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USE OF CHEMICAL BLOSSOM THINNERS IN 'JERSEYMAC' AND 'JONAGOLD' APPLES

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Abstract

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The effects of flower thinning agents as ATS (1.0%, 2.0%, 3.0%) and Dormex (0.25%, 0.5%, 0.75%) on some fruit characteristics and return bloom were evaluated to create alternatives for hand fruit thinning. Chemical thinning treatments were applied at full bloom, and also hand fruit thinning was done after June drop in six years old apple trees of 'Jerseymac' and 'Jonagold' grafted on M9 apple rootstock. Trials were conducted to determine the efficiency and repeatability of thinners during three experimental years. 0.5% Dormex was the most effective application, which increased quality components such as fruit diameter, and fruit weight in 'Jerseymac'. Furthermore, hand thinning gave similar results. 'Jonagold' variety is unstable thinning respond to applications. The results showed that 'Jerseymac' has regular bearing but 'Jonagold' has tended to biennial bearing. Thinning applications for 'Jonagold' was not effective in reducing biennial bearing severity.

Key words: *Malus x domestica,* ammonium thiosulfate, hydrogen cyanamide, biennial bearing

Abbreviations: ATS (Ammonium thiosulfate), BA (6-benzyladenine), NAA (Naphtalene acetic acid), NAD (Naphtalene acetamid)

Introduction

In apples, fruit appearance is very important factor in determining the market value (generally, people buy products with his eyes). Indeed, Kader (1999) has been reported consumers are looking for appearance and structural quality rather than tastes and nutritional quality of fruits. Fruit quality and regular yield can be taken each year and cost competitiveness is important in terms of recycling. Fruit trees as apple which biennial bearing tendency occurring fluctuations in production lead to economic losses.

Fruit quality and productivity are depending on many factors as variety, cultural practices, rootstocks, environmental conditions etc. (Bound, 2005). Most of apple cultivars are heavy fruit set under favorable pollination conditions. Because of high crop load fruit weight, fruit size, fruit quality (Goffinet et al., 1995; Salvador et al., 2006), leaf area, shoot length and flower bud formation is reduced (Koike et al., 1990). Nowadays, in many countries, crop load management has been gained important.

Regular bearing and fruit quality can be proved by reduction of numbers of flower buds, inhibition of flower formation, preventing fruit set by blossom thinning or reducing crop load by fruit let thinning (Webster, 2002). Thinning is one of the cultural practices uses for improved to fruit quality and regulation of yield. In addition, it promotes uniform yield, which optimizes the use of labor, packaging and storage equipment (Byers et

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al., 2003). In practice, thinning can be made manually, mechanically or use of chemicals (ATS, BA, NAA etc.). Hand fruit thinning is done after June drop. This method is not economically but growers want to guarantee their crops because of concerns are used widely. However, late fruit thinning not effective as well as early fruit thinning (Denne, 1963; Goffinet et al., 1995). Mechanical fruit thinning used generally in stone fruit trees. Because of this method occurs fruit bruise is not recommended for apples (Dennis, 2000). Chemical fruit thinning methods were tested by different research in many countries. Generally, plant growth regulators are used such as NAA, NAD, BA and ethephon for fruit thinning. Some of the fruit thinners can reduce fruit quality. In addition, their effects (NAA or BA) may change depend on weather temperature in application time (Greene and Autio, 1998). Therefore, in recent years, studies have been focused on blossom thinners in apples. Several chemicals have been identified which reduced fruit set when applied at flowering time. These were ammonium thiosulfate (ATS), endothallic acid (Endothall), sulfcarbamide (Wilthin), pelargonic acid (Thinex), hydrogen cyanamide (Dormex) and Armothin (Webster and Spencer, 2000). Within these thinners, ATS and Dormex have evaluated as great potential. ATS is an environmentally friendly thinner. Because of this feature, it can be use in organic apple growing. Hydrogen cyanamide is effective blossom thinner for some apple varieties (Fallahi and Willemsen, 2002). However, it is toxic to bees. The effects of ATS and Dormex on fruit quality have been observed in apple, peach and sweet cherry (Fallahi et al., 1998; Janoudi and Flore, 2005; Lenahan and Whiting, 2006; Coneva and Cline, 2006).

