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Pre-harvest Application of ReTain (Aminoethoxyvinylglycine, AVG) Influences Pre-harvest Drop and Fruit Quality of 'Williams' Pears

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ABSTRACT

'Williams' is the highly quality pear cultivar mostly produced in the Eğirdir region of Turkey. ReTain (15% aminoethoxyvinilglycine, AVG) is a plant growth regulator used to control pre-harvest drop and increase fruit weight and firmness. The objective of this study was to determine the responses of AVG treatments on the pre-harvest drop and fruit quality of 'Williams' pear. Pear trees of the cultivar 'Williams' were sprayed 30, 21 and 7 days before commercial harvest (DBH) with AVG, at doses of 100, 125 and 150 mg L^{-1}, and assessed for pre-harvest drop, yield, maturity, delay in harvest, fruit quality, ethylene production and respiration rate at the harvest time. Fruit samples were analyzed for fruit quality parameters which are: fruit width, fruit weight, soluble solids content (SSC), titratable acidity (TA), fruit firmness, fruit colour, fruit macro and micro elements content. Maturation of the 30 and 21 DBH AVG-treated fruits were delayed 3-4 days compared to the 7 DBH AVG-treated and control groups. The pre-harvest drop decreased with all AVG applications by approximately 38-100% in comparison with the control group fruits. AVG treatments increased fruit size (7-10%), fruit weight (26-41%) and fruit firmness (2-16%) of 'Williams' pear. AVG application reduce ethylene production and respiration rate and it was found that the applications enhance the ethylene production and respiration rate by approximately (100%) compared to the control fruits on the harvest date. Results of this study indicated that 30 DBH and 21 DBH AVG-treatments at 100 mg L^{-1} can be recommended for 'Williams' pear cultivar on both pre-harvest fruit drop, as well as in harvest date and fruit quality.

Keywords: Pear; Harvest time; Fruit quality; 'Williams'; Pre-harvest drop; AVG

Hasat Öncesi ReTain (Aminoethoxyvinylglycine, AVG) Uygulamalarının 'Williams' Armut Çeşidinde Hasat Önü Dökümü ve Meyve Kalitesi Üzerine Etkileri

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ÖZET

'Williams' armudu Türkiye'nin Eğirdir bölgesinde üretimi fazla olan kaliteli bir çeşittir. ReTain (% 15 aminoetoksi-vinilglisin, AVG), hasat önü meyve dökümünün kontrolünde, meyve ağırlığı ve meyve eti sertliğinin artırılmasında kullanılmakta olan bir bitki büyüme düzenleyicisidir. Bu çalışma, 'Williams' armudunda hasat önü meyve dökümü ve meyve kalitesi üzerine AVG uygulamalarının etkilerini incelemek amacıyla yürütülmüştür. Bu amaçla, tahmini hasat zamanından (THZ) 30, 21 ve 7 gün önce 0, 100, 125, 150 mg L^{-1} dozlarında AVG armut ağaçlarına püskürtme şeklinde uygulanmıştır. Hasat önü meyve dökümü, verim, olgunluk, hasat tarihinin gecikmesi, meyve kalitesi, meyvelerin etilen üretimi ve solunum hızları hasat zamanında incelenmiştir. Hasat edilen meyvelerin kalite parametreleri olarak meyve çapı, meyve ağırlığı, meyve eti sertliği, meyve rengi, suda çözünebilir kuru madde, titre edilebilir asitlik ve meyvelerde makro-mikro elementler analiz edilmiştir. THZ 30 ve 21 önce uygulanan AVG uygulamaları ile meyve olgunluğu kontrol grubuna ve THZ 7 önce uygulanan AVG uygulamalarına göre 3-4 gün gecikmiştir. AVG uygulamaları ile hasat önü meyve dökümü % 38-100 arasında oldukça azalmış olup meyve boyutu (% 7-10), ağırlığı (% 26-41) ve meyve sertliği de (% 2-16) artmıştır. AVG uygulamaları meyvelerdeki etilen üretimi ve solunum hızını da kontrol grubuna göre neredeyse % 100 yavaşlatmıştır. Sonuç olarak, 'Williams' armut çeşidinde, gerek hasat önü meyve dökümü, gerekse hasat zamanı ve meyve kalitesi bakımından THZ 30 ve 21 gün önceki 100 mg L^{-1}'lik uygulamaların en uygun uygulamalar olduğu tavsiye edilmektedir.

