the IBM® SPSS® Statistics 19 statistical software. Significant differences between the means for each group of Japanese plum fruits were determined by Duncan's multiple range tests at $P < 0.05$. Standard deviation of the mean (SD) was also calculated from the replicates.

3 Results and discussion

The changes in the average weight and diameter of 'Obilnaja' and 'Black Star' plums for each treatment are shown in Table 1. Treatments of GA_3 in different concentrations showed a significant effect on the fruit weight and diameter in both the plum varieties. The fruit weights of 'Obilnaja' and 'Black Star' plums increased by 8.31% and 9.80%, respectively, by GA_3 treatments, as compared with controls. The fruit diameter in both the plum varieties with GA_3 applied at concentrations of 50, 75, and 100 ppm was higher than that of the respective controls, whereas the fruit diameter in the 25-ppm treatment groups was between that of the higher concentration groups and of the corresponding controls. Fruit diameters of 'Obilnaja' and 'Black Star' plums were 50.01 and 55.04 mm, respectively, in the control samples, while the fruit diameter values for 25-ppm GA_3 treatments were 52.17-52.92 and 57.73-58.80 mm, respectively. Similarly, 50- and 100-ppm GA_3 treatments have been reported to improve the mean weight and diameter of the 'Black Diamond' and 'Black Gold' Japanese plum varieties (González-Rossia et al., 2006). Pre-harvest GA_3 treatments have been reported to increase the plum (cv. Angelino) sizes (Erogul & Sen, 2015). Previous studies have reported increased fruit weight and size for 'Crimson Gold' nectarine (García-Pallas et al., 2001), 'Patterson' apricot (Southwick et al., 1997), and peaches and nectarines (González-Rossia et al., 2007).

Weight loss is a factor that limits the storage life of the plum fruit (Table 2). The effect of GA_3 treatments on the weight loss in both the plum varieties was significant after DC and SL; however, not significant in ST. When GA_3 was applied, the weight losses in 'Obilnaja' and 'Black Star' varieties after SL were 14.58% and 12.50% lower than those of the controls, respectively. Similarly, 50-, 75-, and 100-ppm GA_3 treatments limited the weight loss after DC, as compared to controls. Smaller sizes of control samples, as compared to GA_3-applied samples, were effective in achieving higher weight loss values after distribution and SL (Wills et al., 1998). Similarly, it was reported that the pre-harvest GA_3 treatments limited the postharvest weight loss in apples (Krisha et al., 2012). In addition, the ripening process is reported to slow down with pre-harvest GA_3 treatments in cherry (Horvitz et al., 2003) and peach (Han et al., 2003). Such increases became distinctive especially after the SL stage. Lower weight loss in the ST and DC stages can be attributed to the use of MAP packages (Erkan & Eski, 2012; Singh & Singh 2012; Wani et al., 2014) and the limited moisture loss under ambient conditions of temperature and RH. Weight loss during the SL stage was higher than that at the ST and DC stages in this study when the MAP packages were open, and the ambient temperature was high (20 °C and RH was low (70%) during SL for 2 days.

Fruit firmness is directly associated with the mechanical resistance and storage potential. During postharvest, pectins break down and fruits soften, which in turn shortens the storage and SL of the fruits (Peirs et al., 2000). The initial fruit flesh firmness values of GA_3-applied 'Obilnaja' and 'Black Star' plum fruits were higher than those of their control groups. This effect was more evident in 50, 75, and 100 ppm GA_3 samples. The positive effects of 50, 75, and 100 ppm GA_3 treatments on fruit firmness continued in storage, transport, and through the marketing process. After SL, the effects of 50, 75, and 100 ppm GA_3 treatments on fruit flesh firmness in 'Obilnaja' and 'Black Star' plums were 11.25% and 10.21% higher than that of the respective controls (Table 3). It was determined that the positive effects of GA_3 treatments on the fruit firmness of plums extended the storage, transportation, and SL periods. GA_3 treatments during the postharvest period helped preserve the fruit texture and thereby extend the storage period (Krisha et al., 2012). Preharvest GA_3 treatments were determined on cherries (Horvitz et al., 2003,

Table 1. The effect of GA_3 treatment pre-harvest at different concentrations on the average weights (g) and fruit size (mm) of 'Obilnaja' and 'Black Star' plums.

