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Research article

Effects of Pre-Harvest AVG Treatments on Fruit Quality of Jonagold Apple Cultivar throughout Cold Storage

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Abstract. The present study was conducted in 2010 and 2011 years to investigate the effects of pre-harvest aminoethoxyvinylglycine (AVG) treatments on weight loss, flesh firmness, soluble solids content, starch degradation and titratable acidity of Jonagold apple cultivar at harvest and at 60 days post-harvest intervals throughout 180 days cold storage at 2±0.5 °C, 90±5% RH. A total of 225 mg l^{-1} AVG dose was applied at once in a single application at different times. AVG treatments applied at once (225 mg l^{-1}) 8 and 4 weeks before the anticipated harvest time. Unsprayed trees were served as control. The weight loss of AVG1 treatment was lower than control and AVG2 treatment. The flesh firmness of AVG2 was higher than other treatments during cold storage. AVG treatments delayed flesh softening, starch degradation rates and consequently decelerated fruit ripening.

Hasat Öncesi AVG Uygulamalarının Soğukta Muhafaza Süresince Jonagold Elma Çeşidinin Meyve Kalitesi Üzerine Etkileri

Anahtar kelimeler:

Apple, fruit flesh firmness, soluble solids content, starch degradation, weight loss

Özet. Bu çalışma hasat öncesi AVG uygulamalarının Jonagold elma çeşidinin 2±0.5 °C ve 90±5% oransal nemde, 180 gün boyunca 60 günlük fasılalarda, soğukta muhafazası süresince ağırlık kaybı, et sertliği, suda çözünür kuru madde içeriği, nişasta parçalanması ve titre edilebilir asitlik içeriği üzerine etkilerini araştırmak amacı ile 2010 ve 2011 yıllarında yürütülmüştür. AVG'nin 225 mg l^{-1} dozu tahmini hasattan 8 ve 4 hafta önce tek uygulama olacak şekilde ağaçlara püskürtme şeklinde uygulanmıştır. Püskürtülmeyen ağaçlar kontrol olarak değerlendirilmiştir. AVG1 uygulamasının ağırlık kaybı, hem kontrol hem de AVG2 uygulamasından daha düşük olmuştur. Soğukta depolama süresince AVG2 uygulamasının et sertliği diğer uygulamalardan daha yüksek ölçülmüştür. AVG uygulamalarının meyve eti yumuşaması ve nişasta parçalanma hızını geciktirmesi sonucunda meyve olgunlaşması yavaşlatılmıştır.

INTRODUCTION

Turkey has a leading place in world apple production. Meeting the needs of domestic markets and preservation of harvested fruits for long periods for exports are significant issues for country economy. However, storage conditions eventually result in some losses in fruit quality attributes and ultimately result in economic losses. Ethylene inhibitors (1-MCP) are commonly used to prevent such losses in quality attributes (Şen and Turk 2008).

Ethylene inhibitors retard ethylene release encountered throughout ripening process, slow down fruit softening and preserve fruit quality during the cold storage period (Greene 2006; Öztürk *et al.,* 2014). Among the ethylene inhibitors, 1-Methylcyclopropene (1-MCP) and aminoethoxyviniylglicine (AVG) are the leading ones. 1-MCP usually applied in gas form before cold storage and AVG is either sprayed while the fruits are still on trees or dipped into before cold storage (). Effects of AVG vary based on application time, dose, volume and fruit species (Schupp and Greene 2004). The effects of AVG treatments on fruit quality and ripening were reported in various previous researches (Amarante *et al.,* 2002; Schupp and Greene 2004; Byers 1997; Öztürk *et al.,* 2013; Butar *et al.,* 2015).

The present study was carried out to investigate the effects of pre-harvest AVG treatments at different times on weight loss and some other fruit quality attributes during the cold storage of 'Jonagold' apples grown under ecological conditions of Tokat province of Turkey.

MATERIALS AND METHODS

Material

Five-years old uniform apple trees (*Malus domestica* Borkh. cv. Jonagold) grafted on M9 rootstock at Research Station of Horticulture Department of Gaziosmanpaşa University Agricultural Faculty (40º 20' 02.19"N latitude, 36º 28' 30.11"E longitude and 623 m altitude) in the Middle Black Sea Region of Turkey were selected for the experiments.

The trees were grouped in 3 blocks with 9 trees based on proximity in orchard and crop load in each block. Aminoethoxyvinylglycine (AVG) doses were applied to three trees in each block and three trees in each block were considered as control. AVG ('ReTain'; ValentBioSciences Crop, Libertyville, Il) treatments were designated as; Control (0 mg l^{-1}, only surfactant), AVG1 (225 mg l^{-1} 8 weeks before the anticipated harvest date) and AVG2 (225 mg l^{-1} 4 weeks before the anticipated harvest date). The anticipated harvest date was determined based on the number of days after full bloom (the value was 165 days for 'Jonagold'). All spray solutions contained 'Sylgard-309' as surfactant [0.05%, v/v (Dow Corning, Canada Inc., Toronto)].

