RESEARCH ARTICLE

Thinning with NAA, NAD, ethephon, urea and by hand to improve fruit quality of 'Gerdi' apricot

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ABSTRACT

This research was conducted to study the effects of chemical and hand thinning on fruit quality of 'Gerdi' apricot. In the first year, three weeks after full bloom (AFB) branches of mature trees were sprayed with naphthalene acetic acid (NAA) at 10, 20, and 40 mg L^{-1}, naphthalene acetamide (NAD) at 20, 40, and 80 mg L^{-1}, ethephon at 50, 100 and 200 mg L^{-1}, or urea at 0.2, 0.4, and 0.6%. In next year, hand thinning was performed as a separate experiment and leaf to fruit ratio (LFR) was adjusted to 10:1, 20:1 or 30:1 at pit-hardening stage of fruit development. In both years, NAA at 40 mg L^{-1}, NAD at 80 mg L^{-1} and all concentrations of ethephon significantly increased fruit drop. All concentrations of urea significantly increased fruit drop in 2006, but only the two lower concentrations were effective in 2007. NAA at 20 and 40 mg L^{-1}, and NAD at 40 and 80 mg L^{-1} increased fruit weight in 2006, but only the highest concentration of NAD was effective in 2007, while urea was effective at all concentrations in both years. Ethephon effect on fruit weight was not significant at all. Hand thinning consistently increased fruit weight, but length and diameter were increased only at a leaf to fruit ratio of 30:1. Hand thinning also increased total soluble solids (TSS), total soluble solids to total acidity ratio (TSS/TA), pit weight and flesh to pit ratio.

Key words: chemical thinning, fruit characteristics, *Prunus armeniaca*, total soluble solids.

INTRODUCTION

Fruit thinning has been used for many years. Heavy crop load can result in fruits with small size and poor quality, breakage of limbs, exhaustion of tree reserves and reduced cold hardiness (Dennis, 2000). Apricot trees are often affected by spring frost. So, fruit thinning on apricot trees must to be done on time (Bolat and Karlidağ, 1999) and as reported earlier (Surányi, 1982), best results gained when fruit thinning was applied after the danger of spring frost was averted. In blossoming period, favorable weather conditions for insect activity, pollen germination and fertilization can lead to excessive fruit set. This is a special problem with self-fertile apricot cultivars where pollen vectors are require to move the pollen only short distances within individual blossoms (Webster and Spencer, 2000). Fruit thinning can be done by hand, mechanical or chemical methods. In comparison with other methods, hand thinning is more expensive and time consuming one (Ryugo, 1988). Leaf to fruit ratio, total number of fruit per tree, fruit size and the distance between fruits are four main indexes to estimate thinning amount (Mitra et al., 1991). Maximum two fruits are kept on each spur (Mitra et al., 1991). Generally, stone fruits ripening take place during 75-90 days after full bloom (AFB). So, for having good size fruits, leaf to fruit ratio (LFR) must to be adjusted seven weeks after full bloom (AFB) (Ryugo, 1988).

Surányi (1986) reported that 25-75 mg l^{-1} of NAA for 'Hungarian Best' and 50-100 mg l^{-1} of NAA for 'Rose

Apricot', were the best concentrations, and improved fruit size and quality. Thinning of peaches and nectarines with different concentrations of urea at closed pink-stage, full bloom and the early fruitlet stage showed that fruit set reduced significantly, fruitlet weight increased until two weeks after application, and final fruit weight of all treated cultivars increased (Zilkah et al., 1988).

The potassium salt of NAA has been tested as a thinner on the apricot cultivar 'Magyar Kauszi' in Hungary (Surányi, 1978), where it was less effective than the amide of NAA (NAD). In contrast, 'Biborkajszi' cultivar was more sensitive to thinning with potassium salt of NAA than to the NAD. Son (2004) applied NAA at 10, 20, and 30 mg l^{-1} on 'Priana' and 'Beliana' apricot and found that NAA significantly increased fruit weight. Surányi (1978) reported that ethephon was less effective chemical thinner for apricot, but 200 mg l^{-1} ethephon on French prune resulted in optimum thinning, reducing fruit set by 50% and increasing final fruit size and soluble solids in harvested fruits (Martin et al., 1975).