ATS and hydrogen cyanamide cause damage to flower organs and inhibits pollination (Webster, 2002; Greene, 2002). The efficacy of these thinners can be influenced by cultivar, environmental factors and time of application (Fallahi et al., 1998; Janoudi and Flore, 2005). Recognition of these factors is important for maximizing crop value (Byers et al., 2003). Therefore, chemical thinners should be tested separately for each region and variety.

The aim of this research was to investigate effects of blossom thinners on fruit quality and biennial bearing in 'Jerseymac' and 'Jonagold' apples.

Materials and Methods

The study was conducted during three experimental years (2006-2008) in the Fruit Research Station (37°49'17.97"N, 30°52'22.44"E), Egirdir, which is southwestern Isparta located in the Lakes Region, Turkey. The location is the transitional district between the middle of Anatolia and the Mediterranean. 6 years old 'Jerseymac' and 'Jonagold' apple trees at a spacing of 3.0 x 1.5 m on M9 rootstock were selected as experimental trees. Eight treatments including unsprayed control (no thinning), hand thinned just after June drop (1 fruitlet left per cluster), ammonium thiosulfate (ATS) (1.0%, 2.0%, 3.0%) and Dormex (hydrogen cyanamide) (0.25%, 0.5%, 0.75%) were designed. ATS and Dormex were applied at full bloom to the whole tree as a single application and no surfactant was used. The point of run-off applied spray treatments with a handgun sprayer to same tree each year. During the trials, orchards practices were carried routinely.

Table 1
Physical and chemical fruit measurements

Parameters	Measurements
Fruit weight (g)	digital balance (Scaltec, SBA–51) to 0.01 g sensitivity
Fruit diameter (mm)	digital caliper with 0.01 mm resolution
Fruit length (mm)	digital caliper with 0.01 mm resolution
Fruit flesh firmness (lb)	two opposite sides of each fruit, using a hand held penetrometer fitted with a 11 mm diameter probe
Fruit skin color (L* a* b*)	two opposite sides of each fruit with a Minolta Chroma meter model CR-400. The data obtained were evaluated CIELAB color scale
Total soluble solids content (%)	Digital bench refractometer
Titratable acidity (%)	a standard titration with 0.1 N sodium hydroxide and was calculated as malic acid (0.0679)

All of flower clusters were counted and blossom density calculated on each tree for measurement of return bloom just before full bloom. Fruits were harvested at commercial harvest time. Ten fruits were selected as randomly per tree and total 30 fruits were used for fruit quality measurements (Table 1). Fruit samples were also assessed for russet.

Fruits were graded into various size classes. Economically acceptable fruit grades for 'Jonagold' 75 to 85 mm; for 'Jerseymac' 65 to 85 mm diameter was applied.

During the spraying period, meteorological data was taken order to determine effects of temperature and humidity on thinning effect of chemicals. We also observed phytotoxicity of thinners on the tree organs (leaves, shoots and fruits).

The treatments were arranged in a randomized complete block design, with three replications, three trees were used for each treatment. Statistical procedures were performed using statistical analysis systems (SPSS) software version 13. Duncan's multiple range test (DMRT) was used for means separation at a significance level of 5%.

Results and Discussion

Jerseymac

All chemical thinners increased average fruit weight and size at harvest relative to the non-thinned control. The largest fruit were obtained with the hand thinned, 0.5% Dormex and 2.0% ATS in the first trial year (Table 2). In 2007, except for the treatment at 0.5% Dormex, no significant effect of thinning treatments was noted on fruit weight and diameter. 0.5% Dormex give consistent results per year on the fruit quality is extremely important. Fallahi et al. (1998) reported that hydrogen cyanamide was an effective blossom thinner for 'Early Spur Rome', 'Law Rome', 'Gala' and 'Redspur Delicious' apples. The thinning effect increased with increasing concentrations of Dormex, but higher rate of Dormex at 0.75% was negative impact on fruit quality each year. The reduction of fruit size in 'Jerseymac' following application of Dormex at 0.75% contradicts the findings of Fallahi et al. (1992) for 'Rome Beauty'. These differences may have been due to ecological factors occurred during the study or varietal characteristics.