Anahtar Kelimeler: Armut; Hasat zamanı; Meyve kalitesi; 'Williams'; Hasat önü döküm; AVG

1. Introduction

Pre-harvest drop of pears happens because the fruit developed an immaturity, and in most cases, economic damage usually causes a serious economic loss. A good quality 'Williams' (Bartlett) pear should have a fruit medium large-large conical neck; the middle part is wide. Light green peel, a thin, hollow stem with rust coloured surroundings, eating death are yellow. The flesh is white, fine-textured, like butter type, very juicy, sweet and aromatic and the quality is excellent. Suppressing ethylene production in 'Williams' pears may increase yields by reducing premature fruit abscission, and indirectly increase fruit size by delaying harvest of slower-maturing fruit. 'Williams' growers often use the synthetic auxin, naphthaleneacetic acid (NAA), which can compress pre-harvest abscission, however can also result in fruit softening. Reducing fruit ethylene production may reduce the incidence of premature ripening on the tree, enhance the storage life, and reduce the rate of ripening of 'Williams' pears (Clayton et al 2000). AVG (aminoethoxyvinylglycine) inhibit ethylene biosynthesis pathway (Kim et al 2004), and can thus compress ethylene production in many climacteric fruits (Yang et al 1982). Pre and post-harvest applications of AVG have been evaluated as a tool to enhance production and quality attributes of climacteric fruits (Çetinbaş et al 2012). AVG delaying the harvest of fruits result in them being larger and thus increases the yield. Delay in harvesting may convenience flexibility in labor, packaging and fruit processing, storage and marketing (Amarante et al 2005).

Pre and post-harvest treatments with AVG inhibited ethylene production and delayed harvesting of pears (Romani et al 1983) and peaches (Çetinbaş & Koyuncu 2011). With the 'Barlett' pear, pre-harvest AVG treatments either 14 or 7 days before harvest did not affect ethylene production at harvest, but delayed changes in skin colour, softening and starch content (Clayton et al 2000). Andreotti et al (2004) found that pre-harvest treatment with AVG at 125 mg L^{-1} delayed maturation of 'Abbe Fetel' pears by 5 to 15 days.

Therefore, this study was conducted to determine the effects of AVG applications different doses, sprayed 30, 21 and 7 days before commercial harvest, on pre-harvest drop, fruit maturity and fruit quality of 'Williams' pears.

2. Material and Methods

2.1. Plant material

The trials were conducted at the Fruit Research Station of Eğirdir, Turkey in 2011-2012. Uniform 10-years-old pear trees of the cv. 'Williams', grafted on Quince C rootstock and spaced at 1.5x4 m were used. The experiment was designed in completely randomized blocks of 4 replications, using a single tree for each treatment.

2.2. AVG treatments

ReTain was (Valent BioScience Corporation) sprayed at 0 (water+surfactant), 100, 125, 150 mg L^{-1} plus 1% (v v^{-1}) Tween 20 as a surfactant onto fruits and leaves around the fruits until runoff. The spraying was performed with a hand pump sprayer at 7, 21 and 30 days before (DBH) in 2011 and 2012. Application time and dose of AVG were determined according to Çetinbaş & Koyuncu (2011).

2.3. Fruit maturity and harvest determination

When the pear fruits firmness were 80 to 89 N, fruits were harvested at a commercial stage of maturity. AVG-treated fruits and untreated fruits were harvested separately and picked into specially designated bins. After each harvest pick, fruit was transported to the Pomology Laboratory of Fruit Research Station. Fruits were harvested 2 times from 21 to 24 September 2011 (I. year) and from 19 to 23 September 2012 (II. year).

2.4. Yield and pre-harvest drop determination

The yield was determined at harvest as per tree kg in the first and second year. In order to determine the pre-harvest drop rate, existing fruits on each tree were identified one month before commercial harvest (DBH) and then, twice every week. Fallen fruits were counted under the trees in the first and second year. The results were expressed as percent (%).

2.5. Fruit quality determination

Fruit width, fruit weight and fruit firmness: The measurement of twenty fruits were determined using digital calipers for fruit width (mm). Fruit weight (g) was measured by a digital scales sensitive to 0.01 g. Fruit firmness (Newton) was measured by using a texture analyser (Lloyd Instruments LF Plus) incorporating an 8 mm diameter probe.

Soluble solid content (SSC) and titratable acidity (TA): The rates of SSC were measured by a digital refractometer (Palette PR-32 Atago). TA by manual titration with 0.1 N NaOH and expressed as g malic acid 100 g^{-1}.

Fruit colour: The colour of the fruit was measured with a colorimeter (Minolta CR-300). Peel colours were evaluated as CIE L*, a*, b*, C*, h°.

2.6. Respiration rate and ethylene production determination

Ethylene production (µL kg^{-1} h^{-1}) and respiration rate (µL kg^{-1} h^{-1}) were defined pear of close to the jar after 1 day. Measurement of respiratory rate was done with gas analizator. Ethylene production was determined by using gas chromatography with a flame ionization detector (Gunes et al 2001).

