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The Effects of Glycerin Added Ethephon Treatments on Fruit Characteristics of *Actinidia deliciosa* Cv. Hayward

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Abstract

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This study was conducted at Namýk Kemal University, Tekirdag Agriculture Faculty and Department of Horticulture in Turkey in 2005. Kiwifruits of *Actinidia deliciosa* cv. Hayward harvested at the proper stage of maturity with soluble solids content of 6.9% and fruit firmness of 7 kg were treated by 500 and 1000 ppm ethephon with 0 (control), 1, 3 and 5 percentage of glycerin. Afterwards, kiwifruits which were put into polystren package containers were covered with polyethylene bags stored at 20±0.5^{0}C during 6 day. Some important quality characteristics like kiwifruit firmness, soluble solids, titratable acidity, pH, vitamin c content and sensory evaluation were measured and determined at regular intervals in the course of 6 day.

In order to improve penetration effect of glycerin into kiwifruit tissues, different percentages of glycerin were added into ethephon in this study. In conclusion, 3 and 5% glycerin levels were especially enhanced penetration effectiveness of ethephon at 1000 ppm.

Key words: kiwifruit, climacteric, ethephon, ripening, quality

Introduction

Kiwifruit is a climacteric fruit which exhibits a long and slow period of growth and lasts for approximately 6 months from anthesis until harvest, following a simple sigmoidal trend (Gallego et al., 1997). At the beginning of development**,** fruit is very hard, but firmness reduces slightly in the course of the later stages of development. Once harvested, the initially unripe fruit undergoes dramatic softening.

Many changes occur during postharvest ripening of fruit to improve fruit edibility and seed dispersal. Key changes involve modification of the cell wall, conversion of starch and organic acids to sugars, and production of flavor volatiles, re-

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sulting in the unique blend characteristic of any one fruit. Ripening is also often associated with a transient respiratory rise, termed the climacteric, and many postharvest studies have focused on metabolic changes occurring during the climacteric (MacRae et al., 1992)

Kiwifruit is a climacteric frit that is extremely responsive to low concentrations of ethylene, even at low temperatures (Mitchell, 1990).

Unripe kiwifruits can be brought to edible maturity level under room temperature conditions using ethylene treatments (i.e. dipping into solution and fumigation) (Kok and Celik, 2004; Crisosta, 1999) or carbide treatments (Bal and Kok, 2006). The rate of kiwifruit softening is affected by time, temperature, exogenous ethylene levels and fruit maturity level (MacRae et al., 1989; Ritenour et al., 1999).

The utilization of ethylene as an agricultural tool has undergone considerable evolution during its nearly three quarters of a century of use. For this aim, different ethylene sources are used and ethephon (2-chloroethane phosphonic acid) is commercially available under various trade names, such as ethrel.

During the applications of liquid forms of different hormones like ethephon or other chemicals onto surfaces of different plant parts, some surfactants such as liquids of tween group have been used successfully to enhance penetration of externally applied some substances into tissues of plants.

The most well-known physicochemical property of surfactants is their interfacial activity the surfactant molecules migrate to the interface(s) when placed in solution. The alignment of surfactant molecules at the interfaces is a reflection of their tendency to assume the most energetically stable orientation. Surfactants are commonly classified on the basis of the charge or nature of the hydrophilic portion (head) and the flexibility or chemical nature of the hydrophobic portion. Head groups may be anionic, zwitterionic, nonionic, or cationic. The hydrophile-lipophile balance of surfactants determines to a large extent their physical and chemical characteristics (Kamande et al., 2000).

Ben-Tal (1987) examined how ethephon's effect on olive drop could be improved by means of glycerin. By adding of 1% glycerin to the spraying solution, evaporation of the solution and dryness of the sprayed tissue were postponed. The amount of ethephon which penetrated into the plant tissue was gone up by 345%.

The present study was undertaken to assess the effects of different glycerin percentages which was added into different ethephon doses on ethephon's penetration into fruit tissue of *Actinidia deliciosa* cv. Hayward.

