DOI: 10.5433/1679-0359.2015v36n6p3595

AVG application regimes play an important role on pre-harvest drop and ripening of 'Jonagold' apples

A aplicação de doses de AVG desempenha um papel importante na queda, pré-colheita e maturação de maçãs 'Jonagold'

Burhan Ozturk[1*]; Yakup Ozkan[2]; Kenan Yildiz[3]

Abstract

This study was carried out to investigate the effects of different AVG (aminoethoxyvinylglycine) treatments on pre-harvest fruit drop rates and ripening levels of 'Jonagold' apples. A total of 225 mg L^{-1} AVG dose was applied at once in a single application at different times or divided into doses and applied different times. Compared to control treatment, entire AVG treatments increased fruit removal force and significantly decreased the pre-harvest drop rates. AVG treatments applied at once (225 mg L^{-1}) 8 or 4 weeks before the anticipated harvest time were found to be more effective than the divided treatments. AVG treatments inhibited ethylene biosynthesis and such an inhibition was more distinctive in single 225 mg L^{-1} treatments. AVG treatments decreased flesh softening, starch degradation rates and consequently retarded fruit ripening. The 225 mg L^{-1} AVG treatment applied 4 weeks before the harvest significantly increased L* value and hue angle both in the year 2010 and 2011. NAA (naphtaleneacetic acid) at 10 mg L^{-1} sprayed 4 and 2 weeks before anticipated harvest was found to be insignificant in control of pre-harvest fruit drops. NAA treatment decreased flesh firmness, and did not have any significant effects on ethylene biosynthesis.

Key words: Colour, ethylene, firmness, fruit removal force, starch degradation

Resumo

O presente estudo foi realizado para investigar os efeitos de diferentes tratamentos AVG (aminoetoxivinilglicina) sobre as taxas de queda de frutos antes da colheita e níveis de amadurecimento de maçãs 'Jonagold'. Foi aplicada uma dose AVG total de 225 mg L^{-1} numa só vez numa única aplicação em momentos diferentes ou dividida em doses aplicadas e tempos diferentes. Em comparação ao tratamento controle, as aplicações de AVG aumentaram a força de remoção dos frutos e reduziram significativamente as taxas de queda na pré-colheita. A aplicação de AVG de uma só vez (225 mg L^{-1}) ou 4 a 8 semanas antes da época da colheita mostrou-se mais eficaz do que as aplicações efetuadas em doses. O tratamento com AVG inibe a biossíntese de etileno, sendo que esta inibição se verificou mais significativa em tratamentos individuais de 225 mg L^{-1}. O tratamento com AVG diminuiu o amolecimento da polpa, as taxas de degradação do amido e consequentemente retardou o amadurecimento dos frutos. O tratamento com doses de 225 mg L^{-1} de AVG aplicadas quatro semanas antes da colheita aumentou significativamente o valor L * e o ângulo de cor, tanto no ano de 2010 como de 2011. A pulverização de NAA (ácido naftaleno acético) a 10 mg L^{-1} 2 a 4 semanas antes da colheita foi considerada insignificante no controle da queda de frutos na pré-colheita. O tratamento com NAA diminuiu a firmeza da polpa, e não tem quaisquer efeitos significativos sobre a síntese de etileno.

Palavras-chave: Cor, etileno, firmeza, força de remoção dos frutos, degradação do amido

[1] Assist. Prof. Dr., Department of Horticulture, Faculty of Agriculture, University of Ordu, 52200, Ordu, Turkey. E-mail: burhanozturk55@gmail.com

[2] Prof. Dr., Department of Horticulture, Faculty of Agriculture, University of Süleyman Demirel, 32200, Isparta, Turkey. E-mail: yakupozkan@sdu.edu.tr

[3] Prof. Dr., Department of Horticulture, Faculty of Agriculture, University of Gaziosmanpaşa, 60240, Tokat, Turkey. E-mail: kenan.yildiz@gop.edu.tr

[*] Author for correspondence

Recebido para publicação 10/06/14 Aprovado em 09/11/14

Introduction

Fruit drops without reaching the desired ripening and quality levels are common in various apple species. Producers sometimes resort to early-harvest to prevent such drops (PETRI et al., 2006). Since the early-harvested apples are smaller in size than the ones harvested at normal season, a yield loss and significant economic losses are inevitable because smaller ones are sold cheaper in markets (GREENE, 2002; YUAN; CARBAUGH, 2007). Therefore, pre-harvest drops have been the most significant problem of apple producers.

