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Effects of Aminoethoxyvinylglycine on Harvest Time and Fruit Quality of 'Monroe' Peaches

Melike ÇETİNBAŞ[a], Fatma KOYUNCU[b]

[a] *Eğirdir Horticultural Research Institute, 32500, Isparta, TURKEY*

[b] *Süleyman Demirel University, Faculty of Agriculture, Department of Horticulture, 32200, Isparta, TURKEY*

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Corresponding author: Melike ÇETİNBAŞ, e-mail: melikecetinbas@gmail.com, Tel: +90(246) 313 24 20
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ABSTRACT

This study was conducted to prolong the harvest date and enhance the fruit quality of 'Monroe' peaches. For this purpose, ReTain containing 15% aminoethoxyvinylglycine (AVG) was applied to the peach fruits. AVG at concentrations of 0, 100, 150 and 200 mg l^{-1} was sprayed on the peaches 7, 21 and 30 days before commercial harvest. Some fruit quality parameters [fruit weight (g), fruit flesh firmness (N), soluble solids content (SSC, %), titratable acidity (TA, %), fruit colour (L*, a*, b*), sugar content, delay in harvest, ethylene production (μ*l* kg^{-1} h^{-1}) and respiration rate (m*l* CO_2 kg^{-1} h^{-1})] were measured for each treatment. Fruit maturity was delayed about 4-6 days more in AVG-applied fruits than in the control group. A sequential harvest was completed 6-7 days before the normal harvest time. Application of AVG increased the fruit size and fruit weight of 'Monroe' peach. AVG-sprayed fruits were firmer than the fruits of control group. AVG applications also decreased ethylene production and the respiration rate of fruits. As a results, application AVG of 100 or 200 mg l^{-1} concentrations 30 days before commercial harvest for 'Monroe' peach varieties can be recommended.

Keywords: AVG; Fruit quality; Harvest date; 'Monroe cv.'; Peach; Ripening

Aminoethoxyvinylglycine' nin 'Monroe' Şeftali Çeşidinde Hasat Zamanı ve Meyve Kalitesi Üzerine Etkileri

ESER BİLGİSİ

Araştırma Makalesi — Bitkisel Üretim
Sorumlu Yazar: Melike ÇETİNBAŞ, e-posta: melikecetinbas@gmail.com, Tel: +90(246) 313 24 20
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ÖZET

'Monroe' şeftali çeşidinde hasat tarihini geciktirmek ve meyvelerin kalitesini arttırmak amacıyla bu çalışma yürütülmüştür. Bu amaçla, % 15 aminoethoxyvinylglycine (AVG) içeren ReTain bitki büyüme düzenleyicisi şeftali meyvelerine uygulanmıştır. AVG' nin 3 farklı dozu (0, 100, 150, 200 mg l^{-1}), tahmini hasat zamanından 7, 21 ve 30 gün önce şeftali meyvelerine sprey şeklinde uygulanmıştır. Meyvelerde bazı kalite özellikleri [meyve ağırlığı (g),

meyve eti sertliği (N), SÇKM (%), titre edilebilir asitlik (%), meyve rengi (L*, a*, b*), şeker içeriği], hasat tarihinin gecikmesi, meyvelerin etilen üretimi (μl kg^{-1} h^{-1}) ve solunum hızları (ml CO_2 kg^{-1} h^{-1}) her bir uygulama için incelenmiştir. AVG uygulamaları ile meyve olgunluğu kontrol grubuna göre 4-6 gün gecikmiş ve kademeli yapılan hasat, normal hasat periyoduna göre 6-7 gün önce tamamlanmıştır. AVG uygulaması 'Monroe' şeftalisinde meyve büyüklüğünü ve ağırlığını arttırmıştır. AVG uygulanan meyveler kontrol meyvelerine göre daha sert olmuştur. AVG uygulamaları ile meyvelerde etilen üretimi ve solunum hızı azalmıştır. Sonuç olarak, AVG'nin ticari hasattan 30 gün öncesinde 100 veya 200 mg l^{-1} dozlarında 'Monroe' çeşidi şeftalilerinde uygulanması önerilebilir.

Anahtar sözcükler: AVG; Meyve kalitesi; Hasat tarihi; 'Monroe'; Şeftali; Olgunluk

