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APPLE FRUIT CHEMICAL THINNING IN CHIHUAHUA, MÉXICO

RALEO QUÍMICO EN FRUTOS DE MANZANO EN CHIHUAHUA, MÉXICO

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SUMMARY

Chemical fruit thinning is a common practice in apple (*Malus x domestica* Borkh.) orchards for achieving high quality fruits, reduced costs of hand-thinning and promote return of flowering. Hand thinning is a common and high cost practice, not only due to the labor involved, but also because seedling and vigorous clonal rootstocks result in large trees. The chemical thinning agents: Ethephon (ETH), Carbaryl (CB), Naphthalene acetic acid (NAA), 6-Benzyladenine (6-BA), and fish oil were evaluated on 'Golden Delicious' and 'RedChief Delicious' apple trees in 2004 and 2005. Chemical thinning effect was compared with early and late hand-thinnings. Treatments were sprayed when the biggest fruit in the clusters was 10 mm in equatorial diameter. NAA showed the best effect in reducing final fruit set in both cultivars and years evaluated, with results comparable to those of early hand-thinning (thinned when king-fruit size was 10 mm) in 'Golden Delicious' trees. In 'RedChief Delicious', fruit set reduction by NAA, fish oil and CB treatments was similar to early hand-thinned trees only in 2005. In 2005, time spent during supplementary hand-thinning in 'Golden Delicious' trees was reduced by chemical thinning treatments, except by fish oil; whereas in 'RedChief Delicious' only NAA K-salt reduced it in 2004. An increase in fruit equatorial diameter was observed only in 2004 with NAA and fish oil. Alternate bearing, typical of 'Golden Delicious', was not diminished by these chemical thinning treatments.

Index words: *Malus x domestica*, fruit set, carbaryl, ethephon, naphthalene acetic acid, 6-benzyladenine.

RESUMEN

El raleo químico de frutos es una práctica regular en los huertos de manzanas (*Malus x domestica* Borkh.), y es llevada a cabo para obtener frutos de alta calidad, reducir el costo del raleo manual y promover el retorno de la floración. El raleo manual es una práctica común y de alto costo debido principalmente a que los manzanos se encuentran sobre porta-injertos de semilla o clones vigorosos, que dan árboles grandes. Aquí se evaluó el efecto de los raleadores químicos: Etefón (ETH), Carbaril (CB), Ácido naftalenacético (NAA), 6-Benciladenina (6-BA) y aceite de pescado, en manzanos 'Golden Delicious' y 'RedChief Delicious' durante los ciclos 2004 y 2005. El efecto de los raleadores químicos se comparó con tratamientos de raleo manual temprano y tardío. La aspersión de los raleadores

químicos se efectuó cuando el fruto mayor del racimo medía 10 mm de diámetro ecuatorial. El tratamiento con NAA mostró el mayor efecto en reducir el cuajado final de frutos en ambos cultivares y ciclos evaluados, reducción que fue similar al raleo manual temprano (cuando el fruto mayor del racimo medía 10 mm) en 'Golden Delicious'. En 'RedChief Delicious', la reducción en el cuajado de frutos obtenido por los tratamientos de NAA, aceite de pescado y CB fue similar al raleo manual temprano solamente en 2005. En 2005 el tiempo de mano de obra para el raleo manual complementario en los árboles 'Golden Delicious' fue reducido por los tratamientos químicos, excepto el aceite de pescado; en 'RedChief Delicious' solamente el NAA K-salt lo redujo en 2004. Se registró un incremento en el diámetro ecuatorial de frutos solamente en el ciclo 2004 con los tratamientos de NAA y aceite de pescado. La alternancia en la producción observada en 'Golden Delicious' no se logró reducir con los raleadores químicos.

Palabras clave: *Malus x domestica*, cuajado de frutos, ácido naftalenacético, carbaril, etefón, 6-bencil adenina.