Materials and Methods

Kiwifruits (*Actinidia deliciosa* cv. Hayward) were obtained from experimental kiwifruit plantation of Department of Horticulture, Tekirdag Agricultural Faculty of Namik Kemal University in Turkey in 2005.

In this study, 500 and 1000 ppm concentrations of ethephon ($C_2H_6ClO_3P$, 48%) were used to enhance kiwifruit harvest during a very unripe stage (soluble solids content: 6.9% and kiwifruit firmness: 7 kg). In order to obtain well ethephon penetration into kiwifruit tissues and preventing ethephon evaporation, different percentages (0, 1, 3 and 5%) of glycerin ($C_3H_8O_3$) was added into ethephon solution (25 ± 1^0C, 5 min for exposure time) (Roberts and

Tucker 1985). After glycerin added ethephon treatment, polystren package containers were put into polyethylene bags with 10.5µ thickness. Then, they were tightly closed and stored at 20±0.5^{0}C throughout 6 day. After treatment, samples of kiwifruit were taken at 1, 2, 3, 4, 5, and 6th day at progressive stages of softness for examining of their characteristics.

After glycerin added ethephon treatments, some criteria such as kiwifruit firmness (kg), soluble solids (%) titratable acidity (mg/100 ml), pH, vitamin c content (mg/100 g) and sensory evaluation were daily analyzed and measured during the 6 day.

In the research, it was utilized from 144 polystren package containers containing 8 kiwifruits. Each treatment consisted of 3 replicates of 3 polystren package containers and all data were subjected to statistical analyses as completely randomized blocks with 3 factorial designs (Turan 1995). Variance analysis was performed by using TARIST software.

Table 1
Kiwifruit firmness, kg

Ethephon dose		Time						Ethephon effect
		1st day	2nd day	3rd day	4th day	5th day	6th day	
500 ppm		6.47	5.53	4.81	3.56	2.45	1.67	4.08
1000 ppm		6.32	5.62	4.72	3.38	2.37	1.6	4.00
Glycerin dose		Glycerin x time interaction						Glycerin effect
		1st day	2nd day	3rd day	4th day	5th day	6th day	
Control		6.61	6.03	5.11	4.02	2.78	1.87	4.40c
1%		6.49	5.48	4.77	3.45	2.45	1.66	4.05b
3%		6.23	5.42	4.6	3.15	2.21	1.55	3.86a
5%		6.23	5.36	4.58	3.26	2.2	1.46	3.85a
Ethephon dose	Glycerin dose	Ethephon x glycerin x time interaction						Ethephon x glycerin interaction
		1st day	2nd day	3rd day	4th day	5th day	6th day	
500 ppm	Control	6.62	6.09	5.14	4.16	2.87	1.87	4.45
	1%	6.56	5.37	4.87	3.61	2.5	1.75	4.11
	3%	6.42	5.38	4.64	3.18	2.25	1.57	3.91
	5%	6.27	5.29	4.61	3.29	2.19	1.5	3.86
1000 ppm	Control	6.27	5.97	5.09	3.88	2.69	1.87	4.35
	1%	6.6	5.59	4.67	3.29	2.4	1.58	3.99
	3%	6.43	5.47	4.56	3.11	2.17	1.53	3.81
	5%	6.04	5.44	4.55	3.23	2.22	1.42	3.84
Time effect		6.39f	5.57e	4.76d	3.47c	2.41b	1.63a	

$^{**}P$ <0.01 $LSD_{glycerin}$: 0.167 LSD_{time}: 0.205

Results and Discussion

Firmness is an important quality attribute in kiwifruit. During ripening, softening occurs, thus fruit firmness decreases reaching values of 0.9-1.4 kg. When fruit reaches 0.9-1.4 kg it is considered ripe or "ready to eat." This is the level that kiwifruit will achieve its best eating characteristics (Anonymous, 2006). Among the averages of glycerin effect for kiwifruit firmness, the highest value was obtained from control (4.40 kg) and the lowest values were 3.86 and 3.85 kg for 3 and 5% glycerin levels (Table 1).

