Medicon Agriculture & Environmental Sciences
Volume 7 Issue 2 August 2024
Article Type: Research Article
ISSN: 2972-2691

Preharvest 1-Methylcyclopropene Effects on Fruit Quality and Harvest Maturity of 'Pink Lady' Apples

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Received: June 22, 2024; **Published:** July 23, 2024

DOI: 10.55162/MCAES.07.191

Abstract

This research includes the effects of preharvest 1-Methylcyclopropene (1-MCP) (Harvista) treatments on fruit drop, fruit quality and harvest maturity of 'Pink Lady- Cripps Pink' apple cultivar. The research had materialized in 2016 and 2017. For this purpose, preharvest 1-Methylcyclopropene treatments at doses of 50, 100, 150 and 200 g ha^{-1} were applied to 'Cripps pink' apple cultivar in Çanakkale, Lapseki region, Turkey. Samplings collected from trees at application day and 7, 14, 21 and 28 days after applications respectively. Fruit drop rate, flesh firmness, soluble solids content, starch degradation, titratable acidity, skin color, and ethylene production were evaluated after each sampling date. Furthermore, fruits were kept at 20-22°C temperature and 50-60% relative humidity conditions for 7 and 14 days as shelf life to determine the changes in quality assessments. According to the results, Harvista applications with 150 and 200 g ha^{-1} doses were found out as the most positive applications because of preventing fruit drop and minimizing the changes of quality parameters. Harvest maturity could be prolonged for 21 days with these application doses.

Keywords: Cripps pink; 1-Methylcyclopropene; fruit drop; quality parameters; shelf life

Introduction

After China, USA, Italy and Chile; Turkey is one of the main apple producers all over the world. Thus 3.625.960 tons of apples are produced in different regions (FAOSTAT, 2018).

The main apple regions are: Isparta, Karaman, Nigde, Denizli, Antalya and Canakkale. The main cultivars are: 'Red Delicious', 'Golden Delicious', 'Gala', 'Granny Smith', 'Amasya' 'Pink Lady' respectively. Besides some club varieties such as 'Rosy Glow', 'Jeromine', and 'Shiniga Gala' are also popular since 10 years.

The use of 1-Methylcyclopropene (1-MCP) has been evaluated on different vegetables and fruits. The 1-MCP treatments delay physico-chemical changes related to the ripening process and reduce decay, weight loss and chilling injury (Blankenship and Dole, 2003). The main effect of 1-MCP on crops has been related to ethylene action, since 1-MCP blocks the ethylene receptors and inhibits the hormonal action (Sisler and Serek, 1997; Watkins, 2002). The positive effects of 1-MCP on fruit quality were determined on climacteric fruits including apples as reducing ethylene production, softening, color change, loss of titratable acidity and rate of superficial scald (Fan and Mattheis, 1999; Fan et al., 1999; Jiang and Joyce, 2002). In pears 1-MCP reduce ethylene production, softening and water loss (Lelievre et al., 1997; Baritelle et al., 2001). The preharvest usage of 1-MCP has not a great potential yet because of being a new product. However, its usage is increased in US, South Africa, Australia and Chile during the last years.

The aim of the study is to test the potential of preharvest application of 1-MCP in reducing preharvest fruit drop and enlarging the harvest period by delaying the maturity of 'Pink Lady Cripps Pink' cultivar.

Materials and Methods

Plant material

'Cripps pink' apples from Lapseki region in Canakkale- Turkey, were used as plant material. Trees were 10 years old, grafted on M9 dwarf rootstock. The row spacing was 4.0 m and space within row was 1.0 m, while the average height of trees was 3.0 m-3.5 m.

Preharvest applications

Harvista (0.8% 1-Methylcyclopropene as an active ingredient) was applied to apple trees with 50, 100, 150 and 200 g a.i. dosage per ha. mixed with water. Besides these doses were compared with 100 g a.i. dosage per ha mixed with Conosol 260 (milky liquid oil emulsion). Furthermore, control trees were separated as untreated material. The treatments were done at 10.09.2013, 7 days before harvest (Moggia and Pereira, 2007). The application date was determined by using the maturity scale of this cultivar grown in Marmara region (Bıyıklı, 2009). Application details including weather conditions for two years are shown at Table 1.