Since the role of plant hormones in apple ripening and abscission is well-known, growth regulators are commonly used to control pre-harvest fruit drops. Beside the synthetic auxin NAA (naphthaleneacetic acid) and 2, 4, 5-TP (2, 4, 5-trichlorophenoxyacetic acid), daminozide (Alar) is also commonly used to prevent fruit drops. Although some researchers reported significant effects of NAA in prevention of pre-harvest drops (MARINI et al., 1993; CURRY, 2006), others indicated that desired outcomes were not always achieved depending on species and climate factors (GREENE et al., 1987; BYERS, 1997; YILDIZ et al., 2012).

Ethylene is a plant hormone promoting fruit ripening and abscission (YUAN; CARBAUGH, 2007). Inhibition of ethylene biosynthesis may retard fruit ripening and prevent pre-harvest drops. AVG treatments 1-4 weeks before the harvest inhibited ethylene synthesis in apples, nectarines, peaches, pears and plums (JOBLING et al., 2003; GREENE, 2006; LURIE, 2008). A natural ethylene inhibitor AVG was reported to be effective in prevention or reduction of pre-harvest drops in apples (GREENE; SCHUPP, 2004; SCHUPP; GREENE, 2004; GREENE, 2005). Beside reduction in drop rates, AVG also slows down the fruit ripening process and provide supports in flesh firmness preservation during the harvest and post-harvest storage of fruits (GREENE; SCHUPP, 2004; OZTURK et al., 2012).

Jonagold is a widespread high-quality apple in Turkey. Although not as severe as 'Delicious' and 'Golden', pre-harvest drops can be substantial in 'Jonagold' apples in some years and regions depending on temperatures at growing season. Present study was carried to determine the effects of AVG treatments applied in different times and doses on pre-harvest drop rates, fruit ripening levels and fruit quality parameters of 'Jonagold' apple.

Materials and Methods

Site and climatic conditions

Experiments were carried out in Horticultural Research Centre of Gaziosmanpaşa University located at 40°20'02.19″N latitude and 36°28′30.11″E longitude and 623 m above sea level, Tokat Province in middle Black Sea region of Turkey. Soil texture is clay loam with 22% sand, 50% clay and 28% silt and 0.7% organic matter. The soil pH is 8.16. According to average rainfall values for the past decades in the region, the annual lowest and highest average temperatures, relative humidity and rainfall are 8.1–14.2 °C, 56–73%, and 381.8–586.2 mm, respectively (ANONYMOUS, 2011)

Plant material

To determine the effect of AVG on pre-harvest drop and fruit quality parameters of apples, 6-years old sixty three 'Jonagold' apple (*Malus domestica* Borkh) trees grafted on M9 rootstocks were selected and grouped into three blocks with 21 trees in each based on proximity in orchard and crop load. Irrigations were carried out through drip irrigation and macro-micro nutrients were supplied in four aliquots on April 1, May 1, June 1 and July 1. A total of 15 g N (nitrogen), 25 g K_2O (60%, potassium oxide), 5 g $NH_4H_2PO_4$ (monoammonium phosphate) and 25 g K_2SO_4 (potassium sulphate) were supplied to trees. Additionally, 5 g calcium nitrate [Ca (NO_3)] was supplied once in August 1. Any symptoms of nutritional deficiency were not observed in leaf or fruits during the growing season.

Treatments

AVG ('ReTain'; ValentBioSciences Crop, Libertyville, II) treatments were designated as; AVG0 (control), AVG1 (225 mg L^{-1} 8 weeks before the anticipated harvest date), AVG2 (75 mg L^{-1} in triple application 8, 4 and 2 weeks before harvest), AVG3 (225 mg L^{-1} 4 weeks before the anticipated harvest date), AVG4 (75 mg L^{-1} 8 weeks before the harvest plus 150 mg L^{-1} 4 weeks before the anticipated harvest date), AVG5 (75 mg L^{-1} 4 weeks before the anticipated harvest date plus 150 mg L^{-1} 2 weeks before the anticipated harvest date). NAA at 10 mg L^{-1} was sprayed 4 and 2 weeks before the anticipated harvest date as a positive control treatment. 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)]. Pulverized treatments were applied with a low pressure hand sprayer. For each treatment, three trees were used in each block. Two of them were allocated for sampling from which fruits were collected for ethylene and quality analyses at certain dates. No fruits were harvested from the third tree until anticipated harvest date and this served to follow the progression of fruit drop. Three trees in each block were not sprayed and served as control.