Concerning averages of time effect, the highest value was 6.39 kg by 1st day and the lowest value was 1.63 kg by 6th day.

In spite of the fact that physiologically mature and must be left to ripen (conversion of the stored starch into soluble solids) before consumption, kiwifruit are harvested unripe (McGlone et al., 2002).

Our findings from ethephon treatments showed that soluble solids content in kiwi-

Table 2
Soluble solids of kiwifruit juice, %

Ethephon dose		Time						Ethephon effect
		1st day	2nd day	3rd day	4th day	5th day	6th day	
500 ppm		7.42	8.26	9.78	11.01	12.65	14.2	10.55 b
1000 ppm		7.57	8.78	10.33	11.43	13.43	14.64	11.03 a
Glycerin dose		Glycerin x time interaction						Glycerin effect
		1st day	2nd day	3rd day	4th day	5th day	6th day	
Control		7.07	7.48	8.7	10.07	12.07	13.55	9.82 c
1%		7.15	8.58	9.72	11.33	13.00	14.35	10.69 b
3%		7.9	9.00	11.00	11.83	13.65	14.92	11.38 a
5%		7.85	9.00	10.82	11.63	13.45	14.87	11.27 a
Ethephon dose	Glycerin dose	Ethephon x glycerin x time interaction						Ethephon x glycerin interaction
		1st day	2nd day	3rd day	4th day	5th day	6th day	
500 ppm	Control	7.00	7.43	8.53	9.87	11.77	13.43	9.67
	1%	7.07	8.03	9.17	11.1	12.63	14.27	10.38
	3%	7.8	8.63	10.77	11.6	13.27	14.5	11.1
	5%	7.8	8.93	10.67	11.47	12.93	14.6	11.07
1000 ppm	Control	7.13	7.53	8.87	10.27	12.37	13.67	9.97
	1%	7.23	9.13	10.27	11.57	13.37	14.43	11.00
	3%	8.00	9.37	11.23	12.07	14.03	15.33	11.67
	5%	7.9	9.07	10.97	11.8	13.97	15.13	11.47
Time effect		7.49 f	8.52 e	10.06 d	11.22 c	13.04 b	14.42 a	

**P<0.01 $LSD_{ethephon}$: 0.193 $LSD_{glycerin}$: 0273 LSD_{time}: 0.334

fruit also increased depending on ethephon doses when compared to results of other similar studies (Singh and Janes, 2001; Kok and Celik, 2004). Between the averages of ethephon effect, while the highest value was 11.03 % for 1000 ppm; the lowest value became 10.55 % for 500 ppm in our study (Table 2).

From the viewpoint of glycerin effect, the highest values were respectively obtained from 3 and 5% glycerin levels (as 11.38 and 11.27 %) and the lowest value was 9.82 % for control.

When the averages of time effect were examined, it would be seen that the highest value 14.42 % by 6th day and the lowest value was 7.49 % by 1st day.

During the ripening phase of most fruits, acidity decreases and pH increases, generally. Matsumoto et al. (1983) also declare that organic acids are metabolized by the fruit during ripening and storage, resulting in a decrease in total acidity and a rise in pH.