Fruit mineral composition determination: The mineral contents of the fruit samples were analyzed. Samples were washed thoroughly with fountain water, dilute acid (0.2 N HCl) and distilled water to remove surface residues, and dried at 70±5 °C. Dried samples were ground with a stainless-steel mill for analytic procedures. The P, K, Ca, Mg, Fe, Cu, Mn, Zn and B concentrations were determined by Inductively Coupled Plasma Atomic Emission spectrometry (Perkin Elmer Optima, Germany) method. Nitrogen was determined by the Kjeldahl (Gerhardt, Germany) procedure. The resulting data was expressed as a percentage of dry tissue (%) for N, P, K, Ca, Mg, whereas Fe, Cu, Mn, Zn and B were recorded as milligrams per kilogram of dry fruit.

2.7. Statistical analysis of results

The experiment was based as a completely randomized blocking pattern as four replications and was assigned as one tree for each replication. The data was statistically analyzed (Duncan's multiple range test at P≤ 0.05) using SPSS (V.18; Statistical software, SPSS. Inc., USA) software program. Fruit colours and fruit mineral compositons were done during two years and the data presented here are the mean results of these years.

3. Results and Discussion

3.1. Fruit maturity and harvest

Considering fruit firmness and colour, 'Williams' pear harvests of all treatments were performed at harvest maturation in our study. The 30 DBH and 21 DBH AVG treatments were harvested later than control and 7 DBH AVG-treated fruits (In the first and second year). Control and 7 DBH AVG-treated fruits were harvested on the 21st September while 30 and 21 DBH AVG applied fruits were harvested on the 24th September (in 2011). In 2012, fruits were harvested on the 19th September (control and 7 DBH AVG-treated fruits) and 23 September (30 and 21 DBH AVG-treated fruits). Consequently, it was observed AVG treatments delayed harvest time by 3 days. It was reported in many studies done with pears and apples that AVG applications delay harvest time showing similarities with our findings (Clayton et al 2000; Schupp & Greene 2004; Greene 2006; Petri et al 2006; Rath et al 2006; WookJae et al 2006; Kang et al 2007; Whale et al 2008). Phan-Thien et al (2004) showed the effect of 125 mg L^{-1} of AVG sprayed onto 'Gala' and 'Pink Lady' apples in the first 5 to 12 days delayed ripening by 5 to 7 days. In a study conducted in a commercial orchard of 'Arctic Snow' nectarines, application of 125 mg L^{-1} AVG 7 days before anticipated first harvest gave a 2.75 day harvest delay based on standard commercial maturity criteria (Rath & Prentice 2004).

3.2. Yield and pre-harvest drop

In both years, AVG treatments increased fruit yield. AVG concentrations x application times interaction on the yield was found to be statistically significant (P≤0.05) in 2011. In the second year (2012), AVG had not significant effects on yield (Table 1). The highest yield was found in the plot submitted to 30 DBH-100 mg L^{-1} AVG treatment (in the first year). In both years, as illustrated in Table 1, pre-harvest fruit drop was influenced significantly by AVG concentrations and application times (P≤0.05). The highest pre-harvest fruit drop was observed in 7 DBH-control fruits (in 2011). In 2012, fruits of the 21 DBH-control were higher than the others. In both years, the pre-harvest drop was not observed after treatment with 150 mg L^{-1} AVG concentration at 21 DBH (Table 1). Karaçalı (2009) reported that pre harvest drop depends on the plant species and its variety. Hot or cold weather conditions, late time fertilization with high nitrogen content, drought and high soil water level, low boron and magnesium levels in the soil increase pre harvest drop ratio. Cultural practices are not enough to prevent pre harvest drop. Plant growth regulators must be used to prevent pre harvest drop. In our study, AVG treatments were used in an orchard which has regular cultural practice and AVG treatments were used to control pre harvest drop. The effects of AVG applications on pre-harvest fruit drop and yield are highly significant in our research. It was determined that pre-harvest fruit drop was reduced by AVG treatments. Pre-harvest fruit drop has never been detected after 30 DBH-150 mg L^{-1} and all doses of 21 DBH applications. Accordingly, it was found that the aforementioned applications enhance the fruit yield as compared to the other applications. The percentage of pre-harvest fruit drop decreased in parallel with the increase in treatment doses. In one of his studies regarding AVG's effectiveness on pre-harvest apple drop control, Greene (2006) stated that increase in AVG is directly correlated with its concentration, meaning increase in dose. Greene (2006) also reported that the most appropriate and effective time to apply the treatment is 2-3 weeks before the estimated harvest. It was revealed in our study, in line with the results of many researchers, that AVG prevents or reduces the pre-harvest fruit drop (Greene 2006; Petri et al 2006; Rath et al 2006; WookJae et al 2006; Kang et al 2007; Whale et al 2008). These results are considered to be important for the prevention or reduction of pre-harvested losses approximately 10% of pre-harvest drop. We also believe the results affect pear growers favourably on economic aspects.