Pre-harvest fruit drop

To determine pre-harvest fruit drop rates, fruits fallen under tree were counted twice a week from 28 days before the anticipated harvest time until the harvest. Then, fruits remaining on trees were harvested and cumulative drop rates were calculated.

Fruit removal force and fruit firmness

To evaluate fruit removal force and fruit firmness, ten fruits were randomly harvested from two trees in each block for each treatment on 2, 9, 16 and 23rd of September 2010, and 11, 18, 25th of September and 2nd of October 2011. While these fruits were collected, fruit removal force, the force required to remove fruit from the shoot, was measured by using a dynamometer (model, Tronic HF–10, Taiwan). Flesh firmness was measured on three sides of equatorial line of each fruit using a press-mounted Effegi penetrometer (FT 327; McCormick Fruit Tech. Torino, Italy) with 11.1 mm tip.

Internal ethylene concentration

To evaluate internal ethylene concentration, ten fruits were randomly harvested from two trees in each block for each treatment on 11, 18, 25th of September and 2nd of October 2011. A 1-mL air sample from core cavity of each fruit was injected into a gas chromatograph equipped with an active alumina column and Flame Ionization Detector (Perkin Elmer-Clarus 500, USA), using the method of Bramlage et al. (1980). The resulting peaks were compared to that of 100 $\mu L\ L^{-1}$ ethylene standard and the internal ethylene concentration was calculated.

Colour characteristics, soluble solids content, titratable acidity and starch degradation

To evaluate colour characteristics (L*, chroma and hue angle), soluble solids content (SSC), titratable acidity (TA) and starch degradation, ten fruits from two trees in each block for each treatment were harvested on the anticipated harvest date. Skin colour of the sun-exposed side of each fruit was analysed by using a colourimeter (Minolta, model CR–400, Tokyo, Japan). Measurements were obtained by using the CIE colour scale as of L* (light to dark), a* (green to red) and b* (blue to yellow), then a* and b* values were converted into hue angle and chroma. Soluble solids content was measured by using a digital refractometer (model PAL-1, McCormick Fruit Tech., Yakima, Wash). Titratable acid content was measured by manual titration with NaOH and expressed as g malic acid 100 mL^{-1}. Starch-iodine tests of sliced fruits were carried out by using the Cornell Generic Starch-Iodine Index Chart, where 1=100% starch and 8=0% starch (BLANPIED; SILSBY, 1992).

Statistical analysis

A randomized complete block design was used for experiments. 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 analysed with ANOVA by using SAS Version 9.1 (SAS Institute Inc., Cary, NC, 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

Compared to control treatment, AVG1, AVG2 and AVG4 treatments significantly reduced the drop rates on 2nd of September and AVG3 and AVG5 treatments did not have significant effects on drop rates of the year 2010 (Table 1). In other measurement dates, all AVG treatments significantly decreased the drop rates compared to control treatment. Significant differences were observed between AVG treatments. AVG4 treatment was found to be more effective than the other treatments in reducing drop rates especially in early stages. While higher drop rates were observed on 2, 9 and 16th of September in NAA treatment than control treatment, the drop rate of the last harvest date on 23rd of September did not differ between control and NAA treatment.

During the second year (2011), compared to control treatment, all AVG treatments significantly decreased the drop rates on all measurement dates, except for AVG5 at first harvest date (Table 1). AVG1, AVG3 and AVG4 treatments were found to be more effective in drop control than AVG2 and AVG5 treatments. On the contrary to the first year, NAA decreased the drop rates of the first three measurement dates of the year 2011. The difference between the drop rates of NAA and control treatment on the last harvest date was not significant.

Table 1. Effects of aminoethoxyvinylglycine (AVG) and napthaleneacetic acid (NAA) on pre-harvest drop rates of 'Jonagold' apples.

AVG treatments	Time (WBA^z) and dose (mg L^{-1}) of AVG and NAA treatments			Pre-harvest drop (% of total)			
				2010			
	8	4	2	2 Sept.	9 Sept.	16 Sept.	23 Sept.
Control	-	-	-	23.08 b^y	36.09 b	42.01 b	46.75 a
AVG1	225	-	-	20.70 c	25.99 d	29.96 e	33.48 c
AVG2	75	75	75	18.95 c	22.88 e	28.76 e	32.03 c
AVG3	-	225	-	23.23 b	28.28 c	32.32 d	32.32 c
AVG4	75	150	-	12.57 d	22.40 e	25.68 f	28.96 d
AVG5	-	75	150	24.57 b	30.86 c	37.14 c	38.29 b
NAA	-	10	10	31.76 a	41.76 a	46.47 a	48.82 a
				2011			
	8	4	2	11 Sept.	18 Sept.	25 Sept.	2 Oct.
Control	-	-	-	17.31 b	37.71 a	44.56 a	47.60 a
AVG1	225	-	-	6.14 f	8.30 e	10.47 e	11.55 e
AVG2	75	75	75	14.75 c	19.67 c	27.87 c	39.34 c
AVG3	-	225	-	3.69 g	4.92 f	12.30 e	12.30 e
AVG4	75	150	-	8.70 e	14.13 d	21.74 d	26.09 d
AVG5	-	75	150	21.63 a	33.17 b	41.25 b	43.04 b
NAA	-	10	10	11.05 d	33.34 b	41.05 b	48.41 a