INTRODUCTION

In order to reduce labor costs, enhance fruit size and return bloom, chemical fruit thinning is a regular practice in apple (*Malus x domestica* Borkh.) fruit production (Yuan and Greene, 2000; Greene, 2002; Petracek and Silverman, 2003). Apple flower buds become initiated 30 to 40 d after blooming, a period when gibberellins (GA) from developing seeds in growing fruits inhibit floral initiation (Jackson, 2003; Ramírez *et al.*, 2004). Because of this, fruit thinning should be performed within 28 d after full bloom to achieve a good fruit size and high return bloom (Koike *et al.*, 2003). Abscission of immature fruits occurs frequently, varying in magnitude every year depending on fruit set, climatic conditions during flowering, nutritional status, carbohydrate availability, hormonal balance, or any combination of these factors (McArtney, 2005).

Spur-type 'Red Delicious' and 'Golden Delicious' are some of the most widely planted apple cultivars in Cuauhtémoc, Chihuahua, México at an altitude of 2100 m (Guerrero *et al.*, 2002). These cultivars are reported as difficult to thin (Marini, 2002). According to Dorigoni (2004) the activity of 6-benzyladenine (6-BA) is greatly reduced at high elevations, common a condition for other chemical thinners also. To overcome this problem, an aggressive fruit-thinning program is required.

Carbaryl (CB) and naphthalene acetic acid (NAA) are the most commonly used chemical thinners in the Chihuahua apple growing area. Carbaryl is a relatively mild, but effective thinner in spur-type 'Red Delicious' and 'Gala' trees (Marini, 1996), which must be sprayed when the largest fruit in the cluster is 10-12 mm in diameter (Ferree and Schmid, 2001). When CB is mixed with 6-BA + GA₄₊₇ (AccelTM), the thinning effect is comparable to hand-thinning in cvs. 'McIntosh' (Khanizadeh *et al.*, 2004) and 'Fuji' (Ferree and Schmid, 2000). However, when CB is combined with 6-BA on cv. 'Redspur Delicious', the thinning effect can be excessive (Greene and Autio, 1994). CB usefulness is further limited because its toxicity to some predatory mites that are, important for integrated pest management (Hislop and Prokopy, 1981).

Reductions in photosynthesis have been reported in NAA-treated 'RedChief Delicious' trees (Stopar *et al.*, 1997) and 6-BA-treated 'McIntosh' trees (Yuan and Greene, 2000). NAA has shown a strong thinning effect in spur-type 'Red Delicious' trees, but it may also induce an excessive development of pygmy fruits (Marini, 1996). In cv. 'Smoother Golden Delicious' the lowest fruit set was obtained with 8 mg L⁻¹ of NAA (Marini, 2002). An adequate thinning effect and increased fruit size, as well as a higher gain in fruit weight, can be reached with 6-BA than with either NAA or CB, because 6-BA can increase cell division rate in fruit cortex (Elfving and Cline, 1993; Greene and Autio, 1994; Wismer and Proctor, 1995). Also, 6-BA and CB have been more effective than NAA in increasing return bloom (Greene and Autio, 1994). In 'RedChief Delicious' Ethephon (ETH) has been an effective thinner when applied at concentrations > 500 mg L⁻¹, and ineffective at concentrations < 300 mg L⁻¹ (Marini, 2004).

The objective of this study was to compare chemical thinning to late hand-thinning, which is still a common practice at the high altitude of Chihuahua state, the main apple production area in México, with respect to labor for hand-thinning, fruit size and return bloom, in 'Golden Delicious' and 'RedChief Delicious' apple cultivars.

MATERIALS AND METHODS

Experiments were conducted in 2004 and 2005 on 15-year-old trees of cvs. 'RedChief Delicious'/M.M.111 and 'Golden Delicious'/M.M. 106 in a commercial orchard in Cuauhtémoc, Chih., México. Trees were freestanding, trained as a central leader, and planted at 3.0 x 4.3 m. Trees for the experimental plots were visually selected in 2004. All trees were analyzed regarding, flower density and tree size, and no significant differences were found among them (data not shown). Tree vigor was determined by measuring the trunk cross-sectional area, while flower density was determined by using two representative branches per tree and expressed as flower clusters per square centimeter of cross-sectional branch area (BCSA, flower cluster/cm², Lombard *et al.*, 1988). Treatments were applied on the same trees in both seasons. Thinning agents were sprayed at drip point with a motorized portable hand-gun sprayer, using 2 L of solution per tree. Sprayings were done in the morning at temperatures of 20-24 °C. Each treatment was applied to five complete trees (80 % of the solution was sprayed to the upper two thirds of each tree). The mixture of hydrogen cyanamide (DormexTM BASF, Germany), at 10 mL L⁻¹ + mineral oil at 20 mL L⁻¹ was applied 30 d before bloom to prevent the effect of a lack of sufficient chilling units during the previous Winter, to have a shorter and compact blooming period in 'Golden Delicious' trees.