Effects of ATS treatments on fruit quality and yield (data not shown) showed differences year to year. Mean fruit weight from ATS treatments were the higher than unsprayed control in 2006. Insignificant thinning occurred was applied in 2007 on fruit weight and size, except for 3.0% ATS (Table 2). Costa et al. (2004) reported effect of ATS on fruit size is less compared with BA applications. Bound and Wilson (2007) suggested that multiple applications of ATS in 20% and 80% bloom period in 'Hi Early Delicious' apple were effective than single application. On the other hand, Janoudi

Table 2
Effects of thinning treatments on physical fruit properties in "Jerseymac"

Treatment	Fruit weight, g			Fruit diameter, mm			Fruit flesh firmness, lb		
	2006	2007	2008	2006	2007	2008	2006	2007	2008
Control (no thinning)	126b*	131b	152ab	68.46c	69.74b	73.02 ns	13.97ab	14.12	13.65
Hand thinned	159a	142b	167a	74.10a	71.87b	75.58	12.83bc	12.92	13.67
ATS									
1.0%	145ab	132b	149ab	72.64abc	69.13b	73.31	11.60c	12.92	12.9
2.0%	153a	138b	142ab	73.73ab	71.02b	72.01	13.62ab	14.72	11.76
3.0%	142ab	154b	142ab	70.89abc	73.80ab	71.92	12.69bc	12.98	12.78
Dormex									
0.25%	138ab	148b	152ab	71.39abc	73.24ab	73.38	14.74a	13.46	12.32
0.5%	155a	179a	151ab	74.16a	77.51a	73.84	12.70bc	13.2	11.72
0.75%	125b	129b	137b	69.53bc	69.40b	71.18	13.78ab	13.79	11.87

*Means in columns followed by the same letters are not significantly different
ns: not significant

and Flore (2005) have pointed out that thinning activity of ATS is correlated with drying times of the spray.

Generally, fruit flesh firmness is negatively correlated with mean fruit weight. Treatments had widely different effects on fruit flesh firmness. Treatment, which increased flesh firmness over the control, was the 0.25% Dormex in 2006. None of the treatments influence flesh firmness in 2007 and 2008 (Table 2). As expected, 0.5% Dormex, which has bigger fruit, reduced to fruit flesh firmness relative to the unsprayed control.

Some researchers suggest that effects of thinning practices on physical and chemical properties of fruit vary to application doses, variety and year-to-year (Jones et al., 1997; Bregoli et al., 2006). The applications showed different effect on total soluble solids content (TSS) between experiment years (Table 3). TSS was higher in the 1.0% ATS than control and other treatments, in 2006 while 2007 and 2008 only Dormex 0.5% was increased. Due to great variability, none of the treatments showed any significant difference on titratable acidity in 2006 and 2007 (Table 3). Fruit color (results not presented) between thinned and control trees were not statistically significant. Similar to our findings with Fallahi et al. (2004) who tested ATS and Dormex on fruit color in 'Rome Beauty' apple.

In apples, appearance is very important factor in determining of market value. Consumers purchase apple based on appearance and textural quality. Therefore, applications to improve the external appearance of fruit are important in terms of marketability and profitability. The domestic market and export at the level of acceptable values of diameter in 75-85 mm for 'Jerseymac'. Thinning treatments affected fruit size distribution at various percentages. The yield of fruit 75-85 mm was increased by 0.5% Dormex in 2006 and 2007, while best results were obtained from hand thinned, 0.25% Dormex and 1% ATS in 2008 (Table 4).

Jonagold

'Jonagold' variety was unstable thinning respond to applications each trial years and it didn't affect fruit quality characteristics by chemical thinners (Tables 5 and 6). There were some differences in the results year to year compared to 'Jerseymac'. Similarly, Basak (2004) reported effects of ATS applications on fruit diameter, fruit weight and fruit color in 'Jonagold' and 'Gala' is not significant. However, Janoudi and Flore (2005) showed that ATS at either 5% or 10% was effectively in 'Jonagold' with washing of the trees after applications.