Parameter	***Value (1st. year)***	***Value (2nd year)***
Application date	21 October 2016	30 October 2017
Application timing	7 days before of the optimum harvest maturity	7 days before of the optimum harvest maturity
Time of day	09:30 am	11:00 am
Application method	Ultra low volume	Ultra low volume
Application placement	Foliar	Foliar
Temperature of air (°C)	21°C	20°C
Relative humidity (%)	55	62
Wind speed range (m/s)	0,2	0,3
Dew presence (Yes/No)	No	No
Cloud cover (%)	5	10

Table 1: The details of Harvista application on 'Pink Lady Cripps pink' apples.

Quality assessments

Fruits samples were taken on: application date and 7, 14, 21 and 28 days after application. Quality and fruit drop assessments were done at each sampling date. Fruit drops were determined by counting the fallen fruits at each sampling period. Firmness was evaluated by 2 readings per fruit on 8 apples per plot (32 per treatment) using an Effegi penetrometer with a plunger of 11 mm, and values are express in kg cm^{-2} (Turoni, Italy). Starch degradation was determined by the assessment of the grade of starch depolymerisation using CTIFL scale (1-10) and scale materialized by Biyikli, 2009; for Marmara Region- Turkey (Figure 1) on 8 apples per plot (32 per treatment). Soluble solids content (SSC) was assessed by using Atago PAL-1 digital refractometer (Atago, Tokyo, Japan) on 8 apples per plot (32 per treatment). Fruit skin color was measured by using Minolta colorimeter CR 400 (Minolta, Osaka, Japan) on 8 apples per plot (32 per treatment) and b* values were determined. Malic acid content was evaluated by 1 reading per plot using titration method and expressed as ml 100 ml^{-1}. Phenolic compounds was assessed by Gallic acid standard by using Folin- Ciocalteu spectrophotometric method and expressed as GAE mg 100 g^{-1} (Zheng and Wang, 2011). Ethylene emission was determined by using gas analyser ICA-56 (International Controlled Atmosphere Ltd., Tonbridge, UK). Sampled fruits were also kept for 7 and 14 days as shelf life with 20-22°C and 50-60% relative humidity conditions for each sampling date. Fruit firmness and ethylene emission were evaluated after each shelf life period respectively.

Figure 1: Starch index (1-10) for 'Pink Lady' apples (Bıyıklı, 2009).

Statistical analysis

For all data, the homogeneity of variance was tested by Bartlett's Test. If this test indicated no homogeneity of variance, the transformed values were used for a two-way analysis of variance (ANOVA). Student-Newman-Keuls' multiple comparison test was applied to separate treatment means at the 95% confidence level.

Results and Discussion

Fruit drop

Harvista applications affected fruit drop significantly in the first year of research. Furthermore, important differences were found between application rates. Thus the main effect was determined on 150 g a.i. ha^{-1} Harvista rate; 200 g a.i. ha^{-1} and Harvista with Conosol followed this rate respectively (Table 2).

For the second year, 150 g a.i. ha^{-1} Harvista rate followed 200 g a.i. ha^{-1} reduced the fruit drop significantly. Besides Harvista with Conosol was also found effective after these two dosages (Table 3).

Moreover, 50 and 100 g a.i. ha^{-1} Harvista rates had less effects on fruit drops. These effects were visible until 21 days after application. However the most effective rates 150 and 200 of Harvista were still effective at 28^{th} day after application. These effects are very profitable however the period is winter and freezing maybe occurred on fruits in the orchard.

Application	***Dose g ai.ha^{-1}***	***Days after application***			
		7	***14***	***21***	***28***
Control	-	4.25	4.25	4.75	5.75
Harvista Af-701	50	3.75	3.25	3.5	3.5
Harvista Af-701	100	2.5	2	2.25	2
Harvista Af-701	150	0.75	1	0.75	0.75
Harvista Af-701	200	2	1	1.25	1
Harvista 0.8 Of	100	1	1.25	1.5	1.25

Table 2: The effects of different treatments on fruit drop of 'Cripps pink' apples at four sampling dates during 1^{st} year.

Application	Dose g ai/ha^{-1}	Days after application			
		7	14	21	28
Control	-	5.25	3.75	5.5	5.5
Harvista Af-701	50	3.5	4.25	4.25	5.25
Harvista Af-701	100	3.25	3	3	3.25
Harvista Af-701	150	1	0.75	1.25	0.75
Harvista Af-701	200	2	1.5	1	1.5
Harvista 0.8 Of	100	1.5	1.5	1.75	1.75

Table 3: The effects of different treatments on fruit drop of 'Cripps pink' apples at four sampling dates during 2nd year.