When the cluster biggest fruit, also known as king-fruit (which is developed from the central flower of the cluster, and the first to open at bloom) reached 10 mm the trees were treated with the following thinning agents and dosages: Ethephon, 540 mg L⁻¹ (MadurexTM, BASF, Micro Flo Co.); Carbaryl (CB), 480 mg L⁻¹ (Sevin 80 PHTM, Aventis CropScience); NAA as potassium salt, 16.2 mg L⁻¹ (K-saltTM Fruit Fix 800 AMVAC Chem. Corp.); NAA as sodium salt, 18.6 mg L⁻¹ (Fruitone NTM AMVAC Chem. Corp.); 6-benzyladenine, 95 mg L⁻¹ (MaxCelTM Valent BioSciences); and fish oil at 6 mL L⁻¹ (a locally formulated chemical thinner, added with 5 mL L⁻¹ of BionexTM GBM, México). An early hand-thinning treatment, applied when the king fruits measured 10 mm, was included, leaving one fruit per cluster. A late hand-thinning at 60 d after full bloom was also included as control because it represents the local practice. In addition to these treatments, NAA + CB mixtures at concentrations of 5 + 240 mg L⁻¹, and 6-BA + CB at 95 + 240 mg L⁻¹, respectively, were included in 2005. To achieve an even harvest distribution on each tree, all trees were hand-thinned to one fruit per cluster at 60 d (67 d for 'RedChief Delicious' in 2005) after full bloom.

When king fruits reached a 10 mm diameter, thirty fruit clusters were labeled in each tree at application time. Fruits of labeled clusters were counted and expressed as fruits per 100 blossom clusters at 15 and 30 d after treatment in 'Golden Delicious' and at 30 d after treatment in 'RedChief Delicious' in 2004; whereas in 2005 they were counted at 15, 30, and 43 d after treatment in both cultivars. Fruit set evaluation dates were expressed as days after full bloom (DAFB) and were variable because full bloom date is not the same for both cultivars. Time spent in hand-thinning a tree was directly related to its crop load, consequently, a high crop load per tree required more time to thin fruit. Time required to hand-thin the equivalent to 100 kg of fruit at harvest was determined for each tree to compare treatments. Pygmy fruits (equatorial diameter less than 5 cm) at harvest were also evaluated in 'RedChief Delicious', since NAA is reported to induce this king of fruits when used in spur-type 'Delicious' trees (Greene and Autio, 1994). Yield per tree was recorded at harvest. Total soluble solids content was determined with an ATAGO™ model ATC-1E (Tokyo, Japan) refractometer. Flesh firmness was measured from two opposite sides of the fruits, with an electronic texture analyzer model TA-XT2i (Texture Technologies Corp., New York, USA). Average fruit size, as equatorial diameter in mm, was determined on ten randomly harvested fruits in each tree, using a Cranston fruit gauge. Evaluation of return bloom was carried out during the following blooming season by comparing flower density in both consecutive seasons.

A completely randomized experimental design with five replications (complete trees) was used. Data were analyzed by Statistical Analysis System, version 6.12 (SAS Institute, 1996). Mean differences were determined by Tukey test ($P \leq 0.05$).

RESULTS AND DISCUSSION

2004 trials

Fruit set

The highest reduction in 'Golden Delicious' fruit set was found on the NAA-sprayed trees (both formulations, Fruitone N and K-salt) when evaluated at 45 DAFB, effect that was similar to that obtained in the early hand-thinned trees (Table 1). Perhaps the induction of fruit drop required to achieve the benefits sought (larger fruits and higher return bloom) was too late, considering that Koike *et al.* (2003) reported that thinning at 28DAFB was already a late date for 'Golden Delicious'. Moreover, the hand-thinning practice locally used to adjust crop load, must be performed after the fruit drop induced by chemical thinning is already finished.