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

AVG treatments had significant effects on fruit flesh firmness (Table 2). While AVG1 treatment did not cause significant changes in flesh firmness on 2 and 9th of September of the first year, it significantly increased flesh firmness on 16 and 23rd of September compared to control treatment. Although AVG2-treated fruits had a little bit lower flesh firmness than control treatment on 2nd of September, the values of the same treatment were higher than control treatment on 9 and 23rd of September. Although flesh firmness significantly increased with AVG3, AVG4 and AVG5 treatments on 9 and 16th of September, only AVG3 treatment was able to sustain such increasing effect until the last harvest date.

The flesh firmness-increasing effect of AVG treatments was more distinctive in the second year of experiments. Flesh firmness of the last two measurement dates (25th of September and 2nd of October) were found to be higher in AVG treatments than control treatment. AVG1 and AVG3 treatments had the highest flesh firmness values on the last harvest date.

Effects of NAA treatments on flesh firmness varied with regard to years. During the first year, flesh firmness of NAA-treated fruits was lower than control treatment on all measurement dates except for 9th of September. While there were not significant differences between NAA and control treatments on the first three measurement dates of the second year, firmness of NAA-treated fruits were found to be lower than control fruits of the last measurement date.

Table 2. Effects of aminoethoxyvinylglycine (AVG) and napthaleneacetic acid (NAA) on flesh firmness of 'Jonagold' apples.

AVG treatments	Time (WBA^z) and dose (mg L^{-1}) of AVG and NAA treatments			Flesh firmness (N)			
				2010			
	8	4	2	2 Sept.	9 Sept.	16 Sept.	23 Sept.
Control	-	-	-	72.88 a^y	64.84 b	62.25 d	57.58 b
AVG1	225	-	-	71.53 a	66.43 b	64.07 c	62.62 a
AVG2	75	75	75	68.87 b	66.49 b	61.00 d	59.34 b
AVG3	-	225	-	73.29 a	68.26 a	65.22 bc	63.91 a
AVG4	75	150	-	72.09 a	69.09 a	67.73 a	58.75 b
AVG5	-	75	150	69.71 b	68.35 a	66.03 b	58.69 b
NAA	-	10	10	67.53 b	65.10 b	58.51 e	54.43 c
				2011			
	8	4	2	11 Sept.	18 Sept.	25 Sept.	2 Oct.
Control	-	-	-	73.32 b	68.20 b	63.51 c	59.55 c
AVG1	225	-	-	74.08 b	73.46 a	70.62 a	69.71 a
AVG2	75	75	75	73.21 b	67.33 b	66.31 bc	63.45 b
AVG3	-	225	-	77.15 a	72.19 a	72.05 a	69.80 a
AVG4	75	150	-	73.36 b	71.19 ab	67.53 b	62.83 b
AVG5	-	75	150	74.30 b	71.51 ab	71.07 a	64.67 b
NAA	-	10	10	73.10 b	70.12 ab	64.10 c	55.30 d

^{z} Weeks before harvest; ^{y} The means with the same letter do not differ, according to Duncan's multiple range test, $P < 0.05$; n=90 (ten fruits x three replications x three measurements for each fruit) for flesh firmness.

Effects of AVG treatments on fruit removal force were distinctive on the first measurement date (2nd of September) of the first year (2010) (Table 3). Removal forces of all AVG treatments of this date were higher than control treatment. On the second measurement date (9th of September), removal forces of all AVG treatments except for AVG5 were found to be significantly higher than control treatment. While removal forces on 16th of September were significantly higher only in AVG1 treatment than control treatment, significant differences were not observed between the other AVG treatments and control treatment. The lowest removal forces of the last harvest date (23rd of September) were observed in control fruits and the highest values were seen in AVG1 and AVG3 treatments.

