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Response of Maturity and Fruit Quality of 'Angeleno' Plum to Pre-Harvest AVG Applications

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Abstract: The effects of Aminoethoxyvinylglycine on fruit quality and harvest time of 'Angeleno' plum were investigated. For this purpose, ReTain (15 % a.i) was applied as AVG source with 100 mg/l and 50+50 mg/l to plum trees 28 days (single spray) and 14 days (double spray) before optimal harvest. Based on fruits were harvested according to maturation standards data, AVG applications delayed the harvest time about 3 days. AVG treated fruits had significantly firmness than those of the control fruits, and 100 mg/l AVG treatment gave an increase in firmness in the rate of 11 %. However, there was minor increase in fruit weight with AVG; there were no additional effect in fruit size or weight. The obstructive effect of all treatments on production of ethylene and respiration rate was evidence. All treatments decreased rate of ethylene production and respiration rate of fruits. AVG treatment of had no significant effects on the ascorbic acid and total phenolic compounds of fresh fruit. Aminoethoxyvinylglycine applications to 'Angeleno' cultivar can be practiced successfully to manage harvest by delaying and improving fruit firmness.

Keywords: Aminoethoxyvinylglycine, firmness, phenolic, *Prunus salicina*

Hasat Öncesi AVG Uygulamalarının 'Angeleno' Erik Çeşidinde Meyve Kalitesi Ve Hasat Zamanı Üzerine Etkisi

Öz: Bu çalışma; *Prunus cerasifera* anacına aşılı 'Angeleno' erik çeşidinin meyve kalitesi üzerine hasat öncesi Aminoetoksi-vinilglisin (AVG; 100 ppm, 50+50 ppm) uygulamalarının etkilerinin belirlenmesi amacıyla yürütülmüştür. Bu amaçla uygulamalar tahmini hasattan 28 gün önce tekli ve bunu takiben 14 gün sonra tekrar olarak ikili uygulama şeklinde yapılmıştır. Genel olarak AVG uygulamaları hasat zamanını 3 gün geciktirmiştir. AVG uygulamaların meyve ağırlığında az da olsa artışa olumlu etkide bulunduğu görülmektedir. Ancak istatistiki olarak bir fark ortaya çıkmamıştır. Tüm uygulamaların meyve eti sertliği üzerine etkili olduğu ve sertliğin kontrole göre % 11 (AVG 100 ppm) oranında arttığı bulunmuştur. AVG uygulamalarının meyve olgunlaşması üzerine olan geciktirici etkisine paralel olarak meyve renklenmesi de gecikmiştir. Etilen üretimi ve solumun hızı üzerine AVG'nin engelleyici etkisi belirgin bir şekilde ortaya çıkmıştır. AVG uygulamalarının askorbik asit ve toplam fenolik madde üzerine olan etkileri genel olarak istatistik anlamda önemsiz bulunmuştur.

Anahtar Kelimeler: Aminoethoxyvinylglycine, meyve sertliği, fenolikler, *Prunus salicina*

1. Introduction

The world production of plums is 11.282.527t (FAO, 2014) (FAO, 2016). Plum is one of the most popular fruit in both domestic and international markets owing to its delicious taste and aroma. They are excellent source of vitamins, calcium, potassium, magnesium, phosphorus, fiber and bioactive compounds such as anthocyanins, carotenoids and phenolic compounds. Consumption of plums plays an important role in preventing diseases and

maintaining healthy life (Kim et al., 2003; Balık, 2005; Manganaris et al., 2008).

High consumer acceptance is attained for fruit with high soluble solids content (SSC), fruit firmness and phenolic compounds. Marketable quality of plum fruit can be served out according to these parameters (Bal and Çelik, 2008). Plums are among fruits that have a climacteric ripening pattern, in which ethylene is the hormone responsible for triggering the ripening and senescence processes (Özkaya and Dündar, 2009). Climacteric fruits are characterized by enhanced respiration rates and increased ethylene production during ripening, when compared to nonclimacteric fruits.

ReTain, which is the commercial formulation of AVG, It is affecting one or more physiological and biochemical events in the plant. AVG is primary mode of action is to inhibit ethylene biosynthesis. (Scupp and Greene, 2004; Wang and Dilley, 2001; Amarante et al., 2002). This compound is known to competitively inhibit the activity of the enzyme ACC (1-Aminocyclopropanecarboxylate) synthase, ethylene-mediated ripening processes can be delayed (Jobling et al. 2003). AVG temporarily decreases ethylene production, reduces endogenous ethylene levels and delays fruit maturation and ripening as measured by various ripening indices (Butar et al., 2014).

There is no sufficient information available on the effects of pre-harvest applications of AVG on the ripening in plum, which thus warrants investigations. This study was carried out to determination of response of maturity and fruit quality of ‘Angeleno’ plum to AVG pre-harvest applications.

