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Rearch article

The Effect of Aminoethoxyvinylglycine (AVG) on Pre-harvest Fruit Drop and Fruit Quality in Red Chief and Braeburn Apple Cultivars

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Abstract. The study was carried out in 2017 in the semi-dwarf apple orchard established in 2010 in Kemalpaşa village in Tokat province in order to determine the effect of AVG application in different concentrations on the pre-harvest fruit drop and fruit quality of Red Chief and Braeburn apple cultivars. In the study, 7 years-old apple trees of Red Chief and Braeburn cultivars grafted on MM106 rootstock were used. AVG, at 0, 75, 150 and 225 mg L^{-1} combined with a Regulaid' surfactant at 0.1% v/v, was applied to the trees before anticipated harvest. Fruit drop ratio, which varied depending on the cultivar, was lower in the AVG treated trees, and the effect of the application concentration was significant. AVG application was effective in maintaining the fruit retention force. The significant differences in fruit retention force occurred between application concentrations. It was determined that the the fruit retention force was higher in the fruits belonging to the Breaburn cultivar. The effect of AVG on fruit size, SSC pH and acidity rates varied depending on the variety. There was no significant differences in fruit firmness and starch index between cultivars. AVG application increased the fruit firmness and decreased the amount of starch both cultivar. As a result, of this study, it has been revealed that AVG can be used effectively in preventing pre-harvest fruit drop in Redchief ve Braeburn.

Aminoethoxyvinylglycine (AVG) Uygulamasının Red Chief ve Braeburn Elma Çeşitlerinde Hasatönü Meyve Dökümü ve Meyve Kalitesi Üzerine Etkisi

Anahtar kelimeler
Malus comminus, meyve eti sertliği, nişasta indeksi, kopma direnci

Özet. Farklı konsantrasyonlarda AVG uygulamasının Red Chief ve Braeburn elma çeşitlerinde hasatönü meyve dökümü ve meyve kalitesi üzerine etkisinin belirlenmesi amacıyla yürütülen bu çalışma Tokat ili Kemalpaşa köyünde 2010 yılında kurulmuş olan yarı bodur elma bahçesinde 2017 yılında yapıldı. Çalışmada MM106 anacı üzerine aşılı Red Chief ve Braeburn çeşitlerine ait 7-yaşlı elma ağaçları kullanıldı. 0, 75, 150 ve 225 mg L^{-1} konsantrasyonlarda ve %0.1 v / v 'de bir sürfaktan ile kombine edilen AVG, tahmini hasattan 4 hafta önce ağaçlara uygulandı. Çeşide bağlı olarak değişiklik gösteren hasat önü meyve dökümü AVG uygulanmış ağaçlarda daha düşüktü ve uygulama konsatrasyonun etkisi önemliydi. AVG uygulaması meyvede kopma direncinin muhafaza edilmesinde etkili olurken uygulama konsantrasyonları arasında da önemli farklılıklar meydana geldi. Breaburn çeşidine ait meyvelerde kopma direncinin daha yüksek olduğu belirlendi. AVG uygulaması meyvede büyüklük, SSC pH ve asitlik değerleri üzerine etkisi çeşide bağlı olarak farklılık gösterdi. Et sertliği ve nişasta indeksi açısından çeşitler arasında önemli bir faklılık oluşmadı AVG uygulaması meyve et sertliğini arttırırken, nişasta miktarını azalttı. Sonuç olarak bu çalışmadan elde edilen bulgular, AVG'nin Redchief ve Braeburn elma çeşitlerinde hasat önü dükümlerin önlenmesinde etkili bir şekilde kullanılabileceği ortaya koymuştur.