During the second year (2011), removal forces of AVG1 and AVG3 treatments were found to be higher than control treatment on all measurement dates (Table 3). While AVG2 treatment did not cause significant changes in removal force on 11 and 18th of September, significant increases were observed on 25th of September and 2nd of October. Effects of AVG4 and AVG5 treatments on removal force were not as distinctive as the effects of other AVG treatments. These two treatments increase the removal force just a little bit only on the last harvest date. NAA in general did not cause any significant effect on fruit removal force in both years.

Table 3. Effects of aminoethoxyvinylglycine (AVG) and napthaleneacetic acid (NAA) on fruit removal force of 'Jonagold' apples.

AVG treatments	Time (WBA^z) and dose (mg L^{-1}) of AVG and NAA treatments			Fruit removal force (N)			
				2010			
	8	4	2	2 Sept.	9 Sept.	16 Sept.	23 Sept.
Control	-	-	-	20.59 b^y	19.20 c	17.99 b	12.52 e
AVG1	225	-	-	25.00 a	24.66 a	23.08 a	19.28 a
AVG2	75	75	75	23.29 a	22.11 b	20.03 b	16.64 bc
AVG3	-	225	-	23.23 a	22.38 b	19.38 b	18.65 ab
AVG4	75	150	-	24.75 a	21.81 b	18.41 b	15.10 cd
AVG5	-	75	150	23.39 a	20.91 c	17.94 b	16.37 d
NAA	-	10	10	20.14 b	19.61 c	17.90 b	14.10 de
				2011			
	8	4	2	11 Sept.	18 Sept.	25 Sept.	2 Oct.
Control	-	-	-	18.50 b	15.08 c	12.96 c	11.17 d
AVG1	225	-	-	21.26 a	20.82 a	20.60 a	19.54 a
AVG2	75	75	75	17.73 b	17.22 bc	16.90 b	14.69 c
AVG3	-	225	-	21.00 a	18.44 b	17.29 b	16.76 b
AVG4	75	150	-	18.19 b	15.50 c	14.26 c	13.79 c
AVG5	-	75	150	19.23 ab	15.84 c	15.14 bc	14.09 c
NAA	-	10	10	18.34 b	16.22 c	14.52 c	13.17 c

^{z} Weeks before harvest; ^{y} The means with the same letter do not differ according to Duncan's multiple range test, $P < 0.05$; n=30 (ten fruits x three replications) for fruit removal force.

Internal ethylene concentration was measured only in the second year. AVG1 and AVG3 treatments apparently decreased ethylene biosynthesis on all measurement dates (Table 4). Ethylene synthesis of AVG5 treatment was found to be lower than control treatment on all measurement dates except for 25th of September. Ethylene synthesis of AVG-treated fruits was found to be lower than control treatment also on the last harvest date. Inhibiting effect of AVG on ethylene synthesis was more distinctive in AVG1 and AVG3 treatments. While the lowest ethylene concentration on the last harvest date was observed in AVG3 treatment, the second lowest value was seen in AVG1 treatment. NAA increased ethylene biosynthesis only on 25th of September and did not cause any significant change on other dates.

Table 4. Effects of aminoethoxyvinylglycine (AVG) and napthaleneacetic acid (NAA) on internal ethylene concentration (IEC) of 'Jonagold' apples (2011).

AVG treatments	Time (WBA^z) and dose (mg L^{-1}) of AVG and NAA treatments			Internal ethylene concentration (mg L^{-1})			
				2011			
	8	4	2	11 Sept.	18 Sept.	25 Sept.	2 Oct.
Control	-	-	-	30.23 a^y	35.27 a	40.25 bc	66.40 a
AVG1	225	-	-	22.80 cd	25.23 c	32.26 d	42.31 c
AVG2	75	75	75	23.46 cd	29.68 b	36.84 c	53.05 b
AVG3	-	225	-	20.45 d	24.21 c	26.61 e	30.97 d
AVG4	75	150	-	24.21bcd	31.85 ab	38.69 c	54.20 b
AVG5	-	75	150	26.95abc	32.80 ab	44.07 ab	56.66 b
NAA	-	10	10	28.32 ab	32.44 ab	46.52 a	68.35 a

^{z} Weeks before harvest; ^{y} The means with the same letter do not differ according to Duncan's multiple range test, $P < 0.05$; n=30 (ten fruits x three replications) for internal ethylene concentration.