Treatments	Fruit weight (g)		Fruit diameter (mm)	
	'Obilnaja'	'Black Star'	'Obilnaja'	'Black Star'
Control	78.74 b^{z*}	86.38 b**	50.01 b*	55.04 b*
25 ppm GA_3	83.07 a	93.18 a	51.98 ab	56.61 ab
50 ppm GA_3	86.28 a	95.54 a	52.46 a	58.80 a
75 ppm GA_3	85.02 a	94.79 a	52.17 a	57.73 a
100 ppm GA_3	86.78 a	95.88 a	52.92 a	58.74 a

[z] Means separation within rows by Duncan's multiple range test, P < 0.05; *, **, Significant at P < 0.05, or 0.01, respectively.

Table 2. The effect of different pre-harvest GA_3 treatments on the weight loss (%) of 'Obilnaja' and 'Black Star' plums during storage-transport and marketing.

Treatments	'Obilnaja'			'Black Star'		
	ST	DC	SL	ST	DC	SL
Control	0.52^{NS}	0.86 a^{z*}	1.44 a**	0.46^{NS}	0.75 a*	1.28 a*
25 ppm GA_3	0.48	0.75 ab	1.31 b	0.43	0.66 ab	1.17 b
50 ppm GA_3	0.44	0.69 b	1.28 b	0.39	0.62 b	1.13 b
75 ppm GA_3	0.47	0.71 b	1.29 b	0.42	0.61 b	1.15 b
100 ppm GA_3	0.43	0.64 b	1.23 b	0.40	0.63 b	1.12 b

[z]Mean separation within columns by Duncan's multiple range test, P < 0.05; ^{NS}, *, **, Nonsignificant or significant at P < 0.05, or 0.01, respectively.

Clayton et al., 2003) and peaches (Dagar et al., 2012) during cold storage, and it was found that the fruit firmness values were higher as compared to those in the control fruits. The fruit flesh firmness in both the plum varieties showed a steady decrease during storage-transport and marketing. The decreases in the firmness during the ST and marketing processes also resulted from moisture loss. Following water losses, fruits begin to soften (Wills et al., 1998). The decrease in the firmness values during storage, transport, and marketing periods along with increased weight losses were consistent with these results.

The effects of GA_3 treatments on fruit skin C* and h° values of 'Obilnaja' and 'Black Star' plum fruits are given in Figure 1. The effect of GA_3 treatments on C* and h° values in both the plum varieties during storage, transportation, and marketing were similar. The peel C* value of 'Obilnaja' plum fruits varied between 25.24 and 32.13 during storage, transportation, and

Table 3. The effect of different pre-harvest GA_3 treatments on fruit flesh firmness (N) of 'Obilnaja' and 'Black Star' plums during storage-transport and marketing.

Treatments	'Obilnaja'				'Black Star'			
	Initial	ST	DC	SL	Initial	ST	DC	SL
Control	31.57 c[z]**	30.20 c*	27.01 c*	24.42 b*	40.31 c**	37.28 c*	34.67 c*	33.92 b*
25 ppm GA_3	34.63 b	33.38 b	31.72 b	25.08 ab	44.85 b	41.92 b	39.92 b	35.12 ab
50 ppm GA_3	38.54 a	36.45 a	33.53 a	27.04 a	48.84 a	45.98 a	42.16 ab	37.20 a
75 ppm GA_3	37.76 a	36.84 a	32.96 ab	26.50 a	49.62 a	44.83 ab	42.57 ab	36.82 a
100 ppm GA_3	38.24 a	37.59 a	33.91 a	27.96 a	48.59 a	45.54 ab	43.23 a	38.13 a

[z]Mean separation within columns by Duncan's multiple range test, $P < 0.05$; *, **, Significant at $P < 0.05$, or 0.01, respectively.