'Jonagold' did not respond to thinners, this might be explained by genetic differences and also application time, doses, and occurring temperature and humidity during this period. On the other hand, single application of ATS and Dormex in full bloom period may have been not sufficient. The results support previous findings McArtney et al. (1995), Jones et al. (1997), Stopar and Zadravec (2004), and Basak (2004).

Table 3
Effects of thinning treatments on chemical fruit properties in "Jerseymac"

Treatment	Soluble solids content, %			Titratable acidity, %		
	2006	2007	2008	2006	2007	2008
Control (no thinning)	11.33b*	12.86a	10.36bc	0.65 ns	0.64	0.58abc
Hand thinned	11.25b	12.01ab	10.66bc	0.74	0.56	0.67a
ATS						
1.0%	12.23a	11.90ab	9.50bc	0.68	0.56	0.66ab
2.0%	11.15b	11.70b	10.83bc	0.62	0.65	0.56bc
3.0%	11.06b	12.16ab	9.08c	0.60	0.60	0.57abc
Dormex						
0.25%	11.25b	12.83a	11.33b	0.72	0.65	0.52cd
0.5%	11.03b	12.76a	13.86a	0.71	0.57	0.45d
0.75%	11.30b	12.30ab	9.66bc	0.74	0.58	0.56bc

*Means in columns followed by the same letters are not significantly different
ns: not significant

Table 4
Results of thinning treatments on fruit size of "Jerseymac", mm

Treatment	2006				2007				2008			
	75-85	70-75	65-70	<65	75-85	70-75	65-70	<65	75-85	70-75	65-70	<65
Hand thinned	46.7	26.7	23.3	3.3	16.7	53.3	30	0	53.3	43.3	3.3	0
Control (no thinning)	0	40	50	10	10	33.3	56.7	0	23.3	56.7	16.7	3.3
ATS												
1.0%	20	63.3	16.7	0	10	20	60	10	40	36.7	23.3	0
2.0%	40	50	10	0	16.7	40	40	3.3	23.3	40	36.7	0
3.0%	6.7	50	40	3.3	40	46.7	13.3	0	16.7	56.7	20	6.7
Dormex												
0.25%	13.3	43.3	40	3.3	36.7	26.7	33.3	3.3	43.3	23.3	30	3.3
0.5%	53.3	30	16.7	0	73.3	23.3	3.3	0	33.3	56.7	10	0
0.75%	10	46.7	20	23.3	6.7	36.7	50	6.7	13.3	43.3	40	3.3

Table 5
Effects of thinning treatments on physical fruit properties in "Jonagold"

Treatment	Fruit weight, g			Fruit diameter, mm			Fruit flesh firmness, lb		
	2006	2007	2008	2006	2007	2008	2006	2007	2008
Control (no thinning)	275.11^{ns}	244.31b	343a	84.53	81.96b	90.99a	16.45a	14.72b	14.28
Hand thinned	277.57	287.83a	283b	83.63	85.78a	86.06b	14.54c	16.32a	14.1
ATS									
1.0%	268.22	273.14a	284b	82.98	84.67ab	85.77b	15.54ab	15.49ab	14.74
2.0%	285.47	289.06a	305b	84.53	85.57a	88.00ab	15.82ab	15.68ab	14.31
3.0%	284.23	287.30a	279b	84.25	85.37a	85.88b	16.10ab	16.02ab	14.09
Dormex									
0.25%	272.71	277.54a	287b	82.84	85.31a	86.48b	15.32ab	16.06ab	14.47
0.5%	271.44	282.92a	295b	82.87	85.36a	87.43b	16.18ab	14.87b	14.45
0.75%	283.5	259.69ab	296b	84.44	83.46ab	87.18b	14.93b	14.82b	14.56

*Means in columns followed by the same letters are not significantly different
ns: not significant

Table 6
Effects of thinning treatments on chemical fruit properties in "Jonagold"