L*, chroma and hue angle values were measured in both years only on normal harvest date to determine the effects of AVG and NAA treatments on fruit skin colour. While AVG1 and AVG3 treatments significantly increased L* value in both years, other AVG treatments did not cause any significant change in L* value (Table 5). None of the AVG treatments had significant effects on chroma value in the year 2010. However, only AVG1 and AVG5 treatments increased chroma values just a little bit compared to control treatment in the year 2011 (Table 5). Effects of AVG1, AVG2 and AVG5 treatments on hue angle varied with regard to years. AVG3 and AVG4 significantly increased hue angle in both years compared to control treatment (Table 5).

A significant difference was not observed among treatments with regard to soluble solids content of both years and in titratable acidity of the year 2010. Acid contents of AVG-treated fruits of the year 2011 were found to be higher than control and NAA-treated fruits (Table 6). Although starch degradation rates of AVG treatments in the year 2010 were a little bit slower than control treatment, the differences were not found to be significant (Table 6). Starch degradations in AVG1 and AVG3 treatments of the year 2011 were found to be lower than control treatments.

Table 5. Effects of aminoethoxyvinylglycine (AVG) and napthaleneaceticacid (NAA) on L*, chroma and hue angle values of 'Jonagold' apples.

	Time	Treatments						
		Control	AVG1	AVG2	AVG3	AVG4	AVG5	NAA
Time (WBA^z) and dose (mg L^{-1}) of AVG and NAA treatments	8 week	-	225	75	-	75	-	-
	4 week	-	-	75	225	150	75	10
	2 week	-	-	75	-	-	150	10
L*	2010	52.69 bcy	57.40 a	53.00 bc	56.19 a	55.00 ab	52.31 bc	48.71 c
	2011	51.59 c	56.58 a	50.18 c	55.42 ab	52.85 bc	50.69 c	50.35 c
Chroma	2010	40.06 aby	39.42 b	39.55 ab	40.16 ab	40.97 a	39.88 ab	39.22 b
	2011	38.37 b	38.01 b	37.55 b	40.46 a	38.46 b	40.86 a	38.03 b
Hue angle	2010	52.86 dy	56.00 bc	54.86 cd	60.41 a	58.24 ab	55.48 cd	53.92 cd
	2011	58.66 c	59.21 c	55.21 d	64.70 a	63.15 ab	61.33 b	55.36 d

^{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, $P < 0.05$; n=30 (ten fruits x three replications) for L*, chroma and hue angle value.

Table 6. Effects of aminoethoxyvinylglycine (AVG) and napthaleneaceticacid (NAA) on SSC, titratable acidity and starch degradation of 'Jonagold' apples.

	Time	Treatments						
		Control	AVG1	AVG2	AVG3	AVG4	AVG5	NAA
Time (WBA^z) and dose (mg L^{-1}) of AVG and NAA treatments	8 week	-	225	75	-	75	-	-
	4 week	-	-	75	225	150	75	10
	2 week	-	-	75	-	-	150	10
SSC	2010	13.7	13.2	13.6	13	14	14	14.3
	2011	15.1	13.5	13.6	13.2	13.8	13.9	14.2
TA (g malic acid 100 mL^{-1})	2010	0.45	0.46	0.45	0.49	0.4	0.45	0.42
	2011	0.54 cy	0.69 a	0.66 b	0.69 a	0.66 b	0.66 b	0.56 c
Starch degradation ^{x}	2010	8	7	7	7	7	7	8
	2011	7 a	5 b	6 ab	5 b	6 ab	7 a	7 a

^{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, $P < 0.05$; n= 12 for SSC and titratable acidity (TA) (three replications x four different measurements for each replicate). n=30 (ten fruits x three replications) for starch degradation.

Discussion

Similar to previous researches carried out with different apple species (BYERS, 1997; GREENE, 2005; YUAN; CARBAUGH, 2007), AVG in present study was found to be effective in prevention of pre-harvest drops of 'Jonagold' apple. Although all AVG treatments significantly reduced the drop rates compared to control, the treatment of 225 mg L^{-1} AVG applied at once 8 or 4 weeks before the anticipated harvest date was found to be more effective in drop prevention than the other treatments. Such a result reveals that applying a high concentration at once was more effective than applying same dose in portions at different times. Yuan and Carbaugh (2007) also reported the superiority of a single high-dose treatment. Greene (2005) reported large spectrum AVG treatments to prevent pre-harvest drops of apples and indicated better results when applied 4 or 2 weeks before the anticipated harvest date. Similarly, Schupp and Greene (2004) also reported better results of treatments 4 or 2 weeks before the harvest than 8 weeks and indicated that 8 weeks was too early for a treatment to be effective in drop control. In present study, significant differences were not observed between 225 mg L^{-1} AVG treatments applied 8 or 4 weeks before the anticipated harvest date, and both treatments were found to be highly effective in prevention of pre-harvest drops. Such different results from the other studies may be due to species and ecological conditions.