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1. Introduction

Ethylene is a highly potent plant hormone that is intimately involved in basic plant processes such as seed germination, seedling development, flowering, fruit development, abscission, disease resistance and senescence (Kaşka & Yılmaz 1974; Hartmann 1997; Curry 1998; Rath & Prentice 2004). 1-aminocyclopropane-1-carboxylase (ACC) synthase catalyses 1-aminocyclopropane-1-carboxylic acid (ACC) and it is converted to ethylene by ACC oxidase (ACO) (McGlasson et al. 2005). Aminoethoxyvinylglycine (AVG) is a potent inhibitor of ACC synthase in the ethylene biosynthesis pathway (Boller et al 1979; Kim et al 2004) and can thus suppress ethylene production in many climacteric fruits (Yang et al 1982). ReTain® Plant Growth Regulator, containing 15% w w^{-1} AVG, was registered in Australia in October 2001 for use with apples, peaches and nectarines (Rath & Prentice 2004). Pre-harvest spraying with ReTain® has been demonstrated to delay ripening and reduce pre-harvest drop of fruits in apples, peaches, nectarines and other climacteric fruits (Autio & Bramlage 1982; Park et al 1999; Bregoli et al 2002). However, the effects of AVG depend on application concentration and time cultivar and environmental conditions (Matoo et al 1977; Kim et al 2004). Furthermore, AVG is known to be less effective in inhibiting ethylene biosynthesis at lower temperatures (Bramlage et al 1980).

Fruit softening is known to be one of the ripening processes that are most sensitive to ethylene. Fruit softening in peaches is correlated with an increase in ACC and ethylene production. AVG applied as a pre-harvest spray to peaches delays maturation (Rath & Prentice 2004). ReTain® applied 15, 10 or 5 days before the commercial harvest of late maturing peaches cultivars ('O'Henry', 'Summerset') delayed fruit maturity on the tree and delayed harvest. The application of ReTain® at 5-10 days before harvest has shown to be more effective in improving fruit firmness and quality of late maturing cultivars of peach than application at 15 days before harvest.

Noppakoonwong et al (2005) found that AVG applied to 'Tropic Beauty' peach prior to harvest significantly increased fruit size, firmness and sugar concentration. Another study by Kim et al (2004a) showed the effect of various concentrations (100, 150, 200 mg l^{-1}) of AVG sprayed onto 'Mibaekdo' peach trees at 3 and 4 weeks before the commercial harvest date. AVG spraying greatly reduced the pre-harvest fruit drop rate in a concentration-dependent manner. AVG sprayed at 3 weeks before commercial harvest date appeared to be more effective than at 4 weeks before the commercial harvest date. At harvest, the AVG-sprayed fruits had significantly higher weight than control fruits. They also decreased ethylene production and respiration rate.

This study was conducted in Isparta, where is one of the most important production centers for peaches in Turkey. Poor fruit quality leads to serious problems in the marketing of fruits in this area. This problem also causes significant losses in peach cultivation in Turkey. This study examining fruit quality characteristics such as weight, firmness and colour and criteria such as delaying harvest time, reducing the harvest levels and including issues of provision, is one of the

first studies of its type in a Turkish context.

In this study, it was examined that effects of pre-harvest application of ReTain® on harvest delay, fruit size, fruit quality, ethylene production, respiration rate, sugars and some leaf properties of 'Monroe' peach.

2. Materials and Methods

Experiments were conducted in commercial peach orchards located in Isparta, at an altitude of 963 m - 971 m asl. Uniform trees, 14-years-old cv. 'Monroe' peach on *P. persica* rootstock, spaced at 6x5 m were used. Trees were trained into a vase system and pruned in late winter, and standard cultural practices including thinning and pesticide sprays had been used with the trees for several years. The experimental design was a randomized block, with 12 treatments and 5 replicates using a single tree for each treatment. ReTain® containing 15% AVG, obtained from Valent BioSciences Corp., USA, was sprayed at concentrations of 0 (water+surfactant), 100, 150, 200 mg l^{-1} AVG plus 1% (v/v) 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 commercial harvest (DBH) in the first and second years. Fruits were harvested at a commercial stage of maturity when the ground colour changed from green to yellow-red at intervals of 3-4 days for yield and fruit assessment. ReTain-treated fruits and untreated fruits were harvested separately and picked bins. After each harvest, the fruit was transported 30 km to the Postharvest Physiology Laboratory of Horticulture Department where the fruits were placed into cold storage (1°C) until the analyses were performed.