Fruit firmness

In the first year of research, firmness values of untreated fruits did not differ or were higher than that recorded in Harvista with Conosol treated fruits. Apples treated with Harvista (1-MCP) at the rates of 50 and 100 g a.i. ha^{-1} generally did not differ from untreated, except at 21 and 28 days after the Harvista application assessments when their values were lower than ones recorded in untreated fruits. On the contrary, apples treated with Harvista at the rates of 150 and 200 g a.i. ha^{-1} always were significantly firmer than untreated fruits (Table 4). The similar effects were fixed in the second year results. Thus 150 and 200 g a.i. ha^{-1} significantly prevented the fruit softening. Other two rates of Harvista and Harvista with Conosol were in the same statistical group. Similar effects of preharvest 1-MCP treatments on firmness were determined on Gala apples (Moggia and Pereira, 2007).

Sampling days	Application Harvista (g ai/ha) Dose						Days Mean
	Control	AF-701 50	AF-701 100	AF-701 150	AF-701 200	0.8 OF 100	
0	9.37 a	9.37 a	9.37a	9.37 a	9.37 a	9.37 a	9.37 A
7	8.50 e	8.49 e	8.49 e	9.11 b	9.11 b	8.48 e	8.70 B
7+7*	8.09 h	8.11 gh	8.10 h	8.81 c	8.81 c	8.15fgh	8.35 C
7+14*	7.27 n	7.23 n	7.24 n	8.66 d	8.68 d	7.26 n	7.72 D
14	7.07 o	7.08 o	7.04 o	8.49 e	8.48 e	7.05 o	7.54 E
14+7*	6.28qrs	6.31 qr	6.32 qr	8.24 f	8.23fg	6.33 q	6.95 F
14+14*	6.05 v	6.07 uv	6.13tuv	8.05 h	8.04hi	6.14tuv	6.75 G
21	6.13tuv	6.14tuv	6.20 rst	7.92 ij	7.90 j	6.18stu	6.74 G
21+7*	5.85 w	5.85 w	5.90 w	7.60 k	7.58 k	5.90 w	6.44 H
21+14*	5.72 x	5.69 x	5.70 x	7.42 l	7.39lm	5.71 x	6.34HI
28	5.88 w	5.86 w	5.88 w	7.28mn	7.25 n	5.86 w	6.27 IJ
28+7*	5.71 x	5.68 x	5.62 xy	7.05 o	7.06 o	5.61 xy	6.12JK
28+14*	5.53 y	5.52 y	5.53 y	6.86 p	6.86 p	5.55 y	5.98 K
App.Mean	6.725B	6.721B	6.732B	8.066A	8.059A	6.735B	
LSD(0.05)	0.1202						0.1575
LSD App.xDays	0.107						

Table 4: The effects of different treatments on fruit firmness (kgf) of 'Cripps pink' apples at four sampling dates during 1st year. * Shelf life period under shelf life conditions.

Sampling days	*Application Harvista (g ai/ha) Dose*						*Days Mean*
	Control	*AF-701 50*	*AF-701 100*	*AF-701 150*	*AF-701 200*	*0.8 OF 100*	
0	9.23 a	9.23 a	9.23 a	9.23a	9.23 a	9.23 a	9.23 A
7	8.40 f	8.39 f	8.38 f	9.03b	9.01 b	8.37 f	8.60 B
7+7*	8.00 h	8.01 h	8.00 h	8.67c	8.66 cd	8.06 h	8.23 C
7+14*	7.15mno	7.10opqr	7.11opq	8.56e	8.57 de	7.14nop	7.61 D
14	7.04 qrs	7.05pqrs	7.00 s	8.43 f	8.42 f	7.01 rs	7.49 D
14+7*	6.25 u	6.26 u	6.27 u	8.19g	8.16 g	6.28 u	6.90 E
14+14*	6.02 w	6.03 w	6.08vw	8.05h	8.04 h	6.09 vw	6.72 F
21	6.09 vw	6.10 vw	6.15 v	7.86 i	7.88 i	6.14 v	6.70 F
21+7*	5.83 x	5.83 x	5.86 x	7.56 j	7.54 j	5.86 x	6.41 G
21+14*	5.82 x	5.80 x	5.82 x	7.33kl	7.36 k	5.80 x	6.32GH
28	5.66 y	5.67 y	5.65 y	7.25lm	7.21mn	5.68 y	6.18 HI
28+7*	5.59 yz	5.55 z	5.54 z	6.99 s	7.00 s	5.54 z	6.03 IJ
28+14*	5.51 z	5.51 z	5.52 z	6.84 t	6.85 t	5.53 z	5.96 J
App. Mean	6.660 B	6.655 B	6.662B	8.003A	7.990A	6.672 B	
LSD	0.0973						0.1559
LSD App.xDays	0.1059						