Table 1- The effect of AVG treatments on yield and pre-harvest fruit drop in the 'Williams' pear, 2011 and 2012

Çizelge 1- AVG uygulamalarının 'Williams' armudunda verim ve hasat önü meyve dökümüne etkisi, 2011 ve 2012

Application time[1]	*AVG concentrations (mg L^{-1})*	*Yield (kg tree^{-1})*		*Pre-harvest drop (%)*	
		2011	*2012*	*2011*	*2012*
30 d	0	8.30 a-c	9.65	24.92 a	8.52 b
	100	12.4 6a	16.81	0.00 b	2.51 c
	125	9.07 a-c	16.06	0.00 b	0.79 c
	150	7.74 bc	13.05	2.54 b	0.00 c
21 d	0	7.53 bc	11.71	25.60 a	16.43 a
	100	11.18 ab	14.04	0.00 b	0.00 c
	125	6.69 bc	11.84	4.25 b	0.00 c
	150	7.02 bc	15.71	0.00 b	0.00 c
7 d	0	4.42 c	12.62	26.90 a	13.12 a
	100	5.35 c	13.24	6.06 b	1.96 c
	125	6.63 bc	13.68	3.49 b	7.90 b
	150	7.73 bc	14.32	4.75 b	0.84 c
Time					
30		9.39	12.82	6.87	2.96
21		8.10	12.62	7.46	13.12
7		6.03	12.77	10.30	5.96
	AVG concentrations				
	0	6.75	12.17	25.81	12.04
	100	9.66	13.77	2.02	1.49
	125	7.46	13.86	2.58	2.90
	150	7.50	12.92	2.43	0.28
P values					
Time (T)		0.016	0.951	0.747	0.477
Concentrations (C)		0.184	0.381	0.000	0.000
T × C		0.027	0.867	0.000	0.000

[1], days before harvest (DBH); in each column, values followed by the same letter are not significantly different at P≤0.05 level according to Duncan's multiple range test

3.3. Fruit quality

Fruit width, fruit weight and fruit flesh firmness: In both years, AVG applications significantly (P≤0.05) increased fruit width and weight in 'Williams' pear cultivar. The heaviest fruits were obtained from 21 DBH-100 mg L^{-1} (380.46 g in first year and 335.00 g in second year) AVG dose (Table 2). AVG applications increase 'Williams' pear fruit width and weight and it was found that the applications enhance the fruit width by approximately 7-10% and fruit weight by 26-41% in comparison with the control group fruits. Petri et al (2006) states AVG enhances fruit weights of 'Gala' and 'Fuji' apples as compared to the control group. Greene (2006) also expresses that AVG-applied fruits are generally bigger since it helps fruit remain on the tree for a longer time. In our study, the biggest pears were obtained from the application of 21 DBH-100 mg L^{-1} and 21 DBH-150 mg L^{-1}. Venburg et al (2008) stated that continuing research has extended and refined the use of AVG in apples and stone fruit. AVG's ripening and harvest delay effect have been investigated, examining the effect of harvest delay on fruit size and yield. When the untreated fruit and ReTain-treated fruit were harvested at the same stage of ripening, the fruit size in the ReTain treatment was larger due to the 7 days delay. In the ReTain treatments, the mass of small size fruit per tree (<65 mm) was reduced and the mass of larger size fruit per tree (>65 mm) was increased. In addition, the overall yield was 11% greater treatment. In both years, AVG treatments had a significant influenced on fruit flesh firmness. In 2011, Fruit flesh firmness was affected significantly by AVG concentrations and application times ($P \leq 0.05$). In 2012, Fruit flesh firmness was influenced significantly by AVG concentrations ($P \leq 0.05$) (Table 2). In first year, the harder fruits were found after 21 DBH-100 mg L^{-1} (88.72 N) and 7 DBH-100 mg L^{-1} (88.30 N) AVG treatments. However, the fruit firmness-increasing effect of AVG concentrations was more distinctive in the second year experiments. The 125 mg L^{-1} AVG treatment determined the highest fruit firmness values (88.39 N) at the harvest. This was followed by 100 and 150 mg L^{-1} AVG doses (Table 2). Similarly to our findings, the dose of 125 mg L^{-1} AVG enhanced the fruit firmness before the harvest time of 'Tsugaru' apples (WookJae et al 2006). Besides, it was stated that AVG application has favourable impact on fruit firmness of different apple types such as 'McIntosh', 'Spartan', 'Spencer' (Bramlage et al 1980), 'Gala' and 'Jonagold' (Wang & Dilley 2001). In a study done with 'Bartlett' pear, Clayton et al (2000) states that AVG boosted fruit firmness. Keeping the pears

Table 2- The effect of AVG treatments fruit width, weight and flesh firmness in 'Williams' pear, 2011 and 2012