Fruits were harvested 3 times from 28 August to 8 September 2007 (in the first year) and 26 August to 3 September 2008 (in the second year). The data used for analysis in this paper comes from the second harvest because the percentage of commercial mature fruit picked was seen in the second harvest. The fruit weight, fruit colour (measured with a Minolta Chroma Meter CR-300 using the CIE L*, a* and b*), colour space, fruit firmness (using a Lloyd LF Plus Universal Test Machine), and soluble solids content (SSC) (using a digital Palette PR–32 Atago refractometer) were measured. The colour was measured on both sides of the fruit to determine its ground colour and the red exposed area. Therefore, four measurements were done for each fruit. Fruit firmness was tested at two points on the fruit surface with a plunger of 8 mm diameter. Titratable acidity (TA) was determined using a digital buret (Digitrate Isolab 50 m*l*) by titration with 0.1 N NaOH up to pH 8.1, using 10 m*l* of diluted juice, and the TA was expressed as malic acid. Ethylene production (µ*l* kg^{-1} h^{-1}) and respiration rate (mL CO_2 kg^{-1} h^{-1}) were determined for peaches of close to the jar after 1 day at room temperature (20±1 °C) (1 kg of fruit was closed in each jar and the volume of each jar was 4 litres). The measurement of the respiratory rate was done with a gas analyser. The ethylene production rate was determined using gas chromatography with a flame ionization detector. (Gunes et al 2001) To determine the total sugars (%), a modified Anthrone method (Sanz et al 1987) was used. Reducing sugar contents (%) were determined using the dinitrophenol method. This method is a modification of the colorimetric method used by Ross (1959). Reducing sugars were extracted by water and reacted with dinitrophenol solution. The changes in absorbance were measured at 600 nm. Moreover, the leaf area index and the chlorophyll content were determined for twenty leaves showing average growth from the upper, middle, and lower parts of the outer canopy. The leaf area index (LAI) was measured by leaf area meter (AM 300 Area Meter, ADC, BioScientific Ltd.) (Ünlü 2000; Kim et al 2004b). Chlorophyll was extracted with 80% acetone, and measured using a spectrophotometer (UV-1601, Shimadzu, Japan) at 645 and 663 nm.

The experiment was conducted in 3 (application time; 30, 21 or 7 d before of harvesting) × 4 (AVG concentration; 0, 100, 150 or 200 mg l^{-1}) × 2 (years; first and second) factorial arrangements with completely randomized block design. Each treatment had five replications of 20 peaches. Statistical analyses were performed with General

Linear Model using SPSS (V.16; Statistical software, SPSS. Inc., USA). Mean separation was performed using Duncan's multiple range test at $P<0.05$ level.

3. Results and Discussion

3.1. Fruit maturity and harvest time

Effects of AVG concentrations and its application time on fruit weight and fruit firmness were given in Table 1. AVG applications delayed the development of the background colour of 'Monroe' peaches. As a result, AVG-treated fruits were harvested later than control fruits. Fruit maturity was delayed about 4-6 days in AVG-applied fruits. While the control group was harvested 3 times, AVG-treated fruits were harvested twice (in the first and second year). A sequential harvest was completed 6-7 days before the normal harvest time. Our data was in agreement with previous reports on AVG treatments (Ju et al 1999; Sing et al 2003; Rath & Prentice 2004; McGlasson et al 2005; Noppakoonwong et al 2005). AVG treatments had effects on the percentage of commercial mature fruit at each harvesting date.

Table 1-Fruit harvested on each picking date (%) for peach cv. Monroe in first and second year
Çizelge 1-Birinci ve ikinci yılda Monroe şeftalisinin her hasattaki olgun meyve yüzdesi

		Percentage of commercial mature fruit at each harvest date					
Application time, d [1]	*AVG concentrations, mg l*$^{-1}$	*First year* 28 August	*Second year* 26 August	*First year* 3 September	*Second year* 30 August	*First year* 8 September	*Second year* 3 September
30 d	0	14.5	14.8	51.7	55.7	33.8	29.52d
	100	0	0	68.2	59.8	31.8	40.2a
	150	0	0	65.0	61.5	35.0	38.5bc
	200	0	0	71.0	61.8	29.0	38.2bc
21 d	0	22.5	15.5	61.0	42.2	16.5	42.3a
	100	0	0	62.2	60.7	37.8	39.3ab
	150	0	0	65.3	60.8	34.7	39.2ab
	200	0	0	68.0	62.4	32.0	37.6bc
7 d	0	20	13.0	66.0	44.0	14.0	43.0a
	100	0	0	66.8	62.8	33.2	37.2c
	150	0	0	70.2	61.9	29.8	38.1bc
	200	0	0	69.8	63.0	30.2	37.0c
SEM		1.615	1.102	3.260	2.218	3.906	1.493
Main effects (Means)							
Time							
30		3.63	3.70	63.98	59.70	32.90	36.61
21		5.63	3.88	64.13	60.40	30.25	39.60
7		5.00	3.25	68.20	57.93	26.80	38.83
SEM		0.808	0.551	1.630	1.109	1.953	0.747
	AVG Conc.						
	0	19a	14.43a	59.57b	47.30b	21.43b	38.27
	100	0b	0b	65.73a	61.10a	34.27a	38.90
	150	0b	0b	66.83a	61.40a	33.17a	38.60
	200	0b	0b	69.60a	62.40a	30.40a	37.60
SEM		0.993	0.636	1.882	1.280	2.255	0.862
P values							
Time (T)		0.222	0.443	0.137	0.872	0.107	0.019
Conc. (C)		<0.001	<0.001	0.007	0.006	0.002	0.482
T × C		0.189	0.550	0.197	0.876	0.069	<0.001

[1] days before harvest (DBH)

[a-d]: Values in a same column for each effect followed by different letters are significantly different (Duncan, $P \leq 0.05$)

AVG applications increased the percentage of mature peaches compared to the control fruits (2nd and 3th harvest date). In 3 September of second year, the interaction between concentration and application time for mature fruit were found statistically significant (P<0.01). The effects of AVG concentrations were statistically significant (in the first year-28 August (P<0.001), 3 September (P<0.01), 8 September (P<0.01) and second year 26 August (P<0.001), 30 August (P<0.01)). The highest percentage of commercial mature peaches was found with 30 DBH-200 mg l^{-1} (in the first year) and 7 DBH-200 mg l^{-1} (in the second year) AVG treatments (P<0.05).