Twenty fruits were randomly harvested from three trees in each block for each treatment at the anticipated harvest date (23 September 2010 and 2 October 2011). These fruits were used to determine the fruit quality characteristics (fruit flesh firmness, soluble solids content, titratable acidity and starch degradation) at the time of harvest.

Twenty fruits from three trees in each block of every treatment were stored in cardboard boxes in single rows on the anticipated harvest date to evaluate the weight loss (23 September 2010 and 2 October 2011).

In order to determine fruit quality parameters during cold storage, a total of eighty fruits from three trees in each block for each treatment were stored (23 September 2010, 2 October 2011). The harvested apples were immediately placed into cardboard boxes in single rows and transferred to the cold storage at 0 °C temperature and with 90±5 % relative humidity within an hour. Fruits were stored in cold storage during 6 months. The fruits were analyzed on the 60, 120, and 180th days to determine the changes in fruit quality parameters.

Fruit Quality Assessment

Weight loss was determined by the difference between the initial and final weights of each replicate and expressed as %. In each analysis time, 20 fruits were used for each replication. The fruit skin was cut at three different points over the equatorial part of ten fruits and the firmness was measured by using Effegi penetrometer (FT–327; McCormick Fruit Tech, USA) with 11.1 mm tip. The measurement values were expressed as Newton (N). The soluble solids content (SSC) of a homogenate obtained from ten fruits was determined with a digital refractometer (PAL-1, Atago, USA) as percentages. For titratable acidity (TA), 10 ml of extract was taken from each sample, 10 ml of distilled water was added and the value corresponding to consumed sodium hydroxide (NaOH) during the titration with 0.1 N sodium hydroxide to increase the pH of samples to 8.1 was expressed in malic acid (g malic acid 100 mL^{-1}).

Starch-iodine tests of sliced fruits were carried out using the Cornell Generic Starch-Iodine Index Chart, where 1=100% starch and 8=0% starch (Blanpied and Silsby 1992).

Statistical Analysis

The normality of the data was confirmed by the Kolmogorov-Smirnov test and the homogeneity of variances by the Levene's test. The data sets were analyzed with ANOVA by using SAS Version 9.1 (SAS Institute Inc., USA) software. Duncan multiple range test was used to compare treatments when ANOVA showed significant differences among means. The level of significance was set as 5%.

RESULTS AND DISCUSSION

Weight loss rates were reduced in both years throughout the cold storage with both AVG1 and AVG2 treatments. However, significant differences were observed between AVG treatments of the second year. The weight loss obtained from AVG1 treatments was significantly lower than the weight loss obtained from AVG2 treatments (Table 1). Öztürk *et al.* (2013) reported that AVG retarded ripening and consequently decelerated metabolic processes and reduced cellular losses. Weight loss-retarding effect of AVG was probably resulted from retarded ethylene synthesis and consequently retarded ripening (Greene 2006; Argenta *et al.,* 2006).

Table 1. Effects of pre-harvest AVG treatments on weight loss of Jonagold apples.
Çizelge 1. Hasat öncesi AVG uygulamalarının Jonagold elmalarının ağırlık kaybı üzerine etkileri.

AVG treatments	Time (WBA[z]) and dose (mg l^{-1}) of AVG		Weight loss (%)		
			2010		
	8	4	60	120	180
Control	-	-	0.48a[y]	1.29a	1.72a
AVG1	225	-	0.56a	1.12b	1.63b
AVG2	-	225	0.29b	1.13b	1.61b
			2011		
Control	-	-	1.29a	1.86a	2.21a
AVG1	225	-	0.34c	0.58c	0.91c
AVG2	-	225	0.99b	1.45b	1.70b

[z] Weeks before harvest; [y] The means with the same letter do not differ according to Duncan's multiple range test, P<0.05.

Fruit softening was significantly retarded with AVG treatments in both years. Again significant differences were observed between AVG treatments of the second year. Fruit flesh softening was significantly retarded especially with AVG2 treatments (Table 2).

Table 2. Effects of pre-harvest AVG treatments on fruit flesh firmness of Jonagold apples.
Çizelge 2. Hasat öncesi AVG uygulamalarının Jonagold elmalarının meyve eti sertliği üzerine etkileri.

AVG treatments	Time (WBA[z]) and dose (mg l^{-1}) of AVG		Fruit flesh firmness (N)			
			2010			
	8	4	Harvest	60	120	180
Control	-	-	57.58b[y]	45.62b	37.75b	34.84b
AVG1	225	-	62.62a	51.56a	42.08a	41.31a
AVG2	-	225	63.91a	54.15a	41.60a	41.53a
			2011			
Control	-	-	59.55b	44.67c	38.33c	34.14c
AVG1	225	-	69.71a	52.05b	40.40b	36.95b
AVG2	-	225	69.80a	61.26a	43.64a	39.37a

[z] Weeks before harvest; [y] The means with the same letter do not differ according to Duncan's multiple range test, P<0.05.