Fruit ripening-retarding effect of AVG was once again proven in present study. Becoming more distinctive in AVG1 and AVG3 treatments, in general all AVG treatments increased flesh firmness and slowed down the conversion of starch into sugar. Similar results were observed by various researchers for different apple species (BYERS, 1997; GREENE, 2002; SCHUPP; GREENE, 2004; WARGO et al., 2004; YILDIZ et al., 2012).

It was well documented that AVG inhibits ethylene biosynthesis, thus retards fruit ripening (GREENE; SCHUPP, 2004; KANG et al., 2007). Similar findings were also observed in present study. During the second year of the experiments, all AVG treatments significantly decreased ethylene biosynthesis compared to control treatments. The AVG1 and AVG3 treatments with the lowest drop rates had also the lowest ethylene synthesis. Such findings proved that AVG was effective in inhibition of ethylene synthesis and consequently in prevention of pre-harvest drops. Increasing ethylene synthesis increases the activity of enzymes breaking out cell walls in abscission sections of fruits (BROWN, 1997; BONGHI et al., 2000). Such a case reduces fruit removal force and causes fruit drops before the harvest. Increasing fruit removal forces were reported by ethylene inhibiting AVG treatments in apples (AUTIO; BRAMLAGE, 1982; YILDIZ et al., 2012). Similar findings were also observed in present study. Again more distinctive in AVG1 and AVG3 treatments, all AVG treatments increased fruit removal forces.

It was reported that ethylene-inhibiting AVG treatments reduced red skin colour formation of apples (GREENE, 2005). Wargo et al. (2004) reported decreased reddish intensity (higher hue angle) with AVG treatments in apples. Yildiz et al. (2012) indicated that low AVG doses were not affective on skin colour but only a high dose (600 mg L^{-1}) was effective on L* and hue values. Retarding effects of AVG in red colour formation were observed only in AVG1 and AVG3 treatments of present study. L* and hue angles of these two treatments were found to be higher than control fruits.

It was concluded in present study that AVG was definitely effective to control pre-harvest drops of apples. Although AVG has a large spectrum of application, treatments applied in a single dose 8 or 4 weeks before the anticipated harvest time had more effective results in 'Jonagold' apple. A single application of the total dose was significantly more effective than multiple applications with portions of the total dose.

Acknowledgement

This study was supported by the Gaziosmanpaşa University Scientific Project Unit (Project number: 2010/65). The ReTain® used in this study was supplied by ValentBioScience Company and Sylgard-309 surfactant was supplied by Dow Corning Company. Authors appreciate the supports of these companies.

References

ANONYMOUS. Turkish state meteorological service. Regional Directorate of Tokat. Tokat, 2011.

AUTIO, W. R.; BRAMLAGE, W. J. Effect of AVG on maturation, ripening and storage of apples. *Journal of the American Society for Horticultural Science*, Alexandria, v. 107, n. 6, p. 974-1077, 1982.

BLANPIED, W. J.; SILSBY, K. J. Predicting harvest date windows for apples. *Cornell Cooperative Extension and Information Bulletin,* New York, v. 221, n. 1, p. 1-18, 1992.

BONGHI, C.; TONUTTI, P.; RAMINA, A. Biochemical and molecular aspects of fruitlet abscission. *Plant Growth Regulation*, Dordrescht, v. 31, n. 1-2, p. 35-42, 2000.

BRAMLAGE, W. J.; GREENE, D. W.; AUTIO, W. R.; MCLAUGHLIN, J. M. Effects of Aminoethoxyvinylglycine on internal ethylene concentrations and storage of apples. *Journal of the American Society for Horticultural Science,* Alexandria, v. 105, n. 6, p. 847-851, 1980.

BROWN, K. M. Ethylene and abscission. *Physiologia Plantarum*, Sweden, v. 100, n. 3, p. 567-76, 1997.

BYERS, R. E. Effects of aminoethoxyvinylglycine (AVG) on preharvest fruit drop and maturity of 'Delicious' apples. *Journal of Tree Fruit Production*, London, v. 2, n. 1, p. 53-75, 1997.

CURRY, E. Changes in ripening physiology of 'Delicious' and 'Fuji' apples treated preharvest with NAA. *Acta Horticulturae*, Leuven, v. 727, n. 1, p. 481-88, 2006.