3.2. Fruit quality

Fruit weight and fruit firmness: Effects of AVG concentrations and its application time on fruit weight and fruit firmness were given in Table 2. AVG applications had generally positive effects on the fruit weights. In first year, the interaction effects between AVG concentrations and application times on the fruit weight were found statistically significant (P<0.05). In this year, the highest fruit weight was obtained from 100 mg L^{-1} AVG concentration at 30 DBH. In the second year, the main effect of AVG concentrations on fruit weight was statistically significant (P<0.001) and fruits treated with 200 mg l^{-1} AVG concentrations were heavier than the other groups.

Table 2-Fruit weight and firmness in 'Monroe' peaches at harvest as affected by treatment date and AVG concentration

Çizelge 2-AVG dozu ve uygulama zamanın ve 'Monroe' şeftalisinde meyve ağırlığı ve sertliğine etkisi

Application time, d [1]	*AVG concentrations* mg l^{-1}	*Fruit weight, g* *First year*	*Second year*	*Fruit firmness, N* *First year*	*Second year*
30 d	0	284.29abc	188.04	36.72	15.64
	100	341.25a	254.43	44.70	49.42
	150	289.09abc	240.60	30.65	50.44
	200	276.72abc	272.91	33.50	50.62
21 d	0	268.79abc	177.36	23.27	13.47
	100	269.96abc	227.56	25.85	54.49
	150	332.44a	264.65	20.01	45.09
	200	311.95ab	268.92	28.55	42.05
7 d	0	253.12bc	171.45	38.82	12.40
	100	222.30c	259.59	29.19	52.01
	150	308.44ab	201.80	35.61	45.35
	200	335.03a	245.84	36.25	48.84
SEM		18.560	17.424	6.01	5.030
Main effects (Means)					
Time					
30		297.83	238.99	36.39a	41.53
21		295.79	234.62	24.42b	38.78
7		279.72	219.67	34.97a	39.65
SEM		12.031	8.720	3.021	2.515
	AVG Conc.				
	0	268.73	178.95b	32.94	13.84b
	100	277.84	247.19a	33.25	51.97a
	150	309.99	235.68a	28.76	46.96a
	200	307.90	262.56a	32.77	47.17a
SEM		13.840	10.061	0.267	0.030
P values					
Time (T)		0.485	0.203	0.023	0.736
Conc. (C)		0.088	<0.001	0.777	<0.001
T × C		0.010	0.271	0.522	0.870

[1] days before harvest (DBH)

[a-c]: Values in a same column for each effect followed by different letters are significantly different (Duncan, $P \leq 0.05$).

The effects of all the application times and concentrations are quite prominent. The findings on fruit weights in our study are similar to those of Kim et al (2004a), Rath et al (2004), Rath & Prentice (2004) and Amarante et al (2005).

AVG had significant effects (P<0.001) on fruit firmness only for second year (Table 2). All AVG concentrations had higher fruit firmness values than control group. In the first year, the main effect of AVG application times was statistically significant (P<0.05). In this year, the highest fruit firmness (44.70 N) was found with 30 DBH-100 mg l^{-1} AVG treatment. Like our findings, Rath et al (2004) also reported that application 83-125 mg l^{-1} AVG to 'Tatura 204', 'Golden Queen' and 'Taylor Queen' peaches resulted in a reduction 7-14 days of harvesting time with increasing fruit firmness by 7-58% compared to control fruits.

Fruit colour: Effects of AVG concentrations and its application time on fruit colour were given in Table 3. In the both years, interaction effects of AVG concentrations and application times on the fruit colour L* values (bright colour) were statistically significant (P<0.05). The highest L* value was 53.08 with 7 DBH-150 mg l^{-1}, while the lowest L* value was 43.08 with 7 DBH-100 mg l^{-1} in the first year. In the second year, the 21 DBH-control fruits had the highest L* values. AVG

Table 3-Fruit colour (L*, a*, b*) in 'Monroe' peaches at harvest as affected by treatment date and AVG concentration

Çizelge 3-AVG dozu ve uygulama zamanın ve 'Monroe' şeftalisinde meyve rengine (L, a*, b*) etkisi*