Titratable acidity can play an important role in consumer preferences or accep-

Table 3
Titratable acidity of kiwifruit juice, mg/100ml

Ethephon dose		Time						Ethephon effect
		1st day	2nd day	3rd day	4th day	5th day	6th day	
500 ppm		1.81a	1.65bc	1.72b	1.67b	1.57d	1.58cd	1.67
1000 ppm		1.82a	1.70b	1.68b	1.53d	1.59cd	1.59cd	1.65
Glycerin dose		Glycerin x time interaction						Glycerin effect
		1st day	2nd day	3rd day	4th day	5th day	6th day	
Control		1.86	1.69	1.76	1.68	1.59	1.63	1.70a
1%		1.86	1.63	1.69	1.58	1.58	1.6	1.66ab
3%		1.76	1.72	1.67	1.57	1.55	1.55	1.64b
5%		1.77	1.65	1.67	1.57	1.58	1.56	1.63b
Ethephon dose	Glycerin dose	Ethephon x glycerin x time interaction						Ethephon x glycerin interaction
		1st day	2nd day	3rd day	4th day	5th day	6th day	
500 ppm	Control	1.88	1.65	1.82	1.71	1.61	1.64	1.72
	1%	1.85	1.63	1.72	1.65	1.54	1.59	1.66
	3%	1.74	1.71	1.68	1.66	1.54	1.54	1.65
	5%	1.76	1.61	1.65	1.65	1.57	1.56	1.63
1000 ppm	Control	1.83	1.73	1.69	1.64	1.58	1.63	1.68
	1%	1.88	1.64	1.66	1.52	1.62	1.61	1.65
	3%	1.77	1.73	1.66	1.48	1.55	1.56	1.63
	5%	1.79	1.69	1.69	1.49	1.6	1.55	1.63
Time effect		1.81a	1.70b	1.67b	1.60c	1.59c	1.58c	

**P<0.01 $LSD_{glycerin}$: 0.043 LSD_{time}: 0.053 $LSD_{ethephon\ x\ time}$: 7.680

tance (Crisosto et al., 1997). Depending on our treatment doses, titratable acidity also reduced with rising maturity levels of kiwifruit similar to findings of Crisosto and Crisosto (2001), Tombesi et al. (1993)

Table 3 show titratable acidity in kiwifruit juice. According to statistical analyses about ethephon effect, the highest value was 1.67 mg/100ml for 500 ppm and the lowest value was 1.65 mg/100ml for 1000 ppm.

As regards glycerin effect, the highest value was obtained from control (1.70 mg/100ml) and the lowest values were respectively 1.64 and 1.63 mg/100ml for 3 and 5% glycerin levels.

With respect to time effect, averages exhibited differences and while the highest value was 1.81 mg/100ml by 1st day; the lowest values became 1.60, 1.59 and 1.58 mg/100ml by 4th, 5th and 6th day, respectively.

Table 4
pH of kiwifruit juice

Ethephon dose	Time						Ethephon effect
	1st day	2nd day	3rd day	4th day	5th day	6th day	
500 ppm	3.28g	3.29fg	3.33de	3.29g	3.73bc	3.35c	3.32b
1000 ppm	3.32ef	3.32ef	3.35cd	3.40a	3.38bc	3.39ab	3.36a
Glycerin dose	**Glycerin x time interaction**						**Glycerin effect**
	1st day	2nd day	3rd day	4th day	5th day	6th day	
Control	3.35bc	3.3ef	3.38ab	3.35bc	3.35bcd	3.36ab	3.35
1%	3.27f	3.32cde	3.36ab	3.32cde	3.38ab	3.39a	3.34
3%	3.30ef	3.31de	3.31de	3.36ab	3.38ab	3.38ab	3.34
5%	3.27f	3.29ef	3.30ef	3.36ab	3.39a	3.37ab	3.33
Ethephon dose	**Glycerin dose**	**Ethephon x glycerin x time interaction**						**Ethephon x glycerin interaction**
		1st day	2nd day	3rd day	4th day	5th day	6th day	
500 ppm	Control	3.39b-f	3.29n-r	3.34g-n	3.25q-t	3.32l-q	3.32l-q	3.32
	1%	3.23f	3.29o-r	3.36d-k	3.27p-t	3.40a-d	3.38b-g	3.32
	3%	3.25rst	3.28o-s	3.30l-q	3.31j-p	3.38b-g	3.38b-g	3.32
	5%	3.23st	3.30l-q	3.30l-q	3.32l-q	3.38b-g	3.35e-l	3.31
1000 ppm	Control	3.31k-p	3.30l-q	3.41ab	3.48a	3.37b-h	3.39b-f	3.37
	1%	3.31k-p	3.34f-n	3.37b-?	3.36c-j	3.35e-l	3.40a-d	3.35
	3%	3.35e-l	3.34f-n	3.32l-p	3.41abc	3.38b-g	3.38b-g	3.36
	5%	3.30l-q	3.28o-s	3.30l-q	3.39b-f	3.39b-f	3.40a-d	3.35
Time effect		3.30c	3.30c	3.34b	3.35b	3.37a	3.37a	