Çizelge 2- AVG uygulamalarının 'Williams' armudunda meyve çapına, ağırlığına ve sertliğine etkisi, 2011 ve 2012

Application time[1]	*AVG concentrations (mg L^{-1})*	*Fruit width (mm)*		*Fruit weight (g)*		*Fruit flesh firmness (N)*	
		2011	*2012*	*2011*	*2012*	*2011*	*2012*
30 d	0	70.73 f	74.20 cd	189.13 f	226.33 e	78.04 c	84.71
	100	78.07 c	82.94 ab	266.54 c	315.17 a-c	82.12 a-c	88.44
	125	77.03 cd	82.54 ab	252.28 cd	314.00 a-c	86.32 ab	89.25
	150	74.04 e	77.17 b-d	217.23 e	257.67 c-e	86.52 ab	90.12
21 d	0	70.60 f	72.50 cd	193.12 f	241.00 de	76.77 cd	84.31
	100	86.17 a	84.75 a	380.46 a	335.00 a	88.72 a	89.54
	125	80.83 b	84.29 ab	303.19 b	326.67 ab	85.92 a-c	88.15
	150	81.17 b	83.07 ab	302.54 b	330.00 a	87.49 ab	85.57
7 d	0	69.88 f	70.73 d	185.03 f	203.67 e	81.62 a-c	84.34
	100	74.83 de	78.51 a-c	233.94 de	263.33 c-e	88.30 a	85.23
	125	76.48 cd	79.30 a-c	239.06 d	302.33 a-d	85.30 a-c	87.76
	150	81.80 b	77.40 b-d	293.95 b	265.67 b-e	84.45 a-c	86.54
Time							
30		74.97	79.21	231.30	278.29	85.25	88.13
21		79.69	81.15	294.83	308.17	84.73	86.89
7		75.74	76.48	237.99	258.75	84.92	85.97
	AVG concentrations						
	0	70.40	72.48	189.09	223.67	78.81	84.45 b
	100	79.69	82.06	293.65	304.50	86.38	87.74 a
	125	78.11	82.04	264.84	314.33	85.85	88.39 a
	150	79.00	79.21	271.24	284.44	86.15	87.41 a
P values							
Time (T)		0.045	0.117	0.008	0.054	0.832	0.225
Concentrations (C)		0.000	0.000	0.000	0.000	0.006	0.030
T × C		0.000	0.001	0.000	0.000	0.000	0.108

[1], days before harvest (DBH); in each column, values followed by the same letter are not significantly different at $P \leq 0.05$ level according to Duncan's multiple range test

under shelf life conditions and cold storing them protect their hardness more effectively than the control group fruits. As a kind of flavoured pear, 'Williams' directly takes place both in domestic and foreign market. Hence a portion of shelf life is consumed during transport. In accordance with the data obtained from this study, it is probable that increase in fruit firmness may have favourable impact on shelf life of fruits, thus reducing effects of loss of quality during transportation.

Soluble solid content (SSC) and titratable acidity (TA): In both years, AVG concentrations × application time interaction on the SSC and TA in was found to be statistically significant (P≤0.05) (Table 3). In the first year, compared to only 21 DBH-AVG treated fruits showed lower values of SSC, while in the second year all AVG applications determined the same effect. In both years, AVG treatments had unstable effects on TA (Table 3). The effect was reported as variable depending on concentration of AVG application, time of application, variety and environmental conditions (Bramlage et al 1980). AVG applications reduced the SSC amount, however, no effect has been detected at quinic and malic acid amount (Drake et al 2005). Furthermore, Clayton et al (2000) reported that AVG applications

Table 3- The effect of AVG treatments total soluble solids (SSC) and titratable acidity (TA) in 'Williams' pear, 2011 and 2012

Çizelge 3- AVG uygulamalarının 'Williams' armudunda suda çözünebilir kuru madde (SÇKM) ve titre edilebilir asitliğe (TA) etkisi, 2011 ve 2012

Application time[1]	*AVG concentrations (mg L^{-1})*	*SSC (%)*		*TA (%)*	
		2011	*2012*	*2011*	*2012*
30 d	0	14.40 c	16.90 a	0.45 c-e	0.62 a
	100	15.57 a	13.30 cd	0.49 a-d	0.42 cd
	125	15.03 a-c	12.83 d	0.42 de	0.48 b-d
	150	15.93 a	15.43 ab	0.40 e	0.63 a
21 d	0	15.30 a-c	14.93 bc	0.48 a-d	0.59 ab
	100	14.50 bc	14.37 b-d	0.44 c-e	0.49 b-d
	125	14.93 a-c	13.00 c	0.55 a	0.41 d
	150	15.30 a-c	14.07 b-d	0.55 ab	0.54 a-c
7 d	0	14.37 c	15.23 ab	0.44 c-e	0.59 ab
	100	15.43 ab	13.97 b-d	0.47 b-d	0.51 a-d
	125	15.27 a-c	13.03 cd	0.38 e	0.51 a-d
	150	15.27 a-c	14.60 b-d	0.51 a-c	0.60 ab
Time					
30		15.23	14.62	0.44	0.54
21		15.01	14.09	0.50	0.51
7		15.08	14.21	0.45	0.55
	AVG concentrations				
	0	14.69	15.69	0.46	0.60
	100	15.17	13.88	0.47	0.47
	125	15.08	12.96	0.45	0.47
	150	15.50	14.70	0.49	0.59
P values					
Time (T)		0.695	0.654	0.016	0.467
Concentrations (C)		0.056	0.000	0.697	0.000
T × C		0.029	0.000	0.000	0.003