INTRODUCTION

In apple, the pre-harvest fruit drop, which occurs before the fruit reaches the optimum size and color and causes significant economic losses is an important problem for apple growers (Greene, 2006). The pre-harvest fruit drop occur as a result of morphological, anatomical, genotypic and biochemical differentiations (Arseneault *et al.,* 2016). The pre-harvest drop which are explained by events such as the cell differentiation, the response to developmental changes in metabolism, cell separation and the formation of a protective layer in the abscission zone (Estornell *et al.,* 2013; Meir *et al.,* 2019), are associated with the internal hormone balance in the fruit (Ozturk *et al.,* 2019). The fruit drop reaching 50% in some cultivar varies depending on the cultivar, ecological factors (Basak and Buczek, 2010; Robinson *et al.,* 2010) and cultural practices (Ward, 2004; Greene, 2006). However, it was suggested that the factors that affect the internal hormone balance, such as the fruit size (Dal Cin *et al.,* 2007), the location of the fruit in the cluster (cyme) (Dal Cin *et al.,* 2009; Miranda *et al.,* 2005), the location of the fruit on the tree (Arseneault *et al.,* 2016), the number of the seeds (Estornell *et al.,* 2013; Eccher *et al.,* 2015; Ferrero *et al.,* 2015), and the loss of xylem function (Drazeta *et al.,* 2004; Miqueloto *et al.,* 2014) may affect the fruit drop ratio.

Auxins and gibberellins, which affect plant growth and act as chemical messengers, prevent pre-harvest fruit drop while abscisic acid (ABA) and ethylene promote it (Addicott, 1982; Estornell *et al.,* 2013). In studies conducted on apples and tomatoes, it was found that a decrease in the amount of auxin and an increase in the amount of ethylene in the fruit promoted the fruit drop (Thompson and Osborne, 1994; Bangerth, 2000; Hong *et al.,* 2000; Vriezen *et al.,* 2008). It had been seen that in particular, ethylene has been found to be closely related to abscission, and the internal ethylene concentration of non-abscissing fruit was higher than abscising fruit (Greene *et al.,* 2014). Since the abscission and maturation events occur simultaneously, the biochemical role of ethylene in abscission is unclear, it is known that the process following the initiation of abscission is accelerated by ethylene (Arseneault *et al.,* 2016). Due to the effect of the auxin-ethylene interaction on the fruit drop, the effects of the bioregulators such as naphthalene acetic acid (NAA) that promotes auxin concentration (Yuan and Carbaugh, 2007; Dal Cin *et al.,* 2008) and AVG that inhibits ethylene increase (Byers, 1997; Greene and Schupp, 2004; Kang *et al.*, 2007; Dal Cin *et al.,* 2008; Yildiz *et al.,* 2012; Ozturk *et al.,* 2015; Aglar *et al.,* 2016; Souza *et al.,* 2019) on the pre-harvest fruit drop have been determined by previous studies. It has been reported that AVG is more effective than NAA in preventing pre-harvest fruit drop in apples (Greene *et al.,* 1987, Yildiz *et al.,* 2012). However, it has been suggested that the effectiveness of AVG varies according to the cultivar (Autio and Bramlage, 1982), the time (Chun *et al.,* 1997) and the concentration of the application (Schupp and Greene, 2004). By considering this situation, in the study, it was aimed to determine the effect of the different doses of AVG on pre-harvest fruit drop and fruit quality of Red Chief and Braeburn apple cultivars.

MATERIALS AND METHODS

Plant Material

The study was carried out in 2017 in the semi-dwarf apple orchard established in 2010 in Kemalpaşa village in Tokat province(40°20'02.19"N latitude and 36°28'30.11"E longitude and 623 m above sea level). In the study, 7-year-old Red Chief and Braeburn apple trees that were planted with 4 x 2 m planting density, grafted on MM106 rootstock and applied Central Leader training system were used as plant material. The soil of the trial area has a clayey, sandy and silty structure. The experiments were laid out in a randomized complete-block design with three single-tree replications per treatment. The trees were blocked based on proximity in orchard and crop load. AVG ('ReTain'; Valent BioSciences Crop, Libertyville, Il) at 0, 75, 150 and 225 mg L^{-1} combined with a Regulaid' surfactant [0.1%, v v^{-1} (Kalo Inc., Overland Park, KS66211)] at 0.1% v v^{-1}, was applied 4 week (on 1 September 2017 in Red Chief and on 15 September 2017 in Breaburn) before anticipated harvest. Treatments were applied to run off with a low pressure hand sprayer. For each treatment, one tree was used in each block.