'Gerdi' apricot commonly grown in Meshkan, Neyriz, Fars province in Iran. Fruit set of this cultivar is very high in most years. Therefore, fruit size and other quality properties decrease and breakage of limbs occure before harvest. The purpose of this study was to evaluate the effects of NAA, NAD, ethephon, and urea and hand thinning on thinning rate and some of the fruit characteristics in 'Gerdi' apricot.

MATERIALS AND METHODES

The experiments were conducted in 2006 and 2007 on 10-year-old trees of *Prunus armeniaca* L. cv. 'Gerdi' spaced at 6×6 m in the commercial orchard in Neyriz, Fars province in Iran. The design of the experiment was a factorial in a complete randomized design, with four replicates in each treatment. Three weeks AFB (11 April 2006 and 12 April 2007) aqueous solutions of naphthalene acetic acid (NAA) at 10, 20, and 40 mg l^{-1}; naphthalene acetamide (NAD) at 20, 40, and 80 mg l^{-1}; ethephon at 50, 100, and 200 mg l^{-1} or urea at 0.2, 0.4, and 0.6% were applied on four branches per tree to the point of run-off. Control branches were sprayed with distilled water. Also, at the beginning of pit hardening (26 April 2007), leaf to fruit ratios adjusted to 0, 10:1, 20:1, and 30:1 by hand thinning. In order to evaluate the percent of fruit drop, total numbers of fruitlets per branches were recorded before treatment, two weeks after treatment and at harvest time.

The mature fruits were harvested at firm-ripe stage at the end of May and fruit characteristics related to the size such as fruit weight (g), diameter (cm), and length (cm) were measured on 10 fruit samples. Total soluble solids (TSS) content was measured using a digital refractometer (Atago, Tokyo, Japan). Total acidity (TA) was determined by titration with 0.2 N NaOH. Flesh weight (g), nut weight (g), and flesh to nut ratio were also determined. All data were subjected to statistical analysis using SAS statistical software and means were compared using DNMRT ($P<0.05$).

RESULTS

Chemical thinning: Thinning treatments were significantly different in their effects on fruit drop (Table 1). In 2006, all concentrations of ethephon increased fruit drop and at harvest time these treatments, NAA at 40 mg l^{-1} and NAD at 80 mg l^{-1} significantly increased fruit drop. In 2007, Ethephon and urea at all concentrations, NAA at 40 mg l^{-1} and NAD at 80 mg l^{-1} significantly increased fruit drop and at harvest time all concentrations of ethephon, NAA at 40 mg l^{-1}, NAD at 80 mg l^{-1} and urea at 0.2 and 0.4% significantly increased fruit drop (Table 1).

Fruit weight increased significantly up to 37.75 g and 44.13 g in 2006 and 2007, respectively. In 2006, NAA at 20 and 40 mg l^{-1} , NAD at 40 and 80 mg l^{-1} and urea at all concentrations and in 2007, NAD at 80 mg l^{-1} and urea at all concentrations significantly increased fruit weight (Table 2). In both years ethephon reduced fruit weight, but the highest concentration was more effective in decreasing fruit weight (Table 2). Also, fruit volume was affected by these treatments. In compare with the control, NAA at 40 mg l^{-1}, NAD and urea at all concentrations significantly increased fruit volume (Table 2).

In 2006, NAD at 80 mg l^{-1} and urea at 0.2 and 0.6% and in 2007, urea at 0.2 and 0.6% significantly increased fruit length (Table 3). In both years, Urea at 0.2% significantly increased fruit diameter (Table 3), NAD at all concentrations decreased total acidity and NAA at 40 mg l^{-1}, NAD at 80 mg l^{-1} and urea at 0.2% significantly increased TSS (Table 4).

Table 1. Effect of chemical thinning on 'Gerdi' apricot fruit thinning at 2 weeks after treatment and at harvest.