[1], days before harvest (DBH); in each column, values followed by the same letter are not significantly different at P≤0.05 level according to Duncan's multiple range tests

increase SSC amount and reduce the amount of TA, which has also been observed in our results.

Fruit colours: AVG concentrations × application times interaction on the fruit colour component L*, b* and C* values was found to be statistically significant (P≤0.05). AVG concentrations on the h° values in was found to be statistically significant (P≤0.05). AVG treatments had no significant influenced on a* values (Table 4). L* values decreased with AVG treatments. The highest L* value was observed in control fruit groups. The AVG applications increased b* value (yellowness). AVG effected on late ripening and also on late colouration of fruits, for this reason in our study b* value increased. The highest C* value (49.33) was determined in 30 DBH-100 mg L^{-1} AVG fruits. The only AVG concentrations reduced h° values (Table 4). However, all AVG concentrations were included same group in statistics. The effect of AVG applications on fruit coloration resulted differently in several studies. The colouration was delayed for 'Redfree', 'Gala' and 'Golden Delicious' varieties with AVG applications, while red colour was not affected in 'Rome' variety. Greene (2006) stated that decrease in red color is correlated with delay in maturation rather than the prevention of red color development.

Table 4- The effect of AVG treatments fruit colour (L*, a*, b*, C* and h°) in 'Williams' pear (2011 and 2012 means)

Çizelge 4- AVG uygulamalarının 'Williams' armudunda meyve rengine (L, a*, b*, C* and h°) etkisi (2011 ve 2012 ortalamaları)*

Application time[1]	*AVG concentrations (mg L^{-1})*	*Fruit colour*				
		*L**	*a**	*b**	*C**	*h°*
30 d	0	68.45 a	-10.23	45.04 a-d	46.99 b-d	101.90
	100	65.50 bc	-11.13	47.14 a	49.33 a	102.21
	125	64.05 c	-10.40	46.02 a-c	48.34 a-c	101.22
	150	64.17 c	-8.12	46.18 a-c	48.08 a-c	98.54
21 d	0	68.43 a	-9.93	45.34 a-d	47.05 b-d	100.93
	100	63.59 c	-10.62	46.60 ab	49.13 ab	101.20
	125	62.88 c	-8.87	45.74 a-c	48.57 a-c	98.65
	150	64.72 c	-9.02	46.35 a-c	48.96 ab	99.09
7 d	0	67.86 ab	-9.41	45.02 a-d	46.52 cd	100.93
	100	63.27 c	-7.56	46.63 b-d	47.01 b-d	97.34
	125	63.03 c	-9.60	44.12 cd	46.83 b-d	100.11
	150	62.49 c	-5.43	43.25 d	45.31 d	95.29
Time						
30		65.54	-9.96	46.10	46.42	100.97
21		64.91	-9.61	46.01	48.43	100.14
7		64.16	-8.00	44.26	48.18	98.42
	AVG concentrations					
	0	68.25	9.85	45.13	46.85	101.48 a
	100	64.12	9.77	46.12	48.49	100.25 ab
	125	63.32	9.62	45.29	47.91	99.9a b
	150	63.79	7.52	45.26	47.45	97.64 b
P values						
Time (T)		0.275	0.076	0.000	0.000	0.094
Concentrations (C)		0.000	0.085	0.386	0.079	0.041
T × C		0.000	0.133	0.011	0.002	0.094

[1], days before harvest (DBH); in each column, values followed by the same letter are not significantly different at P≤0.05 level according to Duncan's multiple range test

3.4. Ethylene production and respiration rates

As showed in Table 5, ethylene production rate was influenced significantly ($P \leq 0.05$) by AVG applications in 2011 and 2012. In the first year, the ethylene production of all application time in control group fruits illustrated the highest value (5.46 μL kg^{-1} h^{-1}, 4.05 μL kg^{-1} h^{-1} and 3.63 μL kg^{-1} h^{-1}, respectively) while 30 DBH-100 mg L^{-1} AVG fruits had the lowest value (0.22 μL kg^{-1} h^{-1}). In the second experiment year, all of the control groups determined ethylene production. In 2011, AVG concentrations × application time interaction on the fruit respiration rates were found to be statistically significant ($P \leq 0.05$). In 2012, respiration rates of fruits were influenced significantly by AVG concentrations ($P \leq 0.05$). All the AVG-treated fruits showed the lowest respirations rates in 2011 and 2012. Besides all AVG applications were included in the same group in statistics (Table 5). Similar to our findings, Clayton et al (2000) and Bregoli et al (2002) stated that AVG decreases the amount of ethylene and the respiration rate of 'Bartlett' pear, 'Jersey Mac' apple, 'Red Haven' peach, respectively. They also specified that the application doses showed similar impact.