Cumulative Drop Ratio (%)

The total number of fruit on the tree was determined one month before the harvest. Then, twice a week, the fruit dropped from the tree was counted. The number of the dropped fruit was taken from the total number of fruit and expressed in as % per week.

Fruit Retention Force

The retention force of the fruit was measured by using fruit on branches 2 m high. The retention force of the fruit was measured in Newton (N) using a digital force meter (Troni HF-10, 100 N, Taiwan) in the direction of the

fruit stem axis with the help of an aluminum apparatus prepared in accordance with the dimensional characteristics of the fruit (Polat *et al*., 2007).

Fruit Size

The fruit size was determined by measuring the diameter and weight of the fruit. The fruit diameter was determined by taking the average of the results obtained by measuring the fruit width and height using a digital caliper with 0.01 mm precision (Mitutoyo, Japan) and expressed in mm. The weight of each fruit was measured with a digital scale (Radwag, Poland) with a sensitivity of 0.01 g and the fruit weight was determined by taking the average and expressed as g.

Soluble Solids Content, pH and Titratable Acidity

The fruit was shredded with a blender and made homogeneous, and the obtained homogenate was passed through a cheesecloth and fruit juice was obtained. Sufficient amount of juice was dropped into a digital refractometer (PAL-1, McCormick Fruit Tech., Yakima, Wash.) for the measurement of SSC and the value on the screen was recorded as %. pH was measured with a pH meter (Hanna, model HI9321). For titratable acidity (TA) measurements, 10 ml of the obtained juice was taken and 10 ml of distilled water was added on it. Then, samples were expressed in terms of malic acid (g malic acid 100 ml^{-1}) based on the amount of NaOH spent in titration with 0.1 N sodium hydroxide until pH 8.1 was reached.

Fruit Firmness

For the fruit firmness, the fruit peel was cut at three different locations on the equatorial region of the fruit and measured as kg with the 11.1 mm tip of the penetrometer (Effegi brand, model FT-327; MoCormick Fruit Tech, Yakima, WA), then the values have been translated in Newton (N).

Starch Index

The fruit were divided into 2 equal parts, a circular slice with a width of approximately 1 cm was taken from the part on the side of the stem and 0.5% iodized potassium iodide (IKI) solution was applied on this circular slice until the surface was wet. After 5 minutes, the starch containing region was dyed dark blue and evaluated according to the scale prepared by Blanpied and Silsby (1992) (1 to 8 scale range, 1 = 100% starch, 8 = 0% starch).

Statistical Analysis

After analyzing the data obtained from the research with analysis of variance, the level of significance between the treatments means was determined by the Tukey multiple comparison test. The statistical analysis was performed using the SAS package program (SAS 9.1 version, USA). The significance level was taken into account as $p<0.05$ in statistical analysis and interpretation of the results.

RESULTS

Cumulative Drop Ratio (%)

The weekly fruit drop ratio rate increased in directly proportional to the fruit ripening stage. Considering the control application (0 mg L^{-1}) in Red Chief cultivar, it was determined that the fruit drop ratio was 19.80% in the first week (16^{th} Semtember), but in total, 56.60% of the fruit was dropped. It was observed that the fruit drop in AVG applied trees was lower in all measurement periods. However, the cumulative fruit drop ratio varied depending on the AVG application concentration. When the cumulative fruit drop ratio of both cultivars were evaluated, the highest value was obtained with the control application while the drop ratio in the fruit decreased with the increase of AVG concentration. The lowest fruit drop ratio was recorded in 225 mg L^{-1} AVG applied trees. There were the significant differences between the cultivars in terms of the fruit drop ratio. In the first two measurement periods, the fruit drop was higher in Breaburn cultivar while the total fruit drop ratio was higher in Red Chief cultivar. Considering the cumulative fruit drop ratio, it can be said that AVG application is more effective in Red Chief cultivar. When the control and 225 mg L^{-1} AVG applications were compared in both cultivars, the fruit drop in Red Chief cultivar decreased by 44% with 225 mg L^{-1} AVG application while the decrease was 33% in Breaburn cultivar (Table 1).