Contrary to our objectives the fish oil spraying produced the highest fruit set, even higher than late hand-thinned control in 'Golden Delicious', indicating that is not appropriate as a post-bloom thinner; Fish oil has been reported as an efficient bloom thinner (McArtney *et al.*, 2006). Although other physiological processes, such as photosynthesis, were not evaluated in this experiment, other workers (Ju *et al.*, 2001) reported that organic compounds, like soybean oil, can increase photosynthesis, carbohydrate availability and fruit set; such a statement might explain the increase in fruit set caused by fish oil in our experiment.

A reduction in fruit set was not observed on Ethephon (ETH) nor on 6-BA in both cultivars (Table 1). Similar the results were reported by Ferree and Schmid (2000) and Khanizadeh *et al.* (2004), who found that 6-BA (Accel™) by itself did not adequately thin 'Fuji' and 'McIntosh' trees. Marini (1996) showed that 6-BA was the least effective material for thinning spur-type 'Delicious' trees and found a greater efficiency of Ethephon when applied at 18 mm instead of 9 mm of king fruit diameter. The lack of effectiveness observed on 6-BA and ETH in our experiment might be due to the high altitude of the experimental orchard, according to Dorigoni (2004).

Sprays with NAA and CB decreased fruit set in 'RedChief Delicious', although not as much as early hand-thinning (Table 1), a result that match those from Marini (1996) who reported that NAA is an efficient thinner on spur-type 'Delicious' trees.

Yield and fruit quality

Despite the significant reduction of final fruit set caused by NAA treatments on both cultivars, a yield reduction was not observed (Table 2). The late hand-thinning treatment at 60 DAFB standardized all treated trees at similar crop loads. The objective on this trial was to compare chemical thinning with the late hand thinning extensively used in this region.

NAA sprays increased mean fruit equatorial diameter in 'Golden Delicious' (Table 2), as a result of its efficiency as fruit thinner. Fish oil increased both fruit diameter and fruit set, a response that was observed only on 'Golden Delicious' in 2004. Possibly due to its thinning effect, the treatment NAA K-salt produced the biggest fruits at harvest in 'RedChief Delicious'. The increase in fruit size due to NAA sprays is well documented (Greene, 2005). The only significant reduction in fruit firmness was found when Ethephon was sprayed on 'Golden Delicious'. The higher flesh firmness obtained with Carbaryl

(CB) on 'RedChief Delicious' might be explained by the smallest fruit size.

All thinning treatments reduced total soluble solids content on 'Golden Delicious' fruits, while on 'RedChief Delicious' the response was not the same (Table 2). It has

been reported a decrease of soluble solids content on apples treated with 6-BA + CB (Khanizadeh *et al.*, 2004) or NAA (Dennis, 2002) as fruit thinners. Highest total soluble solids content and the smallest fruit size were observed on CB-treated fruits on 'RedChief Delicious' (Table 2).

Table 1. Thinning effects on fruit set, return bloom the following year and time spent for hand-thinning in 'Golden Delicious' and 'RedChief Delicious' apple trees at Cuauhtémoc, Chihuahua, México. 2004 trials.

Treatment	Rate (mg L ⁻¹)	Fruits per 100 clusters		Flower clusters/cm ² BCSA in 2005	TSHT at 60 DAFB (min/tree)
		28 DAFB	45 DAFB		
‘Golden Delicious’					
Late hand-thinned control		273 b	172 b	1.7 c	49.1 abc
Ethephon	540	240 b	151 b	4.9 ab	<i>ld</i>
Carbaryl	480	259 b	171 b	1.9 c	53.4 ab
NAA (K-salt)	16.6	235 b	93 c	4.3 abc	34.4 c
NAA (Fruitone N)	18.6	337 a	109 c	4.1 abc	37.3 c
6-BA	95	242 b	152 b	6.4 a	44.2 bc
Fish oil	6 mL L ⁻¹	340 a	218 a	1.7 c	59.0 a
Early hand-thinning		87 c	87 c	3.6 abc	<i>ld</i>
LSD		40.2	37.3	3.0	14.7
‘RedChief Delicious’					
Late hand-thinned control			259 a	4.0 ns	49.5 a
Ethephon	540		272 a	6.5	34.9 ab
Carbaryl	480		202 bc	7.0	35.8 ab
NAA (K-salt)	16.6		177 c	7.1	24.8 b
NAA (Fruitone N)	18.6		180 c	6.9	46.3 ab
6-BA	95		251 a	7.4	36.2 ab
Fish oil	6 mL L ⁻¹		240 ab	7.3	29.3 ab
Early hand-thinning			79 d	5.9	<i>ld</i>
LSD			38.8	3.7	24.5