Application time, d [1]	*AVG concentrations*	*L**		*a**		*b**	
	mg l^{-1}	*First year*	*Second year*	*First year*	*Second year*	*First year*	*Second year*
30 d	0	45.21bc	49.54ab	27.36	23.41b	25.82bc*	30.07
	100	49.93ab	40.84bc	27.62	27.24ab	28.34b	21.97
	150	48.47abc	41.04bc	29.11	30.75a	31.06a	25.84
	200	51.21ab	38.41c	29.39	30.33ab	29.76ab	22.02
21 d	0	51.16ab	61.66a	26.21	12.78c	32.63a	42.16
	100	47.94abc	39.14c	29.50	27.97ab	27.21bc	21.89
	150	48.49abc	37.91c	30.85	30.22ab	29.92ab	21.42
	200	47.47abc	40.55bc	30.02	29.37ab	26.95bc	23.89
7 d	0	49.21abc	44.75bc	27.95	24.54ab	30.95ab	28.89
	100	43.08c	39.37c	28.58	30.23ab	25.05c	22.96
	150	53.08a	41.98bc	27.97	30.89a	28.55b	25.05
	200	50.70ab	38.32c	29.60	28.87ab	26.29bc	21.61
SEM		1.926	3.016	1.286	2.116	2.441	2.855
Main effects (Means)							
Time							
30		49.13	42.46	28.44	27.80	31.49	24.92
21		48.70	44.82	29.09	25.09	31.18	27.34
7		48.53	41.11	28.63	28.63	31.30	24.63
SEM		0.968	1.510	0.646	1.060	1.227	1.425
	AVG Conc.						
	0	48.83	51.98	27.15b	20.24	30.16	33.71a
	100	46.91	39.78	28.50ab	28.48	29.13	22.27b
	150	49.86	40.17	29.29ab	30.63	32.61	23.98b
	200	49.79	30.09	29.67a	29.52	33.37	22.51b
SEM		1.114	1.743	0.744	1.222	1.411	1.649
P values							
Time (T)		0.971	0.214	0.677	0.049	0.824	0.346
Conc. (C)		0.187	<0.001	0.019	<0.001	0.085	<0.001
T × C		0.018	0.032	0.751	0.045	0.006	0.063

[1] days before harvest (DBH)

[a-c]: Values in a same column for each effect followed by different letters are significantly different (Duncan, $P \leq 0.05$)

concentrations on fruit colour a* values (green to red colour development) were statistically significant (P<0.05) in the first year (Table 3). The best concentration was 200 mg l^{-1} for application times. In the second year, the interaction between concentrations and times on the fruit colour a* values were statistically significant (P<0.05) with AVG-treated fruits having better a* values than the control group. In the first year, the interaction between concentrations and times on the fruit colour b* values (yellow ground colour) were statistically significant (P<0.01). The control fruits and 21 DBH-100 mg l^{-1} treated fruits was near the yellow colour. The highest b* values (33.71) were observed in control fruits in the second year, and effect of AVG concentrations was determined statistically significant (P<0.001). Previous studies showed that the effects of AVG treatment on fruit colour varied. Singh et al (2003) found that AVG treatments had no significant effects on the fruit colour of 'O'Henry' and 'Summerset' peach types, but that the red colour on the yellow surface increased on 'Zee Lady' peach type, implying that the effect of AVG treatments on colour development changes according to the type.

SSC and TA: Effects of the AVG applications on soluble solid contents (SSC) and titratable acidity (TA) changes are shown in Table 4. Effects of AVG concentrations and application

Table 4-Total soluble solids (SSC) and Titratable acidity (TA) in 'Monroe' peaches at harvest as affected by treatment date and AVG concentration

Çizelge 4-AVG dozu ve uygulama zamanın ve 'Monroe' şeftalisinde suda çözünebilir kuru madde ve titre edilebilir asitliğine etkisi

Application time, d [1]	*AVG conc. mg l^{-1}*	*Total soluble solids, %*		*Titratable acidity, %*	
		First year	*Second year*	*First year*	*Second year*
30 d	0	9.96	12.04	0.67	0.52
	100	10.22	12.68	0.56	0.68
	150	9.74	12.95	0.64	0.63
	200	9.70	12.18	0.63	0.60
21 d	0	9.78	11.98	0.62	0.50
	100	9.63	12.55	0.61	0.51
	150	10.55	12.92	0.64	0.61
	200	10.56	12.42	0.63	0.49
7 d	0	9.26	11.95	0.63	0.57
	100	9.80	12.07	0.63	0.64
	150	9.70	11.11	0.63	0.57
	200	10.58	11.50	0.63	0.60
SEM		0.512	0.564	0.022	0.052
Main effects (Means)					
Time					
30		9.81	12.33	0.61	0.61
21		10.15	12.49	0.62	0.53
7		9.93	11.66	0.63	059
SEM		0.257	0.282	0.011	0.026
	AVG Conc.				
	0	9.69	11.99	0.60	0.53
	100	9.90	12.43	0.64	0.56
	150	9.86	12.17	0.63	0.59
	200	10.28	12.03	0.62	0.61
SEM		0.296	0.326	0.012	0.030
P values					
Time (T)		0.604	0.091	0.561	0.072
Conc. (C)		0.519	0.764	0.295	0.296
T × C		0.604	0.814	0.622	0.612

[1] days before harvest (DBH)

times on SSC and TA were not statistically significant. A study was carried out with 'O'Henry', 'Summerset', 'Zee Lady' and 'Elegant Lady' peach types. In this study, it was found that AVG spraying 15, 10 and 5 days before the harvest increased the SSC and TA amounts only of 'O'Henry' and 'Summerset' types (Singh et al 2003).