Fruit Retention Force (N)

Considering the control application, it was observed that the fruit retention force towards the harvest decreased as a natural result. While AVG application was effective in maintaining the retention force in fruit, the significant differences occurred between application concentrations. In the first two weeks, the retention force of AVG applied fruit generally decreased while the fruit retention force increased with the AVG application in the measurements made in the third and fourth weeks, and the statistically significant changes occurred depending on the application concentration. When the fruit retention force was compared by considering the Red Chief cultivar and the control application (0 mg L^{-1}), the fruit retention force, which was 16.51 N in the first measurement period with the control application, was recorded as 15.18 N in the last measurement period. In the125 mg L^{-1} AVG applied fruit, the fruit retention force was 19.05 N in the first measurement period while it rised to 26.89 Newtons in the last measurement period. It was determined that the fruit retention force varied depending on the cultivar, and the retention force was higher in the fruit of the Breaburn cultivar. However, in the last measurement period, the retention force was found to be higher in the fruit of the Red Chief variety, which were applied 125 mg L^{-1} and 250 mg L^{-1} AVG. Considering these data, it can be said that 125 mg L^{-1} and 250 mg L^{-1} AVG applications are more effective on the fruit retention force in Red Chief cultivar (Table 1).

Table 1. Effect of different concentrations of AVG on fruit drop ratio and fruit retention of 'Red Chief' and Breaburn apples.
Çizelge 1. Farklı dozlardaki AVG nin Red Chief ve Breaburn elma çeşitlerinde meyve dökümü ve kopma direnci üzerine etkisi.

Treatment (mg L^{-1})	**Fruit drop ratio (%)**							
	16 September		*23 September*		*30 September*		*07 October*	
	RC	BB	RC	BB	RC	BB	RC	BB
0	19.80Ba	21.15Aa	35.40Ba	37.18Aa	45.10Aa	42.76Ba	56.60Aa	53.24Ba
75	18.71Ba	20.86Aa	28.00Bb	30.22Ab	31.00Bb	34.17Ab	38.20Bb	43.17Ab
125	17.16Bb	18.73Ab	22.70Bc	25.12Ac	31.60Ab	31.16Ac	36.60Bb	42.10Ab
225	16.15Bb	18.02Ab	24.00Ab	22.14Bc	31.20Ab	30.24Ac	31.80Bc	35.80Ac
Treatment (mg L^{-1})	**Fruit retention force (N)**							
	16 September		*23 September*		*30 September*		*07 October*	
	RC	BB	RC	BB	RC	BB	RC	BB
0	16.51Bb	20.10Ac	16.50Bc	19.04Ac	16.18Bc	19.22Ac	15.78Ac	16.48Ac
75	18.54Ba	23.27Ab	18.61Aa	19.42Ab	19.40Ba	22.14Ab	17.38Bbc	19.06Ab
125	19.05Ba	23.86Ab	18.00Ba	23.65Aa	17.60Bb	23.09Ab	26.89Aa	23.76Ba
225	18.92Ba	27.21Aa	17.10Bb	20.68Ab	16.61Bb	28.21Aa	24.66Aab	22.47Bab

RC: Redchief, BB: Breaburn. Means with the same lowercase letter in same columns do not differ according to Tukey's test at $p<0.05$. The same capital letter expreses the difference between the cultivars. Means with the same capital letter in same line do not differ according to Tukey's test. However, the evaluation will be made between cultivars. In other words, the data for each measurement period will be evaluated among themselves.

Fruit Size

Considering the last measurement period (7th October), it was determined that there were the significant differences between cultivar in fruit size determined by measuring fruit weight and diameter, and Breabun cultivar had larger fruit. AVG application affected the fruit weight. In both cultivar, the highest fruit weight values were recorded with 225 mg L^{-1} AVG applied trees. There were the significant differences between application in the Red Chief cultivar, and the lower weight fruit were obtained with the control application. However, in Breaburn cultivar, the difference between the applications was generally not significant, and the smallest fruit were harvested on 125 mg L^{-1} AVG applied trees (Table 2).