Within columns, means with different letters are statistically different according to Tukey ($P \leq 0.05$). DAFB = Days after full bloom. TSHT = Time spent for hand-thinning, one person per tree harvesting 100 kg of fruit; BCSA = Branch cross sectional area; ld = Lost data. LSD = Least significant differences. ns = Non significant differences.

Table 2. Thinning effect on yield, fruit equatorial diameter, firmness and total soluble solid content of 'Golden Delicious' and 'RedChief Delicious' apple trees grown at Cuauhtémoc, Chihuahua, México. 2004.

Treatment	Rate (mg L ⁻¹)	Yield (kg/tree)	Equatorial fruit diameter (mm)	Fruit firmness (N)	Total soluble solids (° Brix)
‘Golden Delicious’					
Late hand-thinned control		105.0 ns	65.4 cd	62.3 ab	13.3 a
Ethephon	540	142.5	64.4 d	64.5 a	12.2 bc
Carbaryl	480	129.0	66.2 bcd	60.9 b	12.3 bc
NAA (K-Salt)	16.6	111.2	67.5 ab	63.2 ab	12.3 bc
NAA (Fruitone N)	18.6	110.2	68.5 a	62.7 ab	12.2 bc
6-BA	95	125.9	64.7 cd	62.3 ab	12.1 c
Fish oil	6 mL L ⁻¹	116.5	68.2 a	61.8 ab	12.1 c
Early hand-thinning		122.0	66.6 abc	63.6 ab	12.8 ab
LSD		48.7	1.96	2.85	0.58
‘RedChief Delicious’					
Late hand-thinned control		58.9 ns	67.9 ab	66.3 e	11.7 bc
Ethephon	540	46.8	65.8 b	70.3 bcd	11.9 abc
Carbaryl	480	37.8	62.3 c	76.9 a	12.4 a
NAA (K-Salt)	16.6	43.9	70.0 a	71.2 bc	11.4 cd
NAA (Fruitone N)	18.6	49.4	65.4 bc	67.2 de	12.0 abc
6-BA	95	53.2	65.1 bc	73.4 ab	11.1 d
Fish oil	6 mL L ⁻¹	43.2	65.7 b	68.5 cde	12.3 ab
Early hand-thinning		37.2	65.3 bc	73.8 ab	11.8 bc
LSD		27.6	3.28	3.91	0.61

Within columns, means with different letter are statistically different according to the Tukey test ($P \leq 0.05$). ns = Non significant differences. LSD = Least significant differences.

Return bloom

At the beginning of the 2004 trials, selected trees had a mean flower density of six flower clusters/cm² of branch cross sectional area. In the next blooming period, 'Golden Delicious' treated with 6-BA induced the highest return bloom (Table 1), even though this treatment was not the most effective fruit thinner in 2004. Similar results were found by Greene and Autio (1994), Wismer and Proctor (1995) and Ramirez *et al.* (2004), who reported that exogenous cytokinins, as 6-BA, can increase flower differentiation and reduce alternate bearing on apple trees. Also, the promotion of flower differentiation by Ethephon may have induced a reduction on vegetative growth and inhibition of photosynthesis rate, causing a fruit thinning effect, as reported by Petracek and Silverman (2003) and by Untiedt and Blanke (2001). The 'Golden Delicious' trees submitted to treatments based on Carbaryl, fish oil or the late hand-thinned control showed an alternate bearing behavior (Table 1).