3.3. Ethylene production and respiration rates

AVG applications significantly reduced the ethylene production rate of the fruits (Table 5). In the first year, the effects of AVG concentrations on ethylene production rate of fruits were found statistically significant (P<0.001). The ethylene production of control group fruits showed the highest value (0.76 μl kg^{-1} h^{-1}) while 21 DBH-100 mg l^{-1} AVG fruits had the lowest value (0.18 μl kg^{-1} h^{-1}). The interaction between concentrations and application times on the fruit ethylene production rate were found statistically significant (P<0.05) in the second year. The highest ethylene production was found in 30 DBH-control fruits (1.09 μl kg^{-1} h^{-1}) and 30 DBH-200 mg l^{-1} AVG fruits showed the lowest value (0.10 μl kg^{-1} h^{-1}). In the first year, the interaction between concentrations and times on the fruit respiration

Table 5-Ethylene production rate and Respiration rate in 'Monroe' peaches at harvest as affected by treatment date and AVG concentration

Çizelge 5-AVG dozu ve uygulama zamanın ve 'Monroe' şeftalisinde etilen üretimi hızı ve solunum hızına etkisi

Application time, d [1]	*AVG concentrations*	*Ethylene production, μl kg^{-1} h^{-1}*		*Respiration rate, ml.CO$_2$ kg^{-1} h^{-1}*	
	mg l^{-1}	*First year*	*Second year*	*First year*	*Second year*
30 d	0	0.75	1.09a	5.06bc	13.62
	100	0.24	0.20de	4.71c	5.37
	150	0.24	0.35cde	8.13a	5.63
	200	0.19	0.10e	5.33abc	7.27
21 d	0	0.76	0.64bc	8.12a	15.47
	100	0.19	0.33de	6.74abc	7.01
	150	0.23	0.29de	6.58abc	6.03
	200	0.18	0.44cd	7.69ab	8.96
7 d	0	0.59	0.87ab	8.10a	20.50
	100	0.30	0.21de	7.69ab	5.35
	150	0.30	0.17de	5.15bc	8.50
	200	0.21	0.15de	6.55abc	5.99
SEM		0.047	0.099	0.866	1.584
Main effects (Means					
Time					
30		0.32	0.44	5.76	8.10
21		0.35	0.43	7.51	9.37
7		0.34	0.35	7.00	10.08
SEM		0.023	0.344	0.305	0.793
	AVG Conc.				
	0	0.71a	0.87	7.28	16.53a
	100	0.25b	0.25	6.36	5.91b
	150	0.26b	0.27	7.03	6.81b
	200	0.19b	0.23	6.53	7.41b
SEM		0.027	0.058	0.501	0.915
P values					
Time (T)		0.986	0.438	0.031	0.178
Conc. (C)		<0.001	<0.001	0.732	<0.001
T × C		0.067	0.012	0.034	0.111

[1] days before harvest (DBH)

[a-e]: Values in a same column for each effect followed by different letters are significantly different (Duncan, $P \leq 0.05$)

rates were found statistically significant (P<0.05) (Table 5). In the second year, the effects of AVG concentrations on respiration rates of fruits were found statistically significant (P<0.001). The 30 DBH-100 mg l^{-1} AVG fruits showed the lowest value in the first year (4.71 ml CO_2 kg^{-1} h^{-1}) and 7 DBH-100 mg l^{-1} AVG fruits showed the lowest value (5.53 ml CO_2 kg^{-1} h^{-1}) in the second year. Similar to our findings, Kim et al (2004a) found that AVG application decreased the ethylene production and respiration rate in the 'Mibaekdo' peach type, and Bregoli et al (2002) found the similar findings for the 'RedHaven' peach type. Moreover, they found no significant effects between application concentrations.

3.4. Total sugar, reducing sugar and sucrose

Total sugar, reducing sugar and sucrose values were given in Table 6. Statistically significant the interaction effects between concentrations and application times on the fruit total sugar (P<0.01 in first year, P<0.001 in second year), reduction sugar (P<0.001 in both years) and sucrose contents (P<0.01 in first year, P<0.001 in second year) were found. In the first year, the highest total sugar content was found in 7 DBH-control fruits.