Table 2. Effect of different concentrations of AVG on fruit size of 'Red Chief' and Breaburn apples.
Çizelge 2. Farklı dozlardaki AVG nin Red Chief ve Breaburn elma çeşitlerinde meyve büyüklüğü üzerine etkisi.

Treatment (mg L^{-1})	**Fruit weight (g)**							
	16 September		*23 September*		*30 September*		*07 October*	
	RC	BB	RC	BB	RC	BB	RC	BB
0	160.00Bb	180.45Ac	165.83Bb	186.35Ab	175.00Bb	197.18Ab	187.66Bc	210.62Aa
75	161.24Bb	195.01Aa	167.37Bb	199.91Aa	177.11Bb	210.66Aa	189.30Bbc	213.19Aa
125	162.18Bb	193.79Aa	175.93Bb	200.91Aa	188.84Ba	205.60Aab	196.23Bb	206.83Ab

Table 2. Continue.
Çizelge 2. Devamı.

Treatment (mg L^{-1})	**Fruit weight (g)**							
	16 September		*23 September*		*30 September*		*07 October*	
	RC	BB	RC	BB	RC	BB	RC	BB
225	175.40Ba	188.37Ab	185.66Aa	188.46Ab	190.29Ba	210.77Aa	231.07Aa	214.08Ba
Treatment (mg L^{-1})	**Fruit diameter (mm)**							
	16 September		*23 September*		*30 September*		*07 October*	
	RC	BB	RC	BB	RC	BB	RC	BB
0	76.45Aa	70.50Ba	71.36Aa	73.60Aab	70.06Ba	75.64Aa	73.44Aa	75.22Aa
75	71.98Aa	70.12Aa	70.82Ba	76.48Aa	62.08Bb	67.82Ab	64.38Bb	72.33Aa
125	72.77Aa	68.68Aa	67.07Aa	69.79Ab	66.03Bab	73.30Aa	66.13Bab	71.49Aa
225	72.06Aa	69.67Aa	70.72Aa	69.21Ab	67.60Ba	72.42Aa	69.23Bab	74.55Aa

RC: Redchief, BB: Breaburn. Means with the same lowercase letter in same columns do not differ according to Tukey's test at p<0.05. The same capital letter expreses the difference between the cultivars. Means with the same capital letter in same line do not differ according to Tukey's test. However, the evaluation will be made between cultivars. In other words, the data for each measurement period will be evaluated among themselves.

Soluble Solids Content, pH and Titratable Acidity

As maturity progressed in the fruit, it was determined that there was an increase in the amount of SSC but a decrease in the last measurement period (7th October). It was observed that the amount of SSC of the fruit usually varied depending on the cultivar, and the fruit of Breaburn cultivar had a higher SSC ratio. It can be said that AVG application affects the amount of SSC in fruit and the ratio of SSC is generally lower in AVG applied fruit (Table 3).

Table 3. Effect of different concentrations of AVG on SSC, pH and titratable acidity of 'Red Chief' and Breaburn apples .
Çizelge 3. Farklı dozlardaki AVG nin Red Chief ve Breaburn elma çeşitlerinde SÇKM, titreedilebilir asitlik ve pH üzerine etkisi.