2. Materials and Methods

Experiments were performed on 9-years old ‘Angeleno’ plum (*Prunus salicina* L. cv. Angelino) trees grafted on *Prunus cerasifera* L. rootstock. Plum trees planted in north south row direction; between row distances 4x4 m, was located in Isparta-Turkey. All the cultural practices including pruning, irrigation, pesticide spray and etc. had been assessed for several years as periodically.

Five trees per treatment were sprayed with ReTain® (ABG 3178, Valent Biosciences Corporation, Libertyville, IL, USA), a commercial product containing 15 % (w/w). ReTain® was applied as an aqueous solution, containing 1 % non-ionic surfactant (Tween 20), onto fruits and leaves around until runoff. For this purpose, treatments of AVG was applied 28 days before anticipated harvest as single spray (100ppm) and following that after 14 days as double spray (50+50ppm). Control trees only received an aqueous solution containing the same concentration of surfactant. Plum fruit at uniform size, free from visual symptoms of disease or blemishes, were harvested at commercial maturity. The fruits picked at the harvest time were immediately transported to the postharvest physiology laboratory. The fruit size, fruit weight, fruit colour, fruit flesh firmness, titratable acidity (TA) soluble solids content (SSC), fruit colour, ethylene production (µL/kg.h.) and respiration rate (mL.C02/kg.h), levels of ascorbic acid and total phenolic compounds were assessed.

The fruit weight, fruit diameter as length and width (mm) were measured. Fruit flesh firmness was determined on the two opposite sides of each fruit, after eliminating a thin layer of the skin, using a texture analyzer (Lloyd Instruments LF Plus). It was defined as the maximum load required penetrating the probe (8 mm) into the fruit flesh (10 mm) by analyzer. The results were expressed in newton (N). Soluble solids content (SSC) was measured using a digital refractometer (Atago Pocket PAL-1) and expressed as percentage (%). pH was determined by using a WTW Inolab pH-Level 2 digital pH metre. Titratable acidity (TA) was determined by using a WTW Inolab Ph-Level 2 through titration of 10 ml of diluted juice with 0.1 N NaOH up to pH 8.1 and the malic acid was expressed as the equivalent. Fruit skin colour was determined using a colorimeter (CR300, Minolta). Minolta color measurement apparatus was calibrated according to the standard white calibration plate.

The values were expressed by the CIE L* (brightness-darkness), a* (+ a*: red, − a*: green) and b* (+ b*: yellow, − b*: blue).

The ethylene production (µL/kg.h) and respiration rate (µL/kg.h) were determined in fruit placed in closed jars after keeping for 24 hours at room temperature (20±1 °C) (1 kg of fruit was closed in each jar and the volume of each jar was 4 liters). Measurements were made in split/splitless (S/SL) of inlet in split mode with gas sampling valve with 1 ml gas sample by using fused silica capillary column (GS-GASPRO, 30 m × 0.32 mm I.D., U.S.A), with thermal conductivity detector (TCD) for respiration rate and using flame ionization detector (FID) for ethylene production. The temperature of the oven, TCD and FID detector S were 40 °C (isothermal), 250°C and 250 °C respectively. Respiration rate (measured as CO2 production) was expressed as ml CO2 kg-1 h-1. Ethylene concentration was expressed as µL/kg.h.

The level of ascorbic acid was determined as reported earlier by using method of Hışıl (1997) and Özkan (2007) by using T80 UV/V spectrophotometer (T80 UV/VIS) and was expressed mg/100 ml. The amount of total phenolic (TP) of methanol extract was determined according to the Folin-Ciocalteu procedure (Singleton and Rossi, 1965). Total phenolic was determined by using T80 UV/VIS spectrophotometer. The total phenolic content was expressed as gallic acid equivalents (GAE) in milligrams per gram of extract, using the Eq.

The experimental design was performed according to a randomized design with five replications, each replication consisting of one tree. Data analysis was done by analysis of SPSS 18 software package and the means were compared with Duncan's multiple range test at $P<0.05$ level.

3. Results and Discussions

Towards the estimated harvest time the harvest parameters such as fruit flesh firmness and SSC were assessed for all fruit groups. The control fruits that became to the harvest maturity were harvested on September 22nd (the average flesh firmness and SSC were 32.646 N and 14.29 %, respectively). Mentioned harvest criteria were determined on 25 September in AVG applied fruits (the average flesh firmness and SSC 33.07 N, 13.09 % (AVG 50+50) and 33.388 N, 14.06 % (AVG 100 ppm), respectively). Therefore; the harvest time was delayed by AVG application for about 3 days.