Table 6-Total sugar, reducing sugar and sucrose in 'Monroe' peaches at harvest as affected by treatment date and AVG concentration

Çizelge 6-AVG dozu ve uygulama zamanın ve 'Monroe' şeftalisinde toplam şeker, indirgen şeker ve sakaroz miktarına etkisi

Application time, d [1]	*AVG concentrations*	*Total sugar, %*		*Reducing sugar, %*		*Sucrose, %*	
	mg l^{-1}	*First year*	*Second year*	*First year*	*Second year*	*First year*	*Second year*
30 d	0	5.14b	6.31f	2.57a	3.30ef	2.49bc	2.92def
	100	5.07b	11.50a	2.53bcd	9.50a	2.46bc	1.94g
	150	5.07b	9.19c	2.54b	5.82bc	2.39c	3.27cde
	200	5.06b	8.26d	2.52f	5.93bc	2.46bc	2.26fg
21 d	0	5.18b	5.21g	2.53cde	2.76f	2.58b	2.39efg
	100	5.07b	10.52b	2.54b	6.49b	2.45bc	3.90bc
	150	5.16b	9.97bc	2.52f	5.12c	2.56b	4.70ab
	200	5.10b	7.04ef	2.54b	4.01d	2.48bc	2.93def
7 d	0	5.44a	7.36e	2.53cde	4.07d	2.82a	3.20cdef
	100	5.09b	10.32b	2.52f	5.16c	2.49bc	5.00a
	150	5.10b	5.29g	2.53def	2.43f	2.49bc	2.77efg
	200	5.07b	10.39b	2.52f	6.44b	2.47bc	3.83bcd
SEM		0.041	0.299	0.003	0.340	0.040	0.289
Main effects (Means							
Time							
30		5.09	8.81	2.54	6.13	2.45	2.60
21		5.13	8.18	2.53	4.60	2.52	3.48
7		5.17	8.34	2.52	4.52	2.57	3.70
SEM		0.021	0.149	0.001	0.170	0.020	0.144
	AVG Conc.						
	0	5.25	6.30	2.54	3.38	2.62	2.83
	100	5.08	10.78	2.53	7.05	2.47	3.62
	150	5.11	8.15	2.53	4.46	2.48	3.58
	200	5.07	8.56	2.53	5.46	2.47	3.01
SEM		0.024	0.172	0.001	0.196	0.023	0.167
P values							
Time (T)		0.026	0.018	<0.001	<0.001	0.002	<0.001
Conc. (C)		<0.001	<0.001	<0.001	<0.001	<0.001	0.004
T × C		0.004	<0.001	<0.001	<0.001	0.002	<0.001

[1] days before harvest (DBH)

[a-g]: Values in a same column for each effect followed by different letters are significantly different (Duncan, $P \leq 0.05$)

In second year, the total sugar content of fruits treated with 30 DBH-100 mg l^{-1} (11.50%) was higher than with the other treatments in the second year. 30 DBH-200 mg l^{-1} (5.06%) treated fruits (in the first year) and 21 DBH-control (5.21%) fruits (in the second year) had the lowest total sugar content. In the first year, in general, the reduction in the sugar content of AVG-treated fruits and of control fruits were similar. The highest reduction in sugar content (2.57%) was in 30 DBH-control fruits. In the second year, 30 DBH-100 mg l^{-1} AVG fruits had the highest sugar content reduction. The sucrose contents of fruits were decreased by AVG treatments in the first year. The lowest sucrose content had 30 DBH-150 mg l^{-1} (in the first year) and the sucrose content of fruits which were treated with 30 DBH-100 mg l^{-1} treatments were lower than the other treatments (in the second year). Colarıč et al (2004) reported that total sugar and sucrose content varied from 6.15 to 9.37% and from 4.61 to 7.01% in peach and nectarine cultivars, respectively. In the current study, the total sugar content was between 5.06-11.50%, the reduction in sugar content was between 2.52-9.50% and the sucrose content was between 1.94-5.00%. Chapman & Horvat (1990) reported that the sucrose content of the 'Monroe' peach was around 7-8% at harvest. In the current study, the effect of AVG on sugar content showed no clear trend for application times and concentrations.

3.5. Leaf Area Index (LAI) and total chlorophyll, chlorophyll a, chlorophyll b in leaf

Mean values of leaf Area Index (LAI) in Table 7 and total chlorophyll, chlorophyll a, chlorophyll b in leaf in Table 8 were given.