Flesh firmness both prolongs post-harvest life of the fruits and increase market value and consumer preferences. In this study, it was observed that AVG-treated fruits preserved their firmness for longer periods. The effects of AVG treatments applied 4 weeks ahead of anticipated harvest date were more remarkable. Thusly, Greene (2006) indicated that effects of AVG might vary based on application times. It was reported in previous studies that AVG preserved fruit flesh firmness (Argenta *et al.,* 2006; Öztürk *et al.,* 2013).

The increase in SSC was retarded with AVG treatments in both years and the greatest SSC value was obtained from the control fruits (Table 3).

Ripening goes on and SSC content increases in apples throughout storage. Öztürk *et al.* (2013) reported this increase in SSC might be resulted from conversion of starch into sugar. AVG has a ripening-retarding effect (Greene and Shupp 2004), thus it might slow down starch conversion into sugar and consequently retard increase in SSC values.

Table 3. Effects of pre-harvest AVG treatments on soluble solids content of Jonagold apples.

Çizelge 3. Hasat öncesi AVG uygulamalarının Jonagold elmalarının suda çözünür kuru madde içeriği üzerine etkileri.

AVG treatments	Time (WBA[z]) and dose (mg l^{-1}) of AVG		Soluble solids content (%)			
			2010			
	8	4	Harvest	60	120	180
Control	-	-	13.7a[y]	15.2a	13.3a	12.5a
AVG1	225	-	13.0b	13.2b	12.8b	11.7b
AVG2	-	225	13.0b	13.3b	12.9b	11.9b
			2011			
Control	-	-	14.7a	15.1a	13.2a	13.0a
AVG1	225	-	13.5b	14.4b	13.4a	12.2b
AVG2	-	225	12.7c	13.2c	12.8b	12.3b

[z] Weeks before harvest; y The means with the same letter do not differ according to Duncan's multiple range test, P<0.05.

The TA values of AVG-treated fruits were not significantly different from the control fruits of the first year. On the other hand, TA values of AVG-treated fruits were significantly higher than the control fruits of the second year (Table 4). Acidity generally decreases during fruit ripening. Higher acidity levels of AVG-treated fruits of the present study might be resulted from ripening-retarding effect of AVG.

Table 4. Effects of pre-harvest AVG treatments on titratable acidity of Jonagold apples.

Çizelge 4. Hasat öncesi AVG uygulamalarının Jonagold elmalarının titre edilebilir asitlik üzerine etkileri.

AVG treatments	Time (WBA[z]) and dose (mg l^{-1}) of AVG		Titratable acidity (% malic acid)			
			2010			
	8	4	Harvest	60	120	180
Control	-	-	0.45b[y]	0.10[ns]	0.08	0.07
AVG1	225	-	0.46b	0.12	0.09	0.09
AVG2	-	225	0.49a	0.10	0.09	0.07
			2011			
Control	-	-	0.54b	0.20b	0.18b	0.16b
AVG1	225	-	0.69a	0.23a	0.21a	0.19a
AVG2	-	225	0.69a	0.24a	0.23a	0.18a

[ns:] non-significant; [z] Weeks before harvest; [y] The means with the same letter do not differ according to Duncan's multiple range test, P<0.05.

In the first year of the experiments, compared to control fruits, while AVG treatments retarded starch degradation at harvest, such an effect of AVG treatments was not observed in other periods. In the second year, both AVG1 and AVG2 treatments significantly retarded starch degradation (Table 5). Greene and Shupp (2004) reported that AVG retarded starch degradation. Greene (2006) also indicated accelerated starch conversion into sugar with the progress of ripening, but reported that AVG treatments decelerated this process.

Table 5. Effects of pre-harvest AVG treatments on starch degradation of Jonagold apples.

Çizelge 5. Hasat öncesi AVG uygulamalarının Jonagold elmalarının nişasta parçalanması üzerine etkileri.

AVG treatments	Time (WBA[z]) and dose (mg l^{-1}) of AVG		Starch degradation [x]			
			2010			
	8	4	Harvest	60	120	180
Control	-	-	8.0a [y]	7.8[ns]	7.8	8.0
AVG1	225	-	7.0b	7.8	7.9	8.0
AVG2	-	225	7.0b	7.8	8.0	8.0
			2011			
Control	-	-	7.2a	8.0a	8.0a	8.0a
AVG1	225	-	5.4b	7.3b	7.7b	8.0a
AVG2	-	225	5.4b	6.3c	6.7c	7.0b

[ns:] non-significant; [x] 1 = 100% starch and 8 = 0% starch, [z] Weeks before harvest; [y] The means with the same letter on the same line do not differ according to Duncan's multiple range test, P<0.05.

CONCLUSION

As to conclude, it was observed that AVG treatments applied 4 and 8 weeks ahead of the anticipated harvest date could be used as an efficient tool to reduce weight loss and losses in some other fruit quality attributes of Jonagold apples throughout the cold storage period of the fruits. It was also observed that AVG treatments applied 4 weeks ahead of anticipated harvest date yielded better outcomes.

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