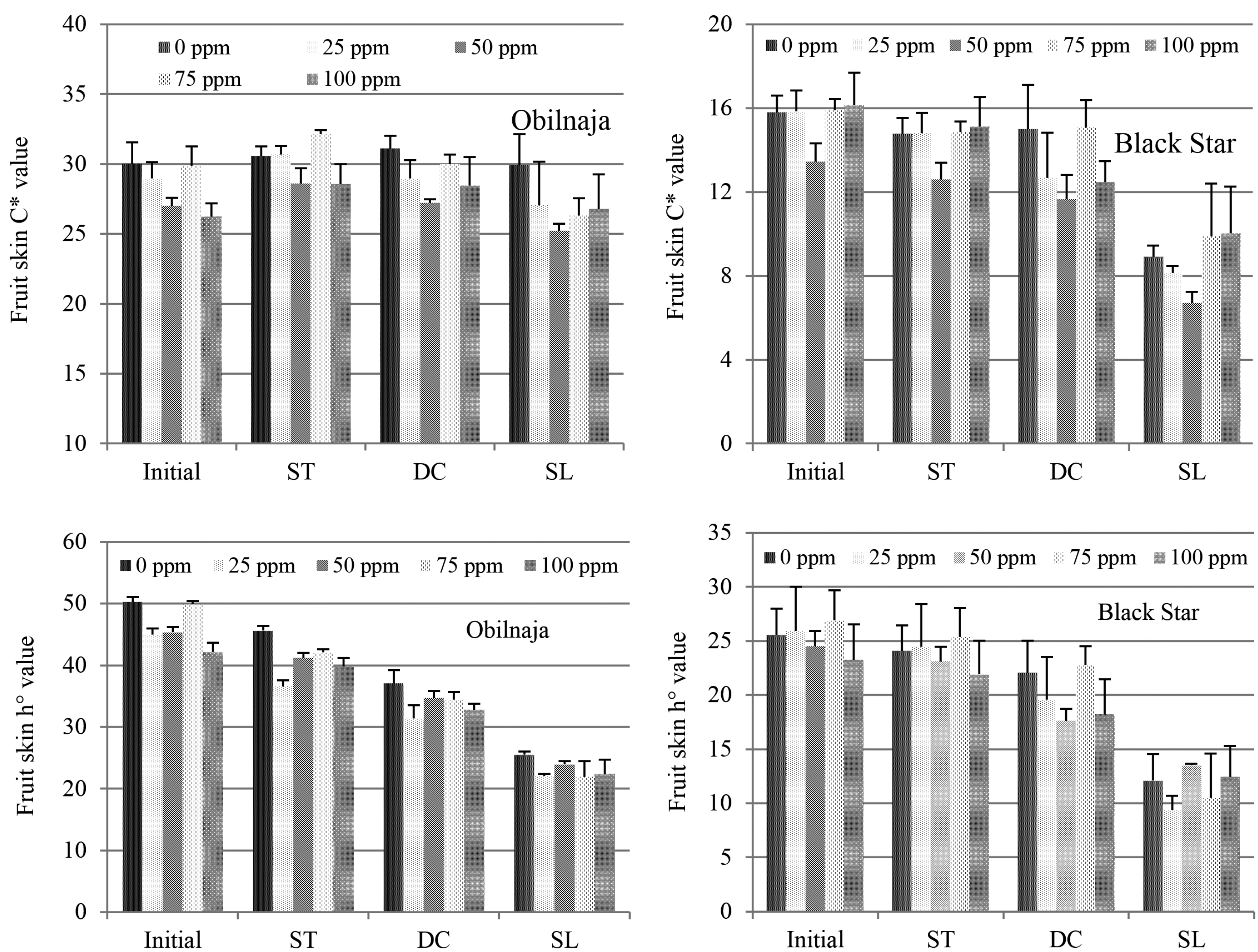

Figure 1. The effect of different pre-harvest GA_3 treatments on fruit skin C* ve h° values of 'Obilnaja' and 'Black Star' plums during storage-transport and marketing.