Treatment (mg L^{-1})	**Soluble solids content (%)**							
	16 September		*23 September*		*30 September*		*07 October*	
	RC	BB	RC	BB	RC	BB	RC	BB
0	11.93Ba	13.21Aa	12.98Ba	13.55Aa	13.13Ba	13.83Aa	12.35Aa	12.07Aa
75	11.68Aa	11.99Ab	12.27Bb	13.32Aa	12.48Bb	13.09Ab	12.16Aa	11.53Bb
125	11.15Ab	11.53Ab	12.20Bb	13.89Aa	12.55Bb	13.23Ab	12.30Aa	11.70Bb
225	10.40Ab	10.76Ab	12.00Bb	12.88Ab	12.33Ab	12.31Ac	10.88Bb	12.03Aa
Treatment (mg L^{-1})	**pH**							
	16 September		*23 September*		*30 September*		*07 October*	
	RC	BB	RC	BB	RC	BB	RC	BB
0	4.28Aa	3.74Bb	4.36Aa	3.94Ba	4.49Aa	3.95Bab	4.54Aa	3.89Ba
75	4.25Aa	3.81Bab	4.38Aa	3.86Ba	4.48Aa	3.92Bb	4.41Ab	3.96Ba
125	4.26Aa	3.89Ba	4.40Aa	3.93Ba	4.43Ab	3.98Ba	4.49Aab	3.90Ba
225	4.28Aa	3.88Ba	4.41Aa	3.85Ba	4.51Aa	3.97Ba	4.56Aa	3.86Ba
Treatment (mg L^{-1})	**Titratable acidity (g malic acid 100 mL^{-1})**							
	16 September		*23 September*		*30 September*		*07 October*	
	RC	BB	RC	BB	RC	BB	RC	BB
0	0.20Bc	0.33Aa	0.23Ba	0.45Aa	0.23Bb	0.47Aa	0.25Bb	0.46Aa
75	0.23Bb	0.35Aa	0.26Ba	0.43Aa	0.26Ba	0.42Ab	0.27Bb	0.38Aab
125	0.26Ba	0.34Aa	0.27Ba	0.42Aa	0.27Ba	0.43Ab	0.30Ba	0.37Ab
225	0.22Bb	0.33Aa	0.25Ba	0.44Aa	0.26Ba	0.42Ab	0.29Ba	0.36Ab

RC: Redchief, BB: Breaburn. Means with the same lowercase letter in same columns do not differ according to Tukey's test at p<0.05. The same capital letter expreses the difference between the cultivars. Means with the same capital letter in same line do not differ according to Tukey's test. However, the evaluation will be made between cultivars. In other words, the data for each measurement period will be evaluated among themselves.

It was determined that the effect of the cultivar in the amount of pH increasing with the progress of maturity was significant and the pH value of the fruit of Red Chief cultivar was higher. The effect of AVG application on pH varied depending on the measurement period and the cultivar. In the Red Chief, there was no effect of AVG application in the first and second measurement periods, in the third and the last measurement periods, 125 mg

L^{-1} and 75 mg L^{-1} AVG applied fruit had lower pH values respectively. In the Breaburn cultivar, the pH value was lower only in 75 mg L^{-1} AVG applied fruit in the third measurement period (Table 3).

The acidity ratio in the fruit differed depending on the cultivar. The acidity ratio was higher in the fruit of the Breaburn cultivar. Again, the effect of AVG varied depending on the measurement period and cultivar. No AVG effect was noted in the second measurement period. In the first period, there was no difference between applications in Breaburn cultivar, it was determined that in the Red Chief cultivar, AVG-applied fruit had higher acidity and the most effective application was 125 mg L^{-1} AVG application. In the third and fourth measurement periods, the acidity ratio of the fruit of Red Chief cultivar increased with the AVG application while the acidity decreased in the Breaburn cultivar (Table 3).

Fruit Firmness and Starch Index

There was no statistically significant difference between cultivars in terms of the fruit firmness. The effect of AVG application on the fruit firmness was significant. The fruit with the highest the fruit firmness values were harvested in AVG-applied trees. Again, the effect of AVG varied depending on the application concentration. With the increase in the concentration, the fruit firmness increased. The highest values were recorded in fruit treated with 225 m L^{-1} AVG (Table 4).

The effect of the cultivar was not significant in starch index values. With the application of AVG, there was a decrease in the amount of starch of the fruit. However, it can be said that application concentration has not been significant in AVG effect. Considering the last measurement period, there was no difference between AVG application concentrations in the Breaburn cultivar while the amount of starch was higher in 225 mg L^{-1} AVG applied fruit in the Red Chief cultivar, and there was no statistically significant difference between this application and the control application (Table 4).