Table 5- The effect of AVG treatments on ethylene production rate and respiration rate in 'Williams' pear, 2011 and 2012

Çizelge 5- AVG uygulamalarının 'Williams' armudunda etilen üretimi ve solunum hızına etkisi, 2011 ve 2012

Application time[1]	*AVG concentrations (mg L^{-1})*	*Ethylene production (μL kg^{-1} h^{-1})*		*Respiration rate (μL kg^{-1} h^{-1})*	
		2011	*2012*	*2011*	*2012*
30 d	0	3.63 a	4.00 ab	42.99 b	42.02
	100	0.22 b	0.00 c	6.20 c	1.99
	125	0.35 b	0.00 c	4.39 c	1.45
	150	0.29 b	0.00 c	6.81 c	1.76
21 d	0	4.05 a	4.30 a	59.11 ab	51.68
	100	0.27 b	0.00 c	6.89 c	1.72
	125	0.36 b	0.00 c	8.14 c	1.59
	150	0.53 b	0.00 c	4.15 c	1.42
7 d	0	5.46 a	2.70 b	78.88 a	62.10
	100	0.27 b	0.00 c	5.49 c	1.74
	125	0.30 b	0.00 c	6.33 c	1.686
	150	0.31 b	0.00 c	5.20 c	1.51
Time					
30		1.12	1.00	15.10	11.81
21		1.30	1.08	19.57	14.10
7		1.58	0.68	23.97	16.76
	AVG concentrations				
	0	4.38	3.66	60.33	51.93 a
	100	0.25	0.00	6.19	1.82 ab
	125	0.34	0.00	6.28	1.56 b
	150	0.38	0.00	5.39	1.57 b
P values					
Time (T)		0.860	0.840	0.755	0.220
Concentrations (C)		0.000	0.000	0.000	0.017
T × C		0.000	0.000	0.000	0.097

[1], days before harvest (DBH); in each column, values followed by the same letter are not significantly different at $P \leq 0.05$ level according to Duncan's multiple range test

3.5. Fruit mineral composition

Effects of AVG applications on 'Williams' pear mineral composition were given in Table 6 and 7 (in 2011 and 2012 means). Interactive effects of AVG concentrations and application times on the calcium were (P≤0.05). Nitrogen and phosphorus were influenced significantly (P≤0.05) by AVG concentrations. The average nitrogen contents were 0.31-0.50% and phosphorus contents were determined between 0.088-0.110%. Potassium and magnesium were not found statistically significant (P≤0.05) (Table 6). AVG treatments showed different effects on calcium contents. 30 DBH-125 mg L^{-1} AVG-treated fruits and 30 DBH-control fruits had the highest calcium (0.083 and 0.085%) contents (Table 6). Effects of AVG concentrations and application times on other mineral contents (iron, copper, manganese, zinc, boron) were not statistically significant (Table 7). Even though not many studies are done regarding the effect of AVG applications on micro and macro elements of fruits, Butar (2013) observed that AVG treatments

Table 6- The effect of AVG treatments on fruit mineral composition (nitrogen, phosphorus, potassium, calcium, magnesium) in 'Williams' pear (2011 and 2012 means)

Çizelge 6- AVG uygulamalarının 'Williams' armudunda meyvenin mineral içeriklerine (azot, fosfor, potasyum, kalsiyum, magnezyum) etkisi (2011 ve 2102 ortalamaları)