marketing, while the initial C* value of 'Black Star' plum fruits changed between 11.66 and 16.14 during ST and DC. The increase in the C* value of 'Black Star' plum fruits at the end of SL was significant and varied between 6.71 and 10.02. The average initial h° values of 'Obilnaja' and 'Black Star' plum fruits varied between 46.51 and 25.23, while the values at the end of their SL decreased to 23.17 and 11.58, respectively. These color changes in the fruit were also related to aging (Wills et al., 1998).

The effects of GA_3 treatments on the TSS content of 'Obilnaja' and 'Black Star' plum fruits are shown in Table 4. TSS content for 50- and 100-ppm GA_3 treatments on 'Obilnaja' plum fruits and all GA_3 treatments in 'Black Star' plum fruits during storage, transportation, and marketing were higher than that in the respective controls. The effect of GA_3 on the increase in TSS content was more evident in the 'Black Star' variety. The average TSS content in 50- and 100-ppm GA_3 treatments in 'Obilnaja' and 'Black Star' plum fruits were 18.06% and 21.50% higher than those in the controls, respectively. Similarly, it was previously determined that pre-harvest GA_3 treatments increases the TSS content in Japanese plums (González-Rossia et al., 2006), cherries (Lenahan et al., 2006), and peaches and nectarines (García-Pallas et al., 2001; González-Rossia et al., 2007; Coneva & Cline, 2006). The changes in the TSS content in plums during storage, transportation, and marketing were limited. No significant increase in the TSS content during storage was reported in Green Gage plums (Guerra & Casquero, 2008).

In both the plum varieties, the effects of GA_3 treatments on the TA content of fruits during storage, transportation, and marketing were similar. The initial TA content of 'Obilnaja' and 'Black Star' plums were 0.50-0.56 and 0.43-0.49 g malic acid/100 mL and, at the end of the storage period, it was 0.39-0.42 and 0.34-0.44 g malic acid/100 mL, respectively (Table 5). TA content of plums was lower at the end of the storage period than at the beginning. These decreases in the values are compatible with the loss in some acids with aging of the fruit. Similar results as ours were obtained in some other previous studies on Japanese plums (Crisosto et al., 2004; Valero et al., 2004; Guerra & Casquero, 2008; Kaynas et al., 2010).

The effects of GA_3 treatments on the total phenolic contents and antioxidant activity in 'Obilnaja' and 'Black Star' plum fruits are shown in Table 6. In both the plum varieties, the effects of GA_3 treatment on the examined chemical properties of fruits

Table 4. The effect of different pre-harvest GA_3 treatments on TSS content (%) of 'Obilnaja' and 'Black Star' plums during storage-transport and marketing.

Treatments	'Obilnaja'				'Black Star'			
	Initial	ST	DC	SL	Initial	ST	DC	SL
Control	11.27 b[z]*	11.23 b*	11.03 b*	10.80 b*	11.80 c**	11.53 b**	11.30 c**	11.37 c**
25 ppm GA_3	11.63 ab	11.43 b	11.27 ab	11.14 ab	12.50 b	12.85 a	12.53 b	12.65 b
50 ppm GA_3	12.37 a	12.30 a	12.37 a	12.87 a	13.27 ab	13.57 a	13.00 a	13.97 a
75 ppm GA_3	12.30 a	12.00 ab	12.10 ab	11.93 a	13.57 a	12.97 a	12.67 ab	12.93 ab
100 ppm GA_3	12.93 a	13.20 a	12.47 a	12.63 a	13.83 a	13.67 a	12.80 a	13.66 ab

[z]Mean separation within columns by Duncan's multiple range test, $P < 0.05$; *, **, Significant at $P \leq 0.05$. or 0.01, respectively.

Table 5. The effect of different pre-harvest GA_3 treatments on TA content (g malic acid/100 ml) of 'Obilnaja' and 'Black Star' plums during storage-transport and marketing.