Treatment	Fruit drop (%)			
	2 weeks after spray		At harvest	
	2006	2007	2006	2007
Control	44.24^{cd}	43.75^{c}	52.42^{c}	49.94^{c}
Naphthalene acetic acid 10 mg L^{-1}	51.97^{bcd}	49.19^{bc}	63.28^{abc}	60.48^{abc}
Naphthalene acetic acid 20 mg L^{-1}	53.00^{bcd}	59.5^{ab}	62.36^{abc}	59.56^{abc}
Naphthalene acetic acid 40 mg L^{-1}	57.98^{abcd}	61.14^{ab}	76.00^{a}	74.51^{a}
Naphthalene acetamid 20 mg L^{-1}	40.72^{d}	38.03^{c}	55.22^{bc}	52.49^{bc}
Naphthalene acetamid 40 mg L^{-1}	60.93^{abc}	58.39^{ab}	65.83^{abc}	63.79^{abc}
Naphthalene acetamid 80 mg L^{-1}	61.47^{abc}	58.04^{ab}	71.59^{ab}	69.84^{a}
Ethephon 50 mg L^{-1}	67.49^{ab}	65.26^{a}	72.00^{ab}	69.72^{a}
Ethephon 100 mg L^{-1}	71.85^{a}	68.75^{a}	77.13^{a}	74.06^{a}
Ethephon 200 mg L^{-1}	68.06^{ab}	66.43^{a}	75.61^{a}	73.04^{a}
Urea 0.2%	61.41^{abc}	59.58^{ab}	67.24^{abc}	65.61^{ab}
Urea 0.4%	59.93^{abc}	57.10^{ab}	67.33^{abc}	66.01^{ab}
Urea 0.6%	59.41^{abc}	57.00^{ab}	66.05^{abc}	64.04^{abc}

Means in each column with the similar superscript letters are not significantly different at $P = 0.05$ using DNMRT.

Table 2. Effect of chemical thinning on 'Gerdi' apricot fruit weight and volume.

Treatment	Weight (g)		Volume (cm^3)	
	2006	2007	2006	2007
Control	26.22^{e}	26.23^{def}	24.96^{e}	24.94^{de}
Naphthalene acetic acid 10 mg L^{-1}	28.23^{cde}	28.02^{cdef}	27.63^{de}	27.63^{cd}
Naphthalene acetic acid 20 mg L^{-1}	31.70^{abcd}	30.85^{bcde}	30.75^{bcde}	30.75^{bcd}
Naphthalene acetic acid 40 mg L^{-1}	33.98^{abcd}	32.60^{bcd}	33.88^{abcd}	33.25^{bc}
Naphthalene acetamid 20 mg L^{-1}	31.68^{abcde}	31.40^{bcde}	30.17^{bcde}	32.17^{bcd}
Naphthalene acetamid 40 mg L^{-1}	33.55^{abc}	32.27^{bcde}	33.50^{abcd}	34.67^{bc}
Naphthalene acetamid 80 mg L^{-1}	35.62^{ab}	34.85^{bc}	35.25^{abc}	34.75^{bc}
Ethephon 50 mg L^{-1}	28.87^{bcde}	26.18d^{ef}	28.87^{cde}	25^{ed}
Ethephon 100 mg L^{-1}	28.47^{bcde}	24.18^{ef}	28.47^{de}	25^{ed}
Ethephon 200 mg L^{-1}	27.46^{ed}	21.83^{f}	27.47^{de}	18.82^{e}
Urea 0.2%	37.75^{a}	44.13^{a}	37.50^{a}	42.5^{a}
Urea 0.4%	34.00^{abcd}	35.48^{bc}	33.75^{abcd}	36.67^{ab}
Urea 0.6%	35.88^{ab}	38.70^{ab}	35.41^{ab}	38.13^{ab}

Means in each column with the similar superscript letters are not significantly different at $P = 0.05$ using DNMRT.

Table 3. Effect of chemical thinning on 'Gerdi' apricot fruit length and diameter in 2006 and 2007.