Table 5: The effects of different treatments on fruit firmness (kgf) of 'Cripps pink' apples at four sampling dates during 2nd year. * Shelf life period under shelf life conditions.

Starch degradation

According to the results of first year, starch degradation values of untreated fruits did not differ or were higher than that recorded in Harvista with Conosol treated fruits. Besides fruits treated with Harvista at the rates of 50 and 100 g a.i. ha^{-1} did not differ from untreated, while fruits treated with Harvista at the rates of 150 and 200 g a.i. ha^{-1} had lower starch degradation than untreated until 28 days except at 7 days after treatment (Table 6). In the second year of the research, fruits were a little more mature at the same periods. Starch degradations of control fruits were lower than all applications. However 150 and 200 g a.i. ha^{-1} had lower starch degradation than untreated until 28 days significantly. The other two application rates and Harvista with Conosol had the same effect level (Table 7). 1-MCP delayed the starch degradation on 'Pink Lady' apples similarly (Sakaldaş and Kaynaş, 2011).

Sampling days	Application Harvista (g ai/ha) Dose						Days Mean
	Control	AF-701 50	AF-701 100	AF-701 150	AF-701 200	0.8 OF 100	
0	6.50 g	6.50 g	6.50 g	6.50 g	6.50 g	6.50 g	6.50E
7	7.00 fg	7.00 fg	7.00 fg	6.75 fg	6.75 fg	6.75 fg	6.88D
14	8.00 d	8.00 d	7.75 de	7.25 ef	7.25 ef	7.75de	7.67C
21	9.00 b	9.00 b	8.75 bc	8.00 d	8.25 cd	8.75bc	8.63B
28	9.75 a	9.75 a	9.75 a	8.75 bc	8.75 bc	9.75 a	9.33A
App.Mean	8.05 A	8.05 A	7.95 A	7.45 B	7.50 B	7.80 A	
LSD (0.05)	0.6282						0.2542
LSD App*Days	0.2785						

Table 6: The effects of different treatments on starch degradation (1-10) of 'Cripps pink' apples at four sampling dates during 1st year.

Sampling days	Application Harvista (g ai/ha) Dose						Days Mean
	Control	AF-701 50	AF-701 100	AF-701 150	AF-701 200	0.8 OF 100	
0	6.75 h	6.75 h	6.75 h	6.75 h	6.75 h	6.75 h	6.75D
7	7.25 fgh	7.25 fgh	7.25 fgh	7.00 gh	7.00 gh	7.00 gh	7.13D
14	8.25cdef	8.25cdef	8.00defg	7.50efgh	7.50efgh	8.00defg	7.92C
21	9.25 abc	9.25 abc	9.00abcd	8.25cdef	8.50bcde	9.00abcd	8.88B
28	10.00 a	9.75 a	9.75 a	9.00abcd	9.00abcd	9.50 ab	9.50A
App.Mean	8.05 A	8.05 A	7.95 A	7.45 B	7.50 B	7.80 A	
LSD (0.05)	0.6282						0.2542
LSD App*Days	0.2785						

Table 7: The effects of different treatments on starch degradation (1-10) of 'Cripps pink' apples at four sampling dates during 2nd year.