**P<0.01 $LSD_{ethephon}$: 0.010 LSD_{time}: 0.018 $LSD_{ethephon\ x\ time}$: 2.563

$LSD_{glycerin\ x\ time}$: 3.625 $LSD_{ethephon\ x\ glycerin\ x\ time}$: 5.126

pH ranges in most fruits vary in 3 to 5 and its values increase with reduction in acidity during ripening due to the utilization of organic acids during respiration or their conversation to sugars (Barret et al. 2005).

Between averages of ethephon effect for pH of kiwifruit juice showed in Table 4, higher value was obtained from 1000 ppm (3.36) than 500 ppm (3.32).

As far as the time effect was concerned, the highest value was 3.37 for 5th and 6th day and the lowest one was 3.30 for 1st and 2nd day.

The highest value of ethephon x time interaction was obtained from 1000 ppm (3.40) by 4th day and the lowest value was obtained from 500 ppm (3.28) by 1st day.

From the glycerin x time interaction stand point, the highest value was 3.39 for 5% glycerin by 5th day and the lowest values were 3.27 for 1 and 5% glycerin levels by 1st day.

Table 5
Vitamin c content of kiwifruit, mg/100 g

Ethephon dose		Time						Ethephon effect
		1st day	2nd day	3rd day	4th day	5th day	6th day	
500 ppm		125.03ab	125.33ab	124.45b	122.17c	115.87e	109.12g	120.33
1000 ppm		126.43a	126.57a	123.94b	120.05d	112.86f	106.41h	119.38
Glycerin dose		Glycerin x time interaction						Glycerin effect
		1st day	2nd day	3rd day	4th day	5th day	6th day	
Control		127.31	127.6	126.13	123.35	116.01	110.29	121.78
0.01		125.69	125.25	123.64	120.71	112.64	107.95	119.31
0.03		124.81	125.55	123.51	120.27	115.13	107.36	119.44
0.05		125.11	125.4	123.49	120.12	113.67	105.45	118.87
Ethephon dose	Glycerin dose	Ethephon x glycerin x time interaction						Ethephon x glycerin interaction
		1st day	2nd day	3rd day	4th day	5th day	6th day	
500 ppm	Control	127.01	127.31	127.01	123.49	117.63	113.23	122.61
	0.01	124.96	124.08	123.2	122.03	114.69	109.71	119.78
	0.03	124.37	124.37	122.91	120.85	116.16	107.65	119.39
	0.05	123.79	125.55	124.67	122.32	114.99	105.89	119.53
1000 ppm	Control	127.6	127.89	125.25	123.2	114.4	107.36	120.95
	0.01	126.43	126.43	124.08	119.39	110.59	106.19	118.85
	0.03	125.25	126.72	124.11	119.68	114.11	107.07	119.49
	0.05	126.43	125.25	122.32	117.92	112.35	105.01	118.21
Time effect		125.73a	125.95a	124.19b	121.11c	114.36d	107.76e	

**P<0.01 $LSD_{glycerin:}$ 0.997 $LSD_{ethephon}$: 0.705 LSD_{time}: 1.221
$LSD_{ethephon\ x\ time}$: 1.729

When ethephon x glycerin x time interaction was examined, it would be seen that the highest value was 3.48 for control of 1000 ppm by 4th day and the lowest value was 3.22 for 500 ppm by 1st day.