Treatment	Length (cm)		Diameter (cm)	
	2006	2007	2006	2007
Control	3.81^{d}	3.97^{cde}	3.55^{bc}	3.62^{bc}
Naphthalene acetic acid 10 mg L^{-1}	4.00^{bcd}	3.98^{cde}	3.51^{bc}	3.89^{bc}
Naphthalene acetic acid 20 mg L^{-1}	4.13^{abcd}	4.07^{cde}	3.63^{bc}	3.60^{bc}
Naphthalene acetic acid 40 mg L^{-1}	4.19^{abcd}	4.16^{bcd}	3.74^{bc}	3.71^{bc}
Naphthalene acetamid 20 mg L^{-1}	4.03^{abcd}	4.01^{cde}	3.55^{bc}	3.53^{bc}
Naphthalene acetamid 40 mg L^{-1}	4.19^{abcd}	4.20^{abc}	3.61^{bc}	3.59^{bc}
Naphthalene acetamid 80 mg L^{-1}	4.35^{abc}	4.33^{abc}	3.75^{bc}	3.73^{bc}
Ethephon 50 mg L^{-1}	4.00^{bcd}	3.95^{cde}	3.58^{bc}	3.54^{bc}
Ethephon 100 mg L^{-1}	3.94^{cd}	3.754^{e}	3.48^{bc}	3.31^{c}
Ethephon 200 mg L^{-1}	3.82^{d}	3.76d^{e}	3.34^{c}	3.30^{c}
Urea 0.2%	4.45^{a}	4.60^{a}	4.15^{a}	4.23^{a}
Urea 0.4%	4.21^{abcd}	4.30^{abc}	3.80^{abc}	3.88^{ab}
Urea 0.6%	4.41^{ab}	4.55^{ab}	3.79^{ab}	3.86^{ab}

Means in each column with the similar superscript letters are not significantly different at $P = 0.05$ using DNMRT.

Table 4. Effect of chemical thinning on 'Gerdi' apricot fruit TA, TSS and TSS to TA ratio in 2006 and 2007.

Treatment	TA (mg/100 mL)		TSS (%)		TSS to TA ratio	
	2006	2007	2006	2007	2006	2007
Control	1.58^{ab}	1.62^{abc}	6.28^{b}	6.28^{b}	3.99^{d}	3.81^{d}
Naphthalene acetic acid 10 mg L^{-1}	1.64^{ab}	1.70^{ab}	6.55^{ab}	6.63^{ab}	3.99^{d}	3.90^{d}
Naphthalene acetic acid 20 mg L^{-1}	1.65^{ab}	1.73^{a}	6.80^{ab}	6.88^{ab}	4.14^{cd}	3.98^{d}
Naphthalene acetic acid 40 mg L^{-1}	1.74^{a}	1.81^{a}	7.93^{d}	8.00^{a}	4.56^{bcd}	4.44^{bcd}
Naphthalene acetamid 20 mg L^{-1}	1.27^{c}	1.34^{e}	6.93^{ab}	7.00^{ab}	5.45^{abc}	5.25^{abc}
Naphthalene acetamid 40 mg L^{-1}	1.28^{c}	1.34^{e}	6.93^{ab}	3.38^{ab}	5.74^{ab}	5.53^{ab}
Naphthalene acetamid 80 mg L^{-1}	1.33^{c}	1.40^{de}	7.05^{ab}	8.00^{a}	6.05^{a}	5.78^{a}
Ethephon 50 mg L^{-1}	1.55^{b}	1.55^{bcd}	7.38^{ab}	7.50^{ab}	4.48^{bcd}	4.53^{abcd}
Ethephon 100 mg L^{-1}	1.53^{b}	1.53^{cd}	7.05^{ab}	7.13^{ab}	4.64^{bcd}	4.68^{abcd}
Ethephon 200 mg L^{-1}	1.53^{b}	1.53^{cd}	6.93^{ab}	7.00^{ab}	4.85^{abcd}	4.93^{bcd}
Urea 0.2%	1.67^{ab}	1.74^{a}	8.05^{a}	8.13^{a}	4.87^{abcd}	4.71^{a-d}
Urea 0.4%	1.62^{ab}	1.69^{abc}	7.25^{ab}	7.25^{ab}	4.49b^{cd}	4.30^{cd}
Urea 0.6%	1.58^{ab}	1.62^{abc}	7.43^{ab}	7.50^{ab}	4.83^{abcd}	4.54^{bcd}

Means in each column with the similar superscript letters are not significantly different at $P = 0.05$ using DNMRT.

Urea at 0.2% had the highest effect on TSS in 2006 and 2007 (Table 3). Thinning treatments also significantly increased TSS to TA ratio. NAD at all concentrations significantly increased this parameter (Table 4). Nut weight was not affected by treatments (Table 5). NAD at all concentrations in 2006 and 2007 and urea at 0.2 and 0.6% in 2007 significantly increased flesh to nut ratio (Table 5).

Hand thinning: Hand thinning affected fruit size of 'Gerdi' cultivar apricot in both aspects of fruit weight and volume (Table 6). Increasing the thinning intensity by adjusting the LFR to 30:1, significantly increased fruit weight (39.02 g) and fruit volume (39.77 cm^3). Also, fruit length and diameter were significantly increased (Table 6). Control fruits registered the lowest value for this parameter.