Treatment	Soluble solids content, %			Titratable acidity, %		
	2006	2007	2008	2006	2007	2008
Control (no thinning)	13.01^{ns}	13.88b	13.10ab	0.44abc	0.55b	0.40ab
Hand thinned	14.13	14.93a	12.98ab	0.45c	0.70a	0.41ab
ATS						
1.0%	13.28	14.06ab	12.65abc	0.43bc	0.68ab	0.40ab
2.0%	13.63	13.76b	12.41bc	0.44abc	0.64ab	0.43ab
3.0%	13.15	13.96b	11.60c	0.47abc	0.61ab	0.37b
Dormex						
0.25%	13.53	14.30ab	13.33ab	0.52a	0.69a	0.39b
0.5%	13.16	13.36bc	13.86a	0.50ab	0.55b	0.45ab
0.75%	13.83	12.86c	12.69abc	0.41c	0.55b	0.54a

*Means in columns followed by the same letters are not significantly different
ns: not significant

Compared with the unsprayed control none of the treatments impact on average fruit weight in 2006, but thinning treatments were increase fruit weight than control in 2007 because of crop load. Only control resulted in significantly (P<0.05) greater meant fruit weight than other treatments in 2008. Return flowering was very poor in all trees in 2007. Our results indicate that neither ATS nor Dormex influence return flowering in 'Jonagold'.

Percentage of large fruit (80-85 mm diameter) increased by hand thinned and 0.75% Dormex in the first year of the study (Table 7). In 2007 and 2008, the majority of fruits were into ≥85mm size category and fruit yield with high commercial value was higher in 1.0% ATS. Bound (2005) also reported that 1% ATS increased rate of fruit into 70 mm or above size category in 'Hi Early Delicious' apple. However, Basak (2004) found same in control, ATS and June drop thinning treatments the rate of fruit over 80 mm. Fruit number into the size category varies according to treatments and years. These differences may be related to the number of fruit on the tree, such as climatic factors and the contribution of orchard practices should not be ignored. Similarly, Hinai (2003), Salvador et al. (2006) and Treder (2008) report is a negative relationship between fruit number and fruit size.

Conclusions

We investigated the effects of blossom thinning agents over the three years on fruit quality and biennial bearing in 'Jerseymac' and 'Jonagold' apple varieties. Thinning treatments have no sufficient effect on biennial bearing in 'Jonagold' apple, while 'Jerseymac' has regularly yield. 'Jonagold' showed unstable responses to thinning agents since the applications did not affect on fruit quality characteristics. Dormex was more effective than ATS during all trial years in 'Jerseymac'. Especially, 0.5% Dormex significantly increased quality components such as fruit diameter and fruit weight in 'Jerseymac' and during the experiment gave consistent results. Similar results were obtained from fruit thinning applied after June drop. The effect of Dormex on fruit quality in 'Jonagold', however, is not consistent. Increasing doses of Dormex (0.75%) was phytotoxic effect on leaves of 'Jerseymac' apple. This effect was seen the application period depending on temperature and humidity in 2007. No phytotoxic effect on 'Jonagold'. Phytotoxic effect was not observed for any ATS dose.

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Table 7
Results of thinning treatments on fruit size of "Jonagold", mm

Treatment	2006			2007			2008		
	>85	80-85	75-80	>85	80-85	75-80	>85	80-85	75-80
Hand thinned	16.7	70	13.3	53.3	46.7	0	63.3	30	6.7
Control (no thinning)	40	53.3	6.7	20	56.7	23.3	93.3	6.7	0
ATS									
1.0%	33.3	40	26.7	30	70	0	53.3	46.7	0
2.0%	40	50	10	53.3	43.3	3.3	80	20	0
3.0%	46.7	43.3	10	53.3	46.7	0	60	33.3	6.7
Dormex									
0.25%	26.7	46.7	26.7	50	50	0	70	23.3	6.7
0.5%	26.7	56.7	16.7	60	36.7	3.3	70	23.3	6.7
0.75%	46.7	33.3	20	26.7	63.3	10	73.3	20	6.7

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