Treatments	'Obilnaja'		'Black Star'	
	Initial	SL	Initial	SL
Control	0.52^{NS}	0.40^{NS}	0.47^{NS}	0.44^{NS}
25 ppm GA_3	0.53	0.35	0.44	0.40
50 ppm GA_3	0.56	0.42	0.43	0.34
75 ppm GA_3	0.53	0.39	0.45	0.40
100 ppm GA_3	0.50	0.41	0.49	0.42

^{NS}, Nonsignificant.

Table 6. The effect of different pre-harvest GA_3 treatments on total phenolic contents (mg GAE/100 g fw) and antioxidant activity (μmol/g fw) of 'Obilnaja' and 'Black Star' plums during storage-transport and marketing.

Treatments	Total phenolic contents				Antioxidant activity			
	'Obilnaja'		'Black Star'		'Obilnaja'		'Black Star'	
	Initial	SL	Initial	SL	Initial	SL	Initial	SL
Control	67.51^{NS}	68.15^{NS}	68.27^{NS}	72.43^{NS}	7.39^{NS}	8.01^{NS}	9.43^{NS}	15.01^{NS}
25 ppm GA_3	63.57	67.75	68.16	71.50	7.89	8.29	7.95	14.07
50 ppm GA_3	66.04	69.70	66.50	73.97	6.65	8.75	9.24	14.25
75 ppm GA_3	67.53	68.86	70.58	74.81	8.18	10.88	9.10	13.04
100 ppm GA_3	64.17	71.02	68.10	72.75	8.16	10.51	10.06	15.47

^{NS}, Nonsignificant.

during storage, transportation, and marketing were similar. The total phenolic contents of 'Obilnaja' and 'Black Star' plums at the end of the SL varied from 67.75 to 71.02 and 71.50 to 74.81 mg GAE/100 g fw, respectively. The total phenol contents of plums were higher at the end than at the beginning of SL. The initial antioxidant activity in 'Obilnaja' and 'Black Star' plums were 7.39-8.18 and 7.95-10.06 μmol/g fw, respectively; and, at the end of the SL, the values were 8.01-10.88 and 13.04-15.47 μmol/g fw, respectively. The antioxidant activity in 'Obilnaja' plums generally showed little change during storage, transportation, and marketing, while a steady increase was noted in the same parameter for the 'Black Star' plum variety. This result can be attributed to the composition content and distribution of phytochemicals that depend on fruit ripeness, cultural practices, growth season, and the postharvest storage conditions (Deshmukh et al., 2011).

No rotting development or physiological deteriorations was observed in either Japanese plum variety during storage, transportation, and marketing; this was believed to be associated with the MAP system used for the storage of plum fruits (Hardenburg et al., 1986; Kader et al., 2002; Nunes, 2008).

4 Conclusion

The present study suggests that the qualities of 'Obilnaja' and 'Black Star' plums can be significantly improved during storage, transportation, and marketing processes by treating the fruits with GA_3 at the preharvest stage. Pre-harvest GA_3 treatments increased the fruit weight and size in this study. Treatments at GA_3 at concentrations 50, 75, and 100 ppm increased the fruit flesh firmness and TSS content for both the studied plum varieties during storage, transportation, and marketing process, along with limited weight loss during the marketing process. Treatments of GA_3 showed no significant effect on the color, TA, and the total phenolic contents or antioxidant activity of plum fruits. At the end of the SL, the fruit flesh firmness, h° value, and TA content decreased, whereas weight loss, total phenolic contents, and antioxidant activity increased in comparison to the baseline values. Our results showed that, in particular, treatment with concentrations of 50, 75, and 100 ppm GA_3 before harvest preserved the quality of 'Obilnaja' and 'Black Star' plums after SL until the fruits reached the consumer. Pre-harvest treatment of GA_3 at 50 ppm in both the plum varieties can thus be recommended due to its preservative effect on the fruit quality.

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