Table 4. Effect of different concentrations of AVG on fruit firmness and starch index of 'Red Chief' and Breaburn apples.
Çizelge 4. Farklı dozlardaki AVG nin Red Chief ve Breaburn elma çeşitlerinde meyve eti sertliği ve nişasta indeksi üzerine etkisi.

Treatment (mg L^{-1})	**Fruit firmness (N)**							
	16 September		*23 September*		*30 September*		*07 October*	
	RC	BB	RC	BB	RC	BB	RC	BB
0	7.48Ab	8.01Ac	7.34Ac	8.00Ac	7.12Ab	7.70Ac	7.10Ac	7.00Ac
75	7.67Aa	8.10Ab	7.56Aa	8.05Ab	7.43Aab	8.00Ab	7.38Ab	7.96Ab
125	7.60Aab	8.46Aa	7.49Aa	8.39Ab	7.51Aab	8.29Ab	7.28Ab	8.26Aa
225	7.58Ab	8.47Aa	7.46Ab	8.45Aa	7.74Aa	8.42Aa	7.63Aa	8.41Aa
Treatment (mg L^{-1})	**Starch index**							
	16 September		*23 September*		*30 September*		*07 October*	
	RC	BB	RC	BB	RC	BB	RC	BB
0	6.77Aa	6.67Aa	6.25Aa	5.56Aa	6.50Aa	7.00Aa	6.50Aa	6.45Aa
75	5.87Ab	5.67Aab	5.21Ab	5.22Aa	5.83Ab	6.67Aa	5.25Ab	6.11Ab
125	5.45Ab	4.33Bc	5.82Ab	5.12a	5.58Ab	6.55Ab	5.75Ab	6.10Ab
225	5.88Ab	5.55Ab	5.77Ab	4.44Ba	5.66Ab	6.00Ab	6.00Aa	6.00Ab

RC: Redchief, BB: Breaburn. Means with the same lowercase letter in same columns do not differ according to Tukey's test at $p<0.05$. The same capital letter expreses the difference between the cultivars. Means with the same capital letter in same line do not differ according to Tukey's test. However, the evaluation will be made between cultivars. In other words, the data for each measurement period will be evaluated among themselves.

DISCUSSION

In apples, pre-harvest fruit drop, which sometimes rises up to 50% and causes significant income losses (Greene, 2006), occur as a result of morphological, anatomical, genetic and biochemical differences (Michelle *et al*., 2016). These fruit drop (Estornell *et al*., 2013; Meir *et al*., 2019), which are explained by events such as cell differentiation in the abscission zone, response to developmental changes in metabolism, cell separation and the formation of a protective layer (Estornell *et al*., 2013; Meir *et al*., 2019) are related to the internal hormone balance in the fruit and especially ethylene (Ozturk *et al*., 2019). The plant hormones that affect plant growth, act as chemical messengers and change growth in low concentration (Davies, 2010) have significant role in pre-harvest fruit drop. It is suggested that auxin and gibberellin inhibit the fruit drop, but ethylene and abscisic acid (ABA) promote (Addicott, 1982; Estornell *et al*., 2013). Therefore, the use of the plant growth regulators that inhibit ethylene synthesis in the plant has been the focus to prevent fruit drop in apples (Michelle et al., 2016). The