GREENE, D. W. An update on preharvest drop control of apples with aminoethoxyvinylglycine (ReTain). *Acta Horticulturae*, Leuven, v. 727, n. 1, p. 311-319, 2006.

______. Preharvest drop control and maturity of Delicious' apples as affected by aminoethoxyvinylglycine (AVG). *Journal of Tree Fruit Production*, London, v. 3, n. 1, p. 1-10, 2002.

______. Time of aminoethoxyvinylglycine influences preharvest drop and quality of 'McIntosh' apples. *Hortscience,* Alexandria, v. 40, n. 7, p. 2056-2060, 2005.

GREENE, D. W.; KAMINSKY, K.; SINCUK, J. An evaluation of stop drop materials in 1986. *Proceedings Massachusetts Fruit Growers' Association*, New England, v. 93, n. 1, p. 74-78, 1987.

GREENE, D. W.; SCHUPP, J. R. Effect of aminoethoxyvinylglycine (AVG) on preharvest drop, fruit quality, and maturation of 'McIntosh' apples. II. Effect of timing and concentration relationships and spray volume. *Hortscience*, Alexandria, v. 39, n. 5, p. 1036-1041, 2004.

JOBLING, J.; PRADHAN, R.; MORRIS, S. C.; MITCHELL, L.; RATH, A. C. The effect of ReTain plant growth regulator [aminoethoxyvinylglycine (AVG)] on the postharvest storage life of 'Tegan Blue' plums. *Australian Journal of Experimental Agriculture*, Victoria, v. 43, n. 5, p. 515-18, 2003.

KANG, I. K.; BYUN, J. K.; KWEON, H. J.; KIM, M. J.; KWON, S. I.; PARK, M. Y.; LEE, D. H.; CHOI, C.; CHOI, D. G. Effects of aminoethoxyvinylglycine on preharvest drop, fruit color, and quality of 'Tsugaru' Apples. *Horticulture Environment and Biotechnology*, Abingdon, v. 48, n. 3, p. 159-164, 2007.

LURIE, S. Regulation of ethylene biosynthesis in fruit by aminoethoxyvinylglycine and 1-methylcyclopropene. *Acta Horticulturae*, Leuven, v. 796, n. 1, p. 31-41, 2008.

MARINI, R. P.; BYERS, R. E.; SOWERS, D. I. Repeated application of NAA control preharvest drop of 'Delicious' apples. *Journal of Horticultural Science*, Ashford, v. 68, n. 2, p. 247-253, 1993.

OZTURK, B.; KUCUKER, E.; KARAMAN, S.; OZKAN, Y. The effect of cold storage and aminoethoxyvinylglycine (AVG) on bioactive compounds of plum (*Prunus salicina* Lindell cv. 'Black Amber'). *Postharvest Biology and Technology*, Amsterdam, v. 72, n. 1, p. 35-41, 2012.

PETRI, J. L.; LEITE, G. B.; ARGENTA, L. C.; BASSO, C. Ripening delay and fruit drop control in 'Imperial Gala' and 'Suprema' (Fuji Sport) apples by applying AVG (aminoethoxyvinylglycine). *Acta Horticulturae*, Leuven, v. 727, n. 1, p. 519-526, 2006.

SCHUPP, J. R.; GREENE, D. W. Effect of aminoethoxyvinylglycine (AVG) on preharvest drop, fruit quality, and maturation of 'McIntosh' apples. II. Effect of timing and concentration relationships and spray volume. *Hortscience*, Alexandria, v. 39, n. 5, p. 1030-1035, 2004.

WARGO, J. M.; MERWIN, I. A.; WATKINS, C. B. Nitrogen fertilization, midsummer trunk girdling, and AVG treatments affect maturity and quality of 'Jonagold' apples. *Hortscience*, Alexandria, v. 39, n. 3, p. 493-500, 2004.

YILDIZ, K.; OZTURK, B.; OZKAN, Y. Effects of aminoethoxyvinylglycine (AVG) on preharvest fruit drop, fruit maturity, and quality of 'Red Chief' apple. *Scientia Horticulturae*, Amsterdam, v. 144, n. 1, p. 121-24, 2012.

YUAN, R.; CARBAUGH, D. H. Effects of NAA, AVG, and 1-MCP on ethylene biosynthesis, preharvest fruit drop, fruit maturity, and quality of 'Golden Supreme' 'Golden Delicious' apples. *Hortscience*, Alexandria, v. 42, n. 1, p. 101-105, 2007.