Soluble solids content

Higher SSC were generally recorded on untreated apples and on Harvista with Conosol treated apples. Fruits treated with Harvista at the rate of 50 and 100 ga.i.ha^{-1} did not differed from untreated, while that treated at the rate of 150 and 200 ga.i.ha^{-1} had lower values at each sampling period. Thus finally, apples treated with Harvista at the rates of 150 and 200 g a.i. ha^{-1} had mostly significantly lower SSC in comparison to untreated (Table 8). Very similar results were fixed at second year of research. Interactive SSC values besides the mean values were nearly the same between control, 50 ga.i.ha-1, 100 ga.i.ha^{-1} and Harvista with Conosol. However 150 and 200 ga.i.ha^{-1} had always lower values with the same level (Table 9). The effect of 1-MCP on SSC was previously reported on 'Fuji' apples (Kaynaş et al., 2012) and Japanese plums (Erkan et al. 2005) during storage. The contrasting results with apples are notable and may be due to different cultivars or other experimental conditions used. (Watkins et al., 2000) found differences in responses of apple cultivars with 1-MCP-treated 'McIntosh' and 'Law Rome' fruit having lower soluble solids and 'Delicious' and 'Empire' having higher soluble solids than untreated fruit.

Sampling days	*Application Harvista (g ai/ha) Dose*						*Days Mean*
	Control	*AF-701 50*	*AF-701 100*	*AF-701 150*	*AF-701 200*	*0.8 OF 100*	
0	13.27 f	13.27 f	13.27 f	13.27f	13.27f	13.27 f	13.27E
7	13.91 e	13.88 e	13.87 e	13.41f	13.39f	13.87 e	13.72D
14	14.56cd	14.57cd	14.55cd	14.46d	14.48d	14.53cd	14.52C
21	14.97 b	14.94 b	14.94 b	14.69c	14.68c	14.94 b	14.86B
28	15.51 a	15.51 a	15.49 a	14.91b	14.92b	15.48 a	15.30A
App.Mean	14.44 A	14.43A	14.42A	14.14B	14.15B	14.42A	
LSD (0.05)	0.1922						0.095
LSD App*Days	0.1041						

Table 8: The effects of different treatments on soluble solids content (SSC) (%) of 'Cripps pink' apples at four sampling dates during 1st year.

Sampling days	*Application Harvista (g ai/ha) Dose*						*Days Mean*
	Control	*AF-701 50*	*AF-701 100*	*AF-701 150*	*AF-701 200*	*0.8 OF 100*	
0	13.73 g	13.73 g	13.73g	13.73g	13.73g	13.73 g	13.73E
7	14.37 e	14.33 e	14.32e	13.88 f	13.87 f	14.32 e	14.18D
14	15.01cd	15.02cd	15.00cd	14.92d	14.90d	14.99cd	14.97C
21	15.40 b	15.36 b	15.36 b	15.11c	15.10c	15.36 b	15.28B
28	15.87 a	15.87 a	15.87 a	15.26b	15.28b	15.84 a	15.67A
App.Mean	14.87A	14.86A	14.85A	14.57B	14.58B	14.85A	
LSD (0.05)	0.1241						0.07068
LSD App*Days	0.0841						

Table 9: The effects of different treatments on soluble solids content (SSC) (%) of 'Cripps pink' apples at four sampling dates during 2nd year.

Titratable Acidity

For the first year of the research, only apples treated at the rates of 150 and 200 g a.i.ha^{-1} had significantly higher content of acids. Other treatments did not differ from values recorded on untreated apples (Table 10). Similarly to the first year results, 150 and 200 g a.i h^{-1} were found effective significantly on acidity content means Malic acid. Similar results were found on 1-MCP treated 'McIntosh' and 'Honeycrisp' apples during cold storage and shelf life (DeEll, 2010). About maintaining TA in 'Red Delicious', 'Granny Smith', 'Fuji', 'Jonagold', ' Ginger Gold', and 'Gala' apples (Fan et al., 1999a,b; Watkins et al.,2000) found that TA of 'Law Rome', 'Delicious', 'Empire', and 'McIntosh' was always higher in 1-MCP-treated fruit.

Sampling days	Application Harvista (g ai/ha) Dose						Days Mean
	Control	AF-701 50	AF-701 100	AF-701 150	AF-701 200	0.8 OF 100	
0	0.782 a	0.782a	0.782 a	0.782a	0.782 a	0.782 a	0.782A
7	0.650cd	0.648d	0.658 bc	0.659b	0.657bcd	0.658bc	0.655 B
14	0.590 f	0.590 f	0.590 f	0.608e	0.608 e	0.591 f	0.596 C
21	0.529 h	0.518 i	0.517 i	0.587 f	0.586 f	0.518 i	0.542D
28	0.480 j	0.477 j	0.478 j	0.561g	0.555 h	0.481 j	0.506 E
App.Mean	0.606 B	0.603B	0.605 B	0.639	0.638 A	0.606 B	
LSD(0.05)	0.009						0.0098
LSD App*Days	0.0108						

Table 10: The effects of different treatments on acidity content (ml.100l-1) of 'Cripps pink' apples at four sampling dates during 1st year.