AVG is an ethylene biosynthesis inhibitor (Torrigiani et al., 2004; Noppakoowong et al., 2005) that delays fruit maturation (Taiz and Zieger, 2008) if applied before harvest (Noppakoonwong et al., 2005). According to many researches which are parallel to our results, pre-harvest application of AVG has delayed the harvest date of different fruit trees (Noppakoonwong et al. 2005; Çetinbaş and Koyuncu, 2011; Butar et al., 2013). Kim et al. (2004) reported that treatments of aminoethoxyvinylglycine sprayed at 3 and 4 weeks before the predicted harvest delayed the harvest date by 3 days of peach (*Prunus persica* cv. Mibaekdo) trees. The results of the effects of AVG applications on some fruit quality features are given in Table 1.

Table 1. Effects of AVG on some fruit characteristics of 'Angeleno' plums
Çizelge 1. *AVG uygulamalarının 'Angeleno' erik çeşidinin bazı meyve özelliklerine etkisi*

Application	Fruit width (mm)	Fruit length (mm)	Fruit weight (g)
Control	54.64^{NS}	50.67^{NS}	94.22^{NS}
AVG (50+50ppm)	54.99	50.29	94.62
AVG (100 ppm)	55.44	50.13	96.37
P value	0.631	0.657	0.840

NS: Non significant

The AVG application showed similar characteristics the fruit sizes and weight in comparison with the control groups. Effects of all treatments on fruit width, fruit length and fruit

weight were not statistically significant (P<0.05). The highest fruit width and fruit weight were 55.44 mm and 96.37g with AVG 100 ppm (single spray) applications. The lowest values of width and weight 54.64 mm and 94.22 g were obtained from the control fruits. Consequently, there was minor increase in fruit weight with AVG; there were no additional effect in fruit width or length. There are similar results obtained other researchers. Pre-treatments of AVG to apple have no a direct effect on fruit weight (Öztürk et al., 2012). Schupp and Greene, (2004) stated that AVG treatments did not effective onto fruit weight of 'McIntosh' apples. However, Amarante et al., (2002) reported pre-harvest application of AVG delayed fruit harvest and increased yield by reducing premature fruit abscission and increasing fruit size of late harvested fruit.

The effects of AVG applications on firmness and SSC have been found statistically significant (P<0.05) (Table 2).

Table 2. Effects of AVG applications on firmness, SSC, pH and TA of 'Angeleno' plums cultivar
Çizelge 2. *AVG uygulamalarının 'Angeleno' erik çeşidinin sertlik, SÇKM, pH ve TA üzerine etkisi*

Application	Fruit flesh firmness (N)	SSC (%)	pH	TA (%)
Control	31.30b*	14.29b*	3.51 ^{NS}	1.37 ^{NS}
AVG (50+50ppm)	33.17ab	14.85ab	3.48	1.29
AVG (100ppm)	34.68a	15.32a	3.48	1.28
P value	0.033	0.043	0.330	0.305

*: Means in columns with the different letter is significant according to Duncan's Multiple Range test, P<0.05.
NS: Non significant

By contrast, pH and TA did not change significantly in all treated fruits compared to untreated. The highest pH value (3.51) was determined from untreated fruits whereas the lowest (3.48) was from AVG treatments. The effect of our applications on TA was found non-significant.

The AVG applications had positive effects on fruit firmness. Both single spray (100 ppm AVG) and double spray (50+50 ppm AVG) sprayed fruits had significantly firmer than fruits of control and all applications supplied an increased firmness in the rate of 6 % (AVG 50+50 ppm) - 11 % (AVG 100 ppm) compared to control. The highest value (34.68 N) was determined in 100 ppm AVG (single spray) treatment, whereas the lowest (31.30 N) was from control fruits. Both (50+50 ppm and 100 ppm) concentrations of AVG significantly delayed fruit softening. This effect could be due to ripening related enzymes, e.g. cellulose, which is regulated by ethylene. According to many researches which are parallel to our results, AVG-treated exhibited significantly higher flesh firmness compared with control (Bregoli et al., 2002; Launder and Jerie, 2000; Ziosi et al. 2006). Also Çetinbaş (2010) reported that 100 mg/l AVG applications supplied an increase in firmness in the rate of 35-73 % in 'Monero' peaches. Bregoli et al. (2002)' stated that 0.32 and 1.28 mM concentrations of AVG significantly delayed fruit softening and in all cases firmness values were almost double compared with the controls. In contrast to our work Kim et al. (2004) found that pre-harvest AVG application tended to decrease fruit firmness. All these findings included ours indicate that flesh firmness of stone fruit an especially remarkable property for postharvest life and consumption.