Table 7-LAI in leaf of 'Monroe' peaches at harvest as affected by treatment date and AVG concentration
Çizelge 7-AVG dozu ve uygulama zamanın ve 'Monroe' şeftalisinin yaprak alan indeksine etkisi

Application time, d [1]	*AVG conc. mg l⁻¹*	*Leaf Area Index (LAI)* *First year*	*Second year*
30 d	0	1.62c	1.57a
	100	1.18d	1.46c
	150	1.14de	1.14c
	200	1.25d	1.60a
21 d	0	1.12de	1.41b
	100	2.23a	1.12c
	150	1.81b	1.16c
	200	0.95e	1.52ab
7 d	0	1.25d	1.20c
	100	1.05de	1.22c
	150	1.16d	1.11c
	200	1.74bc	1.23c
SEM		0.061	0.048
Main effects (Means)			
Time			
30		1.29	1.44
21		1.53	1.30
7		1.30	1.19
SEM		0.031	0.024
	AVG Conc.		
	0	1.33	1.40
	100	1.49	1.27
	150	1.40	1.14
	200	1.31	1.45
SEM		0.035	0.028
P values			
Time (T)		<0.001	<0.001
Conc. (C)		0.008	<0.001
T × C		<0.001	0.001

[1] days before harvest (DBH)
[a-e]: Values in a same column for each effect followed by different letters are significantly different (Duncan, $P \leq 0.05$)

Table 8-Total chlorophyll, Chlorophyll a and Chlorophyll b in leaf of 'Monroe' peaches at harvest as affected by treatment date and AVG concentration

Çizelge 8-AVG dozu ve uygulama zamanın ve 'Monroe' şeftalisi yapraklarında toplam klorofil, klorofil a ve klorofil b miktarına etkisi

Application time, d [1]	*AVG concentrations*	*Total chlorophyll mg g*$^{-1}$		*Chlorophyll a, mg g*$^{-1}$		*Chlorophyll b mg g*$^{-1}$	
	mg l^{-1}	*First year*	*Second year*	*First year*	*Second year*	*First year*	*Second year*
30 d	0	1.07	1.83	0.79	1.26	0.28	0.57
	100	1.58	1.70	1.08	1.25	0.51	0.45
	150	1.59	1.40	1.18	1.06	0.41	0.33
	200	1.82	1.40	1.31	1.07	0.51	0.33
21 d	0	1.47	1.74	1.04	1.27	0.42	0.46
	100	1.33	1.28	0.95	0.95	0.38	0.33
	150	1.72	0.80	1.23	0.62	0.48	0.18
	200	1.55	1.17	1.12	0.91	0.43	0.26
7 d	0	1.51	2.24	0.99	1.48	0.52	0.77
	100	1.46	1.66	1.03	1.09	0.43	0.57
	150	1.67	1.06	1.20	0.75	0.47	0.31
	200	1.35	1.79	0.98	1.36	0.37	0.42
SEM		0.211	0.197	0.131	0.144	0.089	0.100
Main effects (Means)							
Time							
30		1.52	1.58a	1.09	1.16a	0.43	0.42ab
21		1.51	1.25b	1.09	0.94b	0.43	0.31b
7		1.50	1.69a	1.05	1.17a	0.45	0.52a
SEM		0.106	0.099	0.065	0.072	0.044	0.050
	AVG Conc.						
	0	1.35	1.94a	0.94	1.34a	0.41	0.60a
	100	1.46	1.55b	1.02	1.10a	0.44	0.45ab
	150	1.67	1.08c	1.21	0.81b	0.45	0.27b
	200	1.57	1.45b	1.13	1.11a	0.44	0.34b
SEM		0.122	0.114	0.075	0.083	0.051	0.058
P values							
Time (T)		0.990	0.011	0.896	0.053	0.939	0.023
Conc. (C)		0.329	<0.001	0.087	0.002	0.946	0.003
T × C		0.452	0.527	0.471	0.351	0.441	0.946

[1] days before harvest (DBH)

[a-c]: Values in a same column for each effect followed by different letters are significantly different (Duncan, $P \leq 0.05$)

Leaf area was significantly affected by AVG treatments in both years. In first and second year, the interaction between concentrations and times on the fruit total sugar, reduction sugar and sucrose contents were found statistically significant (P<0.001). The highest LAI was found at 21 DBH-100 mg l^{-1} fruits (in the first year), and leaves treated with 30 DBH-200 mg l^{-1} were larger than the other groups (in the second year) (Table 7). In the first year, the total chlorophyll was increased by AVG treatments, but in the second year it was decreased. A similar trend was observed for chlorophyll a and chlorophyll b (Table 8). Only in second year, effect of AVG concentrations (P<0.001) and times (P<0.05) on total chlorophyll, chlorophyll a, chlorophyll b of leaves were found statistically significant. In this study, the total chlorophyll content of peach leaves was 0.80-2.24 mg g^{-1}, the chlorophyll a content was 0.79-1.48 mg g^{-1} and the chlorophyll b content was 0.28-0.77 mg g^{-1}. These findings were found similar to the chlorophyll contents reported by Mordoğan & Gönülsüz (2000).

4. Conclusion

Obtained results are very important to reduce harvesting expenses and to improve uniformity of fruit maturity in a shorter time. These findings could bring great benefits for the marketing of peaches. As a result, regarding effects on weight, firmness and ethylene production as the time of application in terms 30 days before commercial harvest and 100 or 200 mg l^{-1} AVG concentration for 'Monroe' peach varieties can be recommended.

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