Table 5. Effect of chemical thinning on 'Gerdi' apricot fruit nut weight and flesh to nut ratio in 2006 and 2007.

Treatment	Nut weight(g)		flesh to nut ratio	
	2006	2007	2006	2007
Control	2.24^{abc}	2.32^{abcd}	10.78^{c}	10.31^{de}
Naphthalene acetic acid 10 mg L^{-1}	2.22^{abc}	2.27^{abcd}	11.66^{bc}	11.29^{cde}
Naphthalene acetic acid 20 mg L^{-1}	2.28^{abc}	2.35^{abcd}	12.89^{abc}	12.03^{bcde}
Naphthalene acetic acid 40 mg L^{-1}	2.37^{abc}	2.43^{abc}	13.38^{abc}	12.36^{abcde}
Naphthalene acetamid 20 mg L^{-1}	1.96^{c}	2.04^{cd}	15.36^{ab}	14.38^{abc}
Naphthalene acetamid 40 mg L^{-1}	2.04^{bc}	2.11^{cd}	15.67^{ab}	14.55^{abc}
Naphthalene acetamid 80 mg L^{-1}	2.07^{bc}	2.15^{bcd}	16.19^{a}	15.21^{ab}
Ethephon 50 mg L^{-1}	1.98^{c}	2.03^{cd}	13.87^{abc}	11.98^{e}
Ethephon 100 mg L^{-1}	1.95^{c}	2.01^{d}	13.89^{abc}	10.96^{cde}
Ethephon 200 mg L^{-1}	1.96^{c}	2.01^{d}	12.95^{abc}	9.87^{abcde}
Urea 0.2%	2.59^{a}	2.66^{a}	14.00^{abc}	15.85^{a}
Urea 0.4%	2.33^{abc}	2.41^{abcd}	13.64^{abc}	13.75^{abcd}
Urea 0.6%	2.44^{ab}	2.51^{ab}	13.94^{abc}	14.57^{abc}

Means in each column with the similar superscript letters are not significantly different at $P = 0.05$ using DNMRT. Nut= endocarp + seed.

Table 6. Effect of hand thinning at pit hardening stage on 'Gerdi' apricot fruit weight, volume, length and diameter in 2007.

Treatment	Weight (g)	Volume (cm^3)	Length (cm)	Diameter (cm)
Control	29.45[b]	28.67[b]	4.16[b]	3.76[b]
10:1 LFR	35.16[a]	34.76[a]	4.25[ab]	3.84[ab]
20:1 LFR	38.6[a]	37.47[a]	4.35[ab]	3.91[ab]
30:1 LFR	39.02[a]	39.77[a]	4.47[a]	3.99[a]

Means in each column with the similar superscript letters are not significantly different at $P = 0.05$ using DNMRT. LFR: leaf to fruit ratio.

Hand thinning had no significant effect on TA (Table 7), however all of treatments significantly increased TSS (Table 7). In LFR of 20:1 and 30:1, TSS to TA ratio significantly increased (Table 7). All of hand thinning treatments significantly increased nut weight (from 2.36 g for control to 2.62 g for LFR of 30:1) (Table 7). Also, flesh to nut ratio influenced by these treatments.

Table 7. Effect of hand thinning at pit hardening stage on 'Gerdi' apricot fruit TSS, TA, TSS to TA ratio and nut weight and flesh to nut ratio in 2007.

Treatment	TSS (%)	TA (mg/100 mL)	TSS to TA ratio	Nut weight (g)	Flesh to nut ratio
Control	6.87[c]	1.52[a]	4.59[b]	2.36[b]	12.47[b]
10:1 LFR	8[b]	1.59[a]	5.02[ab]	2.6[a]	13.56[ab]
20:1 LFR	8.5[ab]	1.54[a]	5.49[a]	2.6[a]	14.87[a]
30:1 LFR	8.8[a]	1.54[a]	5.77[a]	2.62[a]	15.04[a]

Means in each column with the similar superscript letters are not significantly different at $P = 0.05$ using DNMRT. LFR: leaf to fruit ratio.