Sampling days	Application Harvista (g ai/ha) Dose						Days Mean
	Control	AF-701 50	AF-701 100	AF-701 150	AF-701 200	0.8 OF 100	
0	0.775 a	0.775a	0.775 a	0.775 a	0.775 a	0.775 a	0.775A
7	0.647 cd	0.644d	0.655bc	0.658b	0.656b	0.655bc	0.652B
14	0.587 f	0.587 f	0.587 f	0.602 e	0.602 e	0.588 f	0.592C
21	0.515 h	0.515h	0.514 h	0.580g	0.581g	0.514 h	0.536D
28	0.477 i	0.473 i	0.474 i	0.538g	0.530h	0.478 i	0.495E
App.Mean	0.598 B	0.600B	0.601 B	0.631A	0.629A	0.602 B	
LSD (0.05)	0.0096						0.0086
LSD App*Days	0.0182						

Table 11: The effects of different treatments on acidity content (ml.100l-1) of 'Cripps pink' apples at four sampling dates during 2nd year.

Skin color

First and second year color parameter Hue angle values recorded in control apples were generally comparable to ones recorded in apples treated with Harvista- Conosol and also to that treated with Harvista at the rates of 50 g a.i. ha^{-1} and 100 g a.i. ha^{-1}. Apples treated with Harvista at the rates of 150 and 200 g a.i. ha^{-1} generally demonstrated higher values of Hue angle. Among Harvista treatments some dose effects were statistically significant (Table 12). Similar effects of 1-MCP were found on 'McIntosh' apples (DeEll, 2010). Degreening of 'Fuji' apples was inhibited by 1MCP (Fan and Mattheis, 1999b). While 1-MCP treated 'Red Chief' apples had a greener background color than untreated fruit, chlorophyll fluorescence measurements indicated that loss of chloroplast function was largely independent of ethylene (Mir et al., 2001).

Sampling days	*Application Harvista (g ai/ha) Dose*						*Days Mean*
	Control	*AF-701 50*	*AF-701 100*	*AF-701 150*	*AF-701 200*	*0.8 OF 100*	
0	60.75 a	60.75 a	60.75 a	60.75 a	60.75a	60.75 a	60.75A
7	46.11 d	46.20 d	46.35 d	53.70b	53.77b	46.37d	48.75B
14	41.40 f	41.54ef	42.32ef	49.28 c	49.49c	42.28ef	44.39C
21	36.41 g	36.50 g	37.26 g	46.14d	46.04d	37.26 g	39.93D
28	32.51 h	32.62 h	33.25 h	42.49 e	42.45ef	33.14 h	36.07E
App.Mean	43.43B	43.52B	43.98B	50.46A	50.51A	43.96B	
LSD (0.05)	1.0506						1.0599
LSD App*Days	1.1611						

Table 12: The effects of different treatments on skin color (Hue angle) changes of 'Cripps pink' apples at four sampling dates during 1st year.

Sampling days	*Application Harvista (g ai/ha) Dose*						*Days Mean*
	Control	*AF-701 50*	*AF-701 100*	*AF-701 150*	*AF-701 200*	*0.8 OF 100*	
0	62.64 a	62.64a	62.64 a	62.64 a	62.64 a	62.64a	62.64A
7	49.08d	49.17d	49.30 d	56.05b	56.15b	49.33d	51.51B
14	45.57 f	45.87 f	45.95 f	51.60 c	51.67 c	46.02f	47.78C
21	40.34 h	40.49h	41.29 h	47.43 e	47.36 e	41.21h	43.02D
28	36.29 jk	36.24k	37.24ij	43.98g	43.96g	37.30i	39.17E
App.Mean	46.78 B	46.88B	47.28B	52.33A	52.36A	47.30	
LSD (0.05)	0.9982						0.8467
LSD App*Days	0.9275						

Table 13: The effects of different treatments on skin color (Hue angle) changes of 'Cripps pink' apples at four sampling dates during 2nd year.