Application time[1]	*AVG concentrations (mg L^{-1})*	*Nitrogen*	*Phosphorus*	*Potassium*	*Calcium*	*Magnesium*
				(%)		
30 d	0	0.31	0.091	0.81	0.085 a	0.057
	100	0.41	0.110	0.86	0.064 b	0.049
	125	0.40	0.110	0.84	0.083 a	0.056
	150	0.35	0.100	0.81	0.064 b	0.049
21 d	0	0.34	0.092	0.78	0.061 b	0.052
	100	0.39	0.100	0.78	0.062 b	0.053
	125	0.37	0.100	0.84	0.063 b	0.053
	150	0.32	0.100	0.81	0.068 ab	0.050
7 d	0	0.31	0.088	0.75	0.067 ab	0.052
	100	0.31	0.100	0.78	0.070 ab	0.052
	125	0.50	0.100	0.88	0.059 b	0.056
	150	0.37	0.090	0.75	0.076 ab	0.052
Time						
30		0.36	0.099	0.79	0.074	0.052
21		0.35	0.098	0.82	0.063	0.052
7		0.38	0.095	0.80	0.068	0.053
	AVG concentrations					
	0	0.32b	0.090 b	0.80	0.070	0.054
	100	0.39ab	0.100 a	0.82	0.060	0.051
	125	0.42a	0.100 a	0.83	0.070	0.055
	150	0.35ab	0.096 ab	0.77	0.070	0.050
P values						
Time (T)		0.201	0.555	0.377	0.051	0.862
Concentrations (C)		0.031	0.030	0.198	0.771	0.124
T × C		0.201	0.354	0.485	0.026	0.462

[1], days before harvest (DBH); in each column, values followed by the same letter are not significantly different at P≤0.05 level according to Duncan's multiple range test

affect nitrogen, manganese and iron contents and this effect was noticeably seen in 150 mg L^{-1} AVG treatment of 'Jersey Mac' apple. At the end of 3 days shelf life, and 500 mg L^{-1} and 1000 mg L^{-1} doses of after-harvest AVG-applied 'Fuji' and 'Granny Smith' apples, nitrogen amount was found to reduce in 'Granny Smith' variety, while increase at 500 mg L^{-1} AVG application and decrease at 1000 mg L^{-1} AVG application on 'Fuji' apple. On the other side, it was determined that Ca amount increases with AVG treatments of 'Fuji', Mg amount increases only after 500 mg L^{-1} treatment and both Ca and Mg amounts increase only after 1000 mg L^{-1} AVG application on 'Granny Smith' variety (Fadhil 2007). Karaçalı (2009) stated that pre harvest drop may occur if the phosphorus level decreases and a fruit with high quality can contain phosphorus 11 mg 100 g^{-1}. In our study AVG treatments increased phosphorus levels and fruits contained 10-11 mg 100 g^{-1} phosphorus. It was identified that AVG applications have an effect on the macro elements of fruit. AVG concentrations increased nitrogen contents from 32% to 38% on average and phosphorus contents from 0.090% to 0.099% on average. Referring to the micro elements of fruits, AVG applications were not found to be effective on micro elements.

Table 7- The effect of AVG treatments on fruit mineral composition (Iron, copper, manganese, zinc, boron) in 'Williams' pear (2011 and 2012 means)

Çizelge 7- AVG uygulamalarının 'Williams' armudunda meyvenin mineral içeriklerine (demir, bakır, mangan, çinko, bor) etkisi (2011 ve 2012 ortalamaları)

Application time[1]	*AVG concentrations (mg L^{-1})*	*Iron*	*Copper*	*Manganese*	*Zinc*	*Boron*
				(mg kg^{-1})		
30 d	0	12.74	8.48	3.51	8.56	14.43
	100	12.76	8.75	2.71	8.57	12.36
	125	11.87	8.58	3.00	8.80	13.49
	150	12.13	8.64	2.48	7.86	11.74
21 d	0	11.50	9.28	2.70	8.38	14.54
	100	16.38	8.43	2.89	8.47	14.14
	125	13.53	9.04	2.97	8.69	13.89
	150	12.22	9.62	3.18	9.34	15.15
7 d	0	12.02	8.64	3.08	8.30	13.93
	100	13.31	9.34	3.34	9.64	14.87
	125	11.89	9.91	3.36	9.43	14.11
	150	12.57	9.23	3.07	8.07	14.67
Time						
30		12.06	8.61	2.92	8.45	13.00
21		13.88	9.09	2.94	8.72	14.45
7		12.45	9.28	3.21	9.11	14.35
	AVG concentrations					
	0	12.71	8.80	3.10	8.41	14.30
	100	13.85	8.84	2.98	8.87	13.79
	125	12.52	9.17	3.11	8.97	13.86
	150	12.12	9.16	2.91	8.76	13.85
P values						
Time (T)		0.149	0.147	0.539	0.581	0.083
Concentrations (C)		0.467	0.689	0.923	0.882	0.931
T × C		0.582	0.516	0.900	0.983	0.533

[1], days before harvest (DBH); in each column, values followed by the same letter are not significantly different at $P \leq 0.05$ level according to Duncan's multiple range test

4. Conclusions

Considering all results together, in respect to pre-harvest fruit drop and fruit quality, AVG applications were found to be significant for 'Williams' pear and, the most significant application time and doses were considered to be 100 mg L^{-1} treatment 30 and 21 days before the estimated harvest. High AVG treatment concentrations were used in the study. They were effective also for fruit quality but low AVG concentrations can be advised for human health and environmental conditions.

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