Kiwifruit are known for their high vitamin c content, which is at least twice as high as that found in oranges (Ferguson and Ferguson, 2003; Strik, 2005). Ben-Aire (1981) informs that concentrations of volatile compounds that are associated with the typical flavor of a ripe fruit also increase and vitamin c content decreases during kiwifruit ripening. Our results of vitamin c content agreed with Ben-Aire (1981) that vitamin c content reduced towards kiwifruit ripening.

When it was given attention to averages of ethephon effect for vitamin c content of kiwifruit juice showed in Table 5, it would be seen that the highest value is 120.33 mg/100 g for 500 ppm and the low-

Table 6
Sensory evaluation for kiwifruit

Ethephon dose		Time						Ethephon effect
		1st day	2nd day	3rd day	4th day	5th day	6th day	
500 ppm		1.02	1.68	2.22	2.65	3.33	4.05	2.49b
1000 ppm		1.02	1.72	2.45	2.82	3.43	4.3	2.62a
Glycerin dose		Glycerin x time interaction						Glycerin effect
		1st day	2nd day	3rd day	4th day	5th day	6th day	
Control		1.00j	1.30i	2.03h	2.43g	3.07de	3.9b	2.29c
1%		1.00j	1.50i	2.30g	2.77f	3.17d	4.07b	2.47b
3%		1.03j	2.00h	2.50g	2.87ef	3.63c	4.40a	2.74a
5%		1.03j	2.00h	2.50g	2.87ef	3.67c	4.33a	2.73a
Ethephon dose	Glycerin dose	Ethephon x glycerin x time interaction						Ethephon x glycerin interaction
		1st day	2nd day	3rd day	4th day	5th day	6th day	
500 ppm	Control	1.00	1.33	1.93	2.4	3.00	3.8	2.24
	1%	1.00	1.47	2.27	2.67	3.13	4.00	2.42
	3%	1.00	1.93	2.33	2.73	3.6	4.2	2.63
	5%	1.07	2.00	2.33	2.8	3.6	4.2	2.67
1000 ppm	Control	1.00	1.27	2.13	2.47	3.13	4.00	2.33
	1%	1.00	1.53	2.33	2.87	3.2	4.13	2.51
	3%	1.07	2.07	2.67	3.00	3.67	4.6	2.84
	5%	1.00	2.00	2.67	2.93	3.73	4.48	2.8
Time effect		1.02f	1.70e	2.33d	2.73c	3.38b	4.16a	

**P<0.01 $LSD_{glycerin}$: 0.090 LSD_{time}: 0.111 $LSD_{glycerin\ x\ time}$: 0.22
$LSD_{ethephon}$: 0.064

est value is 119.38 mg/100 g for 1000 ppm.

On the other hand, as to average of time effect; the highest values were respectively 125.95 and 125.73 mg/100 g for 2nd and 1st day and the lowest value was 107.76 mg/100 g for 6th day.

Consumer preference for kiwifruit is determined primarily by the sugar–acid balance with fruit firmness and fruit volatile content causing a large moderating effect (Jaeger et al., 2003).

After ethephon treatment, higher scores in sensory evaluation were obtained at the end of our study. Concerning glycerin x time interaction, the highest values were 4.40 and 4.33 for 3 and 5% glycerin levels by 6th day and the lowest values were 1.00 for control and 1% glycerin levels by 1st day (Table 6).

As for ethephon effect, the highest value was obtained from 1000 ppm (2.62) than 500 ppm (2.49).

The highest values of glycerin effect were respectively 2.74 and 2.73 for 3 and 5% glycerin levels.

Regarding time effect, while the highest value was 4.16 for 6th day; the lowest one was obtained from 1st day (1.02).

Conclusions

The results of present study showed that 1000 ppm ethephon with glycerin had remarkable role on ripening and improving quality characteristics of kiwifruit. 3 and 5% of glycerin were especially found to be effective on penetration of ethephon into kiwifruit tissues.

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