Phenolic compounds

According to the results of first year, all applicate apples had significantly lower content of phenolic compounds in comparison to control. Apples treated with Harvista at the rate of 50 and 100 g a.i. ha^{-1} were statistically different to high rates 150, 200 g a.i. ha^{-1} and Harvista with Conosol, these three treatments showed the lowest total phenolic compounds content (Table 14). The differences were observed until 28 days. The results of second year were very similar to the first years results. Rates of 150, 200 g a.i. ha^{-1} and Harvista with Conosol had the lowest total phenolic compounds content during whole period (Table 15). Phenolic compounds are good markers of volatiles thus volatile formation in apples is differentially inhibited by 1-MCP (Fan and Mattheis, 1999a). 1-MCP inhibited total alcohol and total ester formation in 'Fuji' (Fan and Mattheis, 1999a) and 'Gala' apples (Fan and Mattheis, 2001), while hexanol production was not affected in 'Fuji'. Total volatiles were inhibited in 'McIntosh' and 'Delicious' (Rupasinghe et al., 2000).

Application	Dose g i.ha^{-1}	Days after application					App. Mean
		0	7	14	21	28	
Control	-	607.65 i	642.10g	677.0e	707.35b	725.25a	671.87AA
Harvista**	50	607.65 i	642.78g	676.70e	707.55b	725.38a	672.01A AAA
Harvista	100	607.65 i	642.45g	676.88e	707.58b	725.32a	671.98A
Harvista	150	607.65 i	625.48h	657.95f	683.98d	701.07c	655.23B
Harvista	200	607.65 i	625.17h	657.50f	683.65d	701.10c	655.02B
Harvista OF	100	607.65 i	626.63h	660.53f	685.08d	704.18bc	656.81B
Days Mean		607.65E E	634.10D	667.76C	695.86B	713.72A	3.4416
lsd (0.05)		3.1418					
LSD (App*Days)		4.9253					

Table 14: The effects of different treatments on phenolic compounds (GAE mg 100g-1) of 'Cripps pink' apples at four sampling dates during 1st year. **AF 701.

Application	Dose g ai.ha^{-1}	Days after application					App. Mean
		0	7	14	21	28	
Control	-	618.95j	647.30g	692.73 d	724.00 b	743.03 a	685.20 A
Harvista**	50	618.95j	647.73g	693.17 d	724.38 b	743.38 a	685.52 A
Harvista	100	618.95j	647.00g	692.60 d	723.60 b	742.60 a	684.95 A
Harvista	150	618.95j	631.62i	658.40 f	671.60 e	713.78 c	658.87 B
Harvista	200	618.95j	629.65i	657.68 f	671.58 e	713.50 c	658.27 B
Harvista OF	100	618.95j	635.15h	658.98 f	672.80 e	714.70 c	660.12 B
Days Mean		618.95 E	639.74 D	675.59 C	697.99 B	728.50 A	5.8424
lsd (0.05)		5.3333					5.8424
LSD (App*Days)		2.2196					

Table 15: The effects of different treatments on phenolic compounds (GAE mg 100g-1) of 'Cripps pink' apples at four sampling dates during 2nd year. *AF 701.

Ethylene emission

According to the results of both years, ethylene production increased during fruit storage at shelf life conditions. Untreated apples emitted most ethylene. Apple treated with Harvista- at the rate of 50 g a.i. ha^{-1} did not differ much from untreated emission values. Fruits treated with Harvista at the rates of 150 g a.i. ha^{-1} and 200 g a.i. ha^{-1} emitted a much lower quantity of ethylene (Table 8) followed by the rate of 100 g a.i. ha^{-1} and Harvista with Conosol. The similar effects of 1-MCP were fixed on many apple cultivars (Fan and Mattheis, 1999a, b). 1-MCP lowered ethylene production in strawberry (Jiang et al., 2001), slowed ethylene production in apricots and plums (Dong et al., 2002), and 'Red Delicious' and 'Granny Smith' apples (Fan et al., 1999a, b). When fruit were treated with 1-MCP the ethylene climacteric was delayed by 6 days and reduced in magnitude over 50% in avocado (Jeong et al., 2002) treated with 1-MCP.