physiological events regulated by ethylene, such as ethylene synthesis and therefore pre-harvest fruit drop, may be prevented by aminoethoxyvinylglycine (AVG) binding to the active site of enzyme 1-aminocyclopropane-1-carboxylate synthase (ACS) and inhibiting theisis of ethylene immediate precursor aminocyclopropane- 1-carboxylate (ACC), which is thereafter converted into ethylene by ACC oxidase (ACO) (Huai *et al*., 2001). AVG, which inhibits the increase in internal ethylene, has been shown to be effective in preventing pre-harvest fruit drop (Byers, 1997; Greene and Schupp, 2004; Kang *et al*., 2007; Dal Cin *et al*., 2008; Robinson *et al*., 2010; Yildiz *et al*., 2012; Ozturk *et al*., 2015; Aglar *et al*., 2016; Souza *et al*., 2019). In the study, smilarly with these results, AVG application had a positive effect on preserving the fruit retention force and thus preventing fruit drop, but this effect varied depending on the cultivar and application concentration. As a matter of fact, (McFadyen *et al*., 2012; Ozkan *et al*., 2016) have reported that the effect of AVG on fruit drop varies depending on the variety and application concentration. In the study, the application of AVG in the fruit size varied depending on the cultivars was effective. There were differences in the effect depending on the application concentration and cultivar. The highest fruit weight values were recorded in the trees treated with 225 mg L^{-1} AVG in both cultivar while the Redchief cultivar, there were the significant differences between applications, and the fruit weight was lower with the control application. However, in the Braeburn cultivar, the difference between applications was generally not significant, the smallest fruit were harvested on trees treated with 125 mg L^{-1} AVG. The supporting the study result, Phan-Thien et al. (2004), Greene (2006) and Petri et al. (2006) reported that the different results were obtained regarding the AVG effect on fruit size while Autio and Bramlage (1982) and Chun et al. (1997) determined that the effect of AVG on fruit weight may vary depending on the cultivar, application dose and ecological factors. However, it has been suggested that AVG significantly reduces fruit size in apples (Aglar *et al*., 2016), but has no significant effect on sweet cherry (Aglar *et al.,* 2014).

With the progression of the fruit ripening, naturally SSC increases and acidity decreases, It is expected that AVG application, which delays fruit ripening with its effect on ethylene synthesis, has an effect that decreases SSC and increases acidity. The previous studies have shown the accuracy of this assumption. Thus Greene and Schupp (2004), Yildiz *et al*., (2012); Aglar *et al*., (2016) and Ozturk *et al*., (2019) reported that with AVG application, there was a decrease in the amount of SSC in the fruit and an increase in the acidity rate.

In the study, the effect of AVG application on fruit firmness was significant. The fruit with higher fruit firmness values were harvested on AVG-applied trees. The effect of AVG varied depending on the application concentration and the fruit frimness increased with the increase in the concentration. This is related to AVG inhibiting ethylene synthesis (Greene, 2006; Yildiz *et al*., 2012). In Apple (Byers, 1997; Greene, 2005; Amarante *et al*., 2002; Argenta *et al*., 2006; Greene, 2006; Yuan and Carbaugh, 2007; Yildiz *et al*., 2012; Aglar *et al*., 2016; Ozturk *et al*., 2019) and sweet cherry (Aglar *et al*., 2014; Koc Guler *et al*., 2019) have shown that AVG application is effective in maintaining the fruit firmness.

Starch index, which is an indicator of fruit maturity, also affects the fruit drop (Blanpied and Silsby, 1992). The bio-regulators such as AVG and Naphthalene acetic acid (NAA), which are used to prevent the fruit drop, slow down starch degradation (Byers, 1997; Greene, 2005; Yuan and Carbaugh, 2007). In the previous studies, it was reported that with AVG application, the starch degradation was delayed in apple cultivars such as, "Red Chief" (Yildiz *et al*., 2012), "McIntosh" (Stover *et al*., 2003) while Schupp and Greene (2004) suggested that the effect varies depending on the application concentration. In the study, there was a decrease in the amount of starch in the fruit with AVG application. However, it can be said that application concentration has not been significant in AVG effect.

As a result, AVG application had a positive effect on maintaining the fruit retention force and thus the fruit drop, but this effect varied depending on the cultivar and application concentration. The effect of AVG application on fruit size, SSC, acidity, fruit firmness and starch degradation was found to be significant. Considering the results of the study, the study revealed that AVG application can be used effectively to prevent pre-harvest fruit drop.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

DECLARATION OF AUTHOR CONTRIBUTION

EK and EA contribted to the planning, design, analysis of fruit and data analysis of experiment, and writing of the manuscript.

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