DISCUSSION

Chemical thinning: In this study NAA and NAD significantly increased fruit drop. This data is in agreement with previous reports showed that application of NAA at 20 mg.l^{-1} (4 weeks AFB) was a good treatment for fruit thinning of apricot (Surányi, 1986; Bolat and Karlidağ, 1999; Son, 2004). Results showed that the difference between NAA and NAD on fruit abscission of 'Gerdi' cultivar was not significant, and this finding is not in agreement with trails conducted in 'Hungary' cultivar (Surányi, 1978), that reported differences in thinning efficiency from application of potassium salt of NAA and NAD for different cultivars of apricot.

NAA application stimulates ethylene production in fruitlet and this increased concentration could induce abscission (Dennis, 2000). Ebert and Bangerth (1982) measured both extractable and diffusible auxin content of apple fruitlets following application of carbamyle, ethephon and NAD and they concluded that reduced auxin transport was the major responsible in thinning that occurred due to these treatments.

Urea at all concentrations induced fruitlet abscission in apricot trees and its effect was the same as NAA and NAD. The results of this study were in agreement with previous reports that urea significantly reduced fruit set in peaches and nectarines (Zilkah et al., 1988), and pistachio (Rahemi and Ramezanian, 2007). Ethephon effectively induced fruit abscission. As ethephon is absorbed by the tissue, its hydrolysis occures and released ethylene induces abscission by elevating respiration rate and production of enzymes which hydrolyze cellulose in the abscission layer (Wolpert and Ferguson, 1990). The result of this study was in agreement with Estembridge and Gambrell (1971), who found that for peach cultivars, application of ethrel at 100 to 150 mg l^{-1} in endosperm cytokinesis stage resulted in sufficient thinning.

The application of NAA, NAD and urea significantly increased fruit weight and volume in the harvested fruits. This data confirms previous reports that increasing NAA and NAD concentrations had an increased effect on fruit weight in apricot (Son, 2004). The biggest fruit was related to 0.2% urea treatment. Zilkah et al. (1988) also found that urea significantly increased the final fruit weight of peaches and nectarines. In this experiment, ethephon at all concentrations significantly increased fruit thinning, but had no effects on weight, volume, and length of fruits at harvest. Treated fruits with ethephon had the lowest fruit diameter. El-Zeftawi (1976) reported that application of ethephon at 300 mg l^{-1} on mandarin increased fruit thinning, but it produced smaller fruits. In fact, by increase in ethephon concentration, the pH of ethephon solution decresed and this resulted in increased fruit thinning and decreased fruit weight and volume. Our observation in the orchard showed that ethephon treatments caused some leaf abscission (data not shown) and it was concluded that in this instances the leaf to fruit ratio was not enough to fruit feeding. In our previous research on 'Gerdi' cultivar that we sprayed ethephon at the same concentrations in this orchard at two weeks AFB, the same results were obtained (Taghipour and Rahemi, 2010). On the other hand, these treatments on 'Khiary' cultivar led to good results without any defoliation (Taghipour and Rahemi, 2009). Thus, we concluded that the time of application was not responsible factor for negative effects of ethephon and it was related to the differences in vigor of cultivars, because 'Khiary' apricot is too vigorous and the leaves may not be affected by the ethephon. NAD at all concentrations reduced TA; probably it was related to its effect on fruit ripening. Treated fruits ripened about one week earlier than control ones (Data not shown). In this experiment increasing NAA and NAD concentrations significantly increased TSS content, similar to the reported results of Son (2004). Flesh to nut ratio was the greatest in fruits treated with NAD. This data was in agreement with Son (2004) that stated 20 mg l^{-1} NAA had positive effects on flesh to nut ratio of 'Beliana' apricot.

Hand thinning: The results of this experiment showed that hand thinning significantly increased fruit weight, volume and quality and from this aspect, highest leaf to fruit ratio adjustment was the best treatment. Removing excessive fruits by fruitlet thinning prevent the energy draining of the tree by pits. Also, TSS and other fruit quality characteristics improved by hand thinning.

Dhinesh Babu and Yadave (2004) reported that hand thinning of peach trees in subtropical north eastern India, significantly increased fruit weight. Our results were in agreement with Son (2004), who reported that hand thinning increased fruit weight and TSS.

It was concluded that chemical thinning increased fruitlet abscission, but hand thinning had the added benefit of being able to selectively remove any small and frost damaged fruits. Anyway, hand thinning is more expensive and time consuming than chemical method of fruit thinning.

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