Sampling days	*Application Harvista (g ai/ha) Dose*						*Days Mean*
	Control	*AF-701 50*	*AF-701 100*	*AF-701 150*	*AF-701 200*	*0.8 OF 100*	
0	0.80 u	0.80 u	0.80 u	0.80 u	0.80 u	0.80 u	0.80 F
7+7*	12.95 n	12.95n	11.53 o	1.63 u	1.58 u	11.30 o	8.65 E
7+14*	37.88 l	38.28l	26.95m	2.83 t	2.95 t	26.75m	22.60D
14+7*	57.10 j	57.20j	41.28 k	3.10 t	3.08 t	41.23 k	33.83C
14+14*	78.53de	78.35e	58.00 j	4.53 s	4.55 s	57.73 j	46.95B
21+7*	74.73 f	74.70f	61.90 i	5.23 s	5.00 s	61.48 i	47.17B
21+14*	82.68 c	82.38c	71.83 h	7.10 r	7.08 r	71.38 h	53.74B
28+7*	79.23de	79.35d	73.60 g	7.50qr	7.75pqr	73.03 g	53.41B
28+14*	99.15 a	98.98a	86.43 b	8.28pq	8.60 p	85.95 b	64.56A
App. mean	58.11A	58.1 A	48.03B	4.62 C	4.53 C	47.74B	
LSD (0.05)	7.7482						0.9978
LSD (App*Days)	6.3263						

Table 16: The effects of different treatments on ethylene emission (ppm) of 'Cripps pink' apples at four sampling dates during 1st year. *Shelf life under shelf life conditions.

Sampling days	*Application Harvista (g ai/ha) Dose*						*Days Mean*
	Control	*AF-701 50*	*AF-701 100*	*AF-701 150*	*AF-701 200*	*0.8 OF 100*	
0	0.85 w	0.85 w	0.85 w	0.85 w	0.85 w	0.85 w	0.85 F
7+7*	13.48m	13.55m	11.75n	1.73 v	1.68 v	11.50n	8.95 E
7+14*	38.63 k	38.15 k	27.55 l	3.33 u	3.45ut	27.38 l	23.08D
14+7*	59.45 h	59.38 h	41.63 j	3.98 t	3.73 ut	41.75 j	34.98C
14+14*	81.25 d	80.75 d	58.65 i	5.25 s	5.33 s	58.30 i	48.25B
21+7*	75.53 e	75.78 e	63.18g	6.15 r	5.98 r	62.85g	48.24B
21+14*	84.60 c	84.23 c	72.43 f	7.85 q	8.03 q	72.15 f	54.88B
28+7*	81.05 d	81.23 d	75.70e	8.38pq	8.57 p	75.33e	55.04B
28+14*	99.38 a	99.85 a	88.10b	9.50 o	9.70 o	87.65b	65.70A
App. mean	59.29A	59.37A	48.87B	5.22 C	5.26 C	48.64B	
LSD (0.05)	7.8069						0.5385
LSD (0.05)	6.3743						

Table 17: The effects of different treatments on ethylene emission (ppm) of 'Cripps pink' apples at four sampling dates during 2nd year. *Shelf life under shelf life conditions.

Conclusions

The results of 2 years showed that, Harvista applications reduced fruit drop on 'Pink Lady Cripps Pink' apples. Besides, apples treated with Harvista at the rates of 150 and 200 g a.i. ha^{-1} were firmer than untreated fruits, had minor starch degradation, lower soluble solids content, higher content of malic acid, higher values of color parameter hue, lower total phenolic compounds content and emitted a much lower quantity of ethylene. These two application doses were followed by the rate of 100 g a.i. ha^{-1} with Conosol. However, Harvista at the rates of 50 and 100 g a.i. ha^{-1} had no effects on fruit quality parameters compared to untreated apples. Quality losses may be occurred by different climatic and environmental effects besides the yield of next year may be reduced thus 28 days should not be preferred. Preharvest 1-MCP at the rates of 150 and 200 g a.i. ha^{-1} will be very good alternatives for enlarging the harvest period and fruit quality losses are still very low until 21 days. Practically the rate of 150 g a.i. ha^{-1} should be materialized because of the application cost.

Acknowledgements

The author thanks to Agrofresh Turkey Co Ltd. company for treatment material and Lider Agriculture Co. Ltd.- Canakkale/Turkey for plant material.

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