The sprayed AVG affects on SSC were statistically significant. However single spray AVG (100 ppm) was the most effective application on SSC and this application gave an increase in SSC in the rate of 7 %. The SSC obtained from control, double and single spray of AVG applications was found as 14.29 %, 14.85 % and 15.32 %, respectively (Table 2). Studies on climacteric fruits (Bregoti et al., 2002; Çetinbaş, 2010; Noppakoonwong et al., 2005; Butar et al., 2013) have shown that AVG application pre-harvest increased sugar concentration. These responses may be an advantage for low-chill, early maturing stone fruit varieties that, because of their short fruit development periods, exhibit

small fruit size, medium firmness and low sugar concentrations (Noppakoonwong et al., 2005).

The results of all treatments on fruit colour are indicated in Table 3.

Table 3. Effects of AVG applications on skin colour of 'Angeleno' plums
Çizelge 3. *AVG uygulamalarının 'Angeleno' erik çeşidinin meyve kabuk rengi üzerine etkisi*

Application	L*	a*	b*
Control	31.25 ^{NS}	9.35 ^{NS}	0.50 ^{NS}
AVG (50+50 ppm)	30.20	7.32	-1.05
AVG (100 ppm)	31.05	8.93	0.45
P value	0.512	0.178	0.161

NS: Non significant

There was no statistically significance among AVG applications. The highest values were obtained from untreated fruits as L* (31.25), a* (9.35) and b* (0.50). The lowest values of L* (30.20), a* (7.32) and b* (-1.05) were obtained from the 50+50 ppm AVG treated fruits. All applications show similar characteristics of the L value when compared to the control group. It is believed that the reason for the similarity of the L * value is due to the variety feature of the 'Angeleno' plum fruit, which is a misty fruit. When the a * value indicating red coloring is examined, development of red color was delay by AVG. Similar to our findings, Greene and Schupp (2004) and Öztürk et al., (2012) stated that the effect of AVG on red color development is not direct, the delay is a natural result.

In the present study, the effect of the treatments on ethylene production and respiration rate was found as statistically significant ($P<0.05$). These results are presented in Table 4.

Table 4. Effects of AVG on respiration rate and ethylene production of 'Angeleno' plums
Çizelge 4. *AVG uygulamalarının 'Angeleno' erik çeşidinin meyve solunum hızı ve etilen üretim miktarı* üzerine etkisi

Application	Respiration rate (mL.$C0_2$/kg.h)	Ethylene production (µL/kg.h)
Control	0.066a*	0.073a*
AVG (50+50 ppm)	0.003b	0.048b
AVG (100 ppm)	0.005b	0.053b
P value	0.001	0.007

*: Means in columns with the diffrentletter is significant according to Duncan's Multiple Range test, $P<0.05$.
NS: Non significant

All treatments have been decreased rate of ethylene and respiratory. The obstructive effect of all treatments on production of ethylene and respiration is clearer than fruits. In a similarly, pre-harvest AVG application suppressed ethylene production (Yuan and Li, 2008 and Torrigiani et al., 2004). Correspondingly Çetinbaş (2010) stated that pre-harvest spray application of AVG obstructed ethylene production and reduced respiration rate of 'Monero' peach variety.

The highest ascorbic acid value (23.29 mg/100 ml) was determined in single sprayed of 100 ppm AVG treatment, whereas the lowest values (14.91 mg/ml) from untreated fruits. Plums are rich in phenolic compounds, particularly 'Angeleno' (Gıl et al., 2002). The control fruits have the highest total phenolic compounds (0.312 mg galik acid/g); double AVG application has the lowest one. There was no statistically significant ($p<0.05$) result about the ascorbic acid and total phenolic compounds (Table 5).

Table 5. Effects of AVG on total phenolic compounds and ascorbic acid of 'Angeleno' plums
Çizelge 5. *AVG uygulamalarının 'Angeleno' erik çeşidinin L-askorbik asit ve toplam fenolik madde içeriği üzerine etkisi*

Application	Total phenolic compounds (mg gallik asit/ g)	Ascorbic acid (mg/100 ml)
Control	0.312 ^{NS}	14.91 ^{NS}
AVG (50+50 ppm)	0.307	20.65
AVG (100 ppm)	0.306	23.29
P value	0.433	0.935

NS: Non significant

The values of phenolic substance content of the fruits changes depending on a lot of factor such as their variety, ecological conditions and maturity level (Bal, 2012).

4. Conclusions

In conclusion, pre-harvest spray application of AVG delayed the ripening process in 'Angeleno' Japanese plum due to reduced endogenous ethylene production. In our study applications of AVG delayed harvest time, reduced ethylene production and respiration rate but increased quality parameters of plum fruit such as firmness and SSC. The many known effects of AVG for a lot of other fruit varieties have also been observed in the 'Angeleno' plum varieties. Aminoethoxyvinylglycine applications to 'Angeleno' cultivar can be practiced successfully to manage harvest by delaying and improving fruit firmness.

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