Return bloom in 'RedChief Delicious' was similar for all treatments, showing a regular bearing behaviour (Ta-

ble 1); according to Jackson (2003), spur-type cultivars like 'RedChief Delicious' have a balance between bearing and nonbearing spurs in order to ensure regular cropping.

2005 trials

Fruit set

Apple trees undergo several natural fruit drops. A significant natural fruit drop was observed on the control late hand-thinned trees after 42 and 53 DAFB on 'Golden Delicious' and 'RedChief Delicious', respectively (Table 3). The natural fruit drop will vary each year in response to those factors previously mentioned. Most of the chemical thinning sprays increased fruit drop due to an increase of the natural competition among fruitlets, a physiological phenomenon on which chemical fruit thinning is based (Dennis, 2002). Based on the three sequential fruit set evaluations, fruit drop was almost completed at 42 DAFB in 'Golden Delicious' and at 53 DAFB in 'RedChief Delicious'; it is then appropriate to perform the supplementary hand thinning practice at those times.

Table 3. Thinning effect on fruit set, return bloom the following year and time spent for hand-thinning on 'Golden Delicious' and 'RedChief Delicious' apple trees at Cuauhtémoc, Chihuahua, México. 2005.

Treatment	Rate (mg L ⁻¹)	Fruits per 100 clusters			Flower clusters/cm ² BCSA in 2006	TSHT at 60 DAFB (min/tree)
		27 DAFB [†]	42 DAFB [†]	56 DAFB [†]		
‘Golden Delicious’						
Late hand-thinned control		392 a	365 a	367 a	6.7 a	69.0 a
Ethephon	540	318 b	268 b	260 b	2.3 cde	30.6 b
Carbaryl	480	324 b	266 b	266 b	4.4 abc	30.0 b
NAA (K-salt)	16.6	328 b	156 d	137 de	1.5 cde	14.4 b
NAA (Fruitone N)	18.6	382 a	206 c	177 cd	3.9 abc	27.6 b
6-BA	95	408 a	281 b	270 b	0.1 de	30.6 b
Fish oil	6 mL L ⁻¹	383 a	344 a	337 a	3.0 bcd	60.0 a
6-BA + Carbaryl	95 + 240	277 c	222 c	216 c	2.1 cde	33.0
NAA (K-Salt) + Carbaryl	5 + 240	315 bc	204 c	204 c	0.05 e	30.0 b
Early hand-thinning		100 d	100 e	100 e	5.5 ab	14.4 b
LSD		40.2	40.5	40.2	2.9	20.7
‘RedChief Delicious’		38 DAFB	53 DAFB	66 DAFB		
Late hand-thinned control		300 a	217 a	200 ab	4.2 ns	30.0 a
Ethephon	540	236 b	162 bc	152 cd	2.9	31.2 a
Carbaryl	480	232 b	125 cd	112 de	3.6	28.2 a
NAA (K-salt)	16.6	223 b	130 cd	118 de	4.1	25.8 a
NAA (Fruitone N)	18.6	235 b	113 d	98 e	4.1	24.6 a
6-BA	95	227 b	158 bc	141 cd	2.8	26.4 a
Fish oil	6 mL L ⁻¹	210 b	128 cd	115 de	3.2	24.0 a
6-BA + Carbaryl	95 + 240	278 a	217 a	204 a	3.6	31.8 a
NAA (K-Salt) + Carbaryl	5 + 240	278 a	172 b	160 bc	3.7	29.4 a
Early hand-thinning		100 c	100 d	100 e	3.7	7.2 b
LSD		39.4	40.1	39.9	2.2	14.7

Means with different letter in a column are statistically different (Tukey, 0.05). DAFB = Days after full bloom; TSHT = Time spent for hand-thinning by one person per tree with 100 kg of fruit at harvest; BCSA = Branch cross sectional area. LSD = Least significant differences. ns = No significant differences.

Reduction of fruit set by most chemical thinners was easily visible at 27 DAFB for 'Golden Delicious' and at 38 DAFB for 'RedChief Delicious' (Table 3). It has been reported that a period of 10-30 DAFB is critical for fruit abscission, which is caused by reduction on photosynthate flow (Stopar, 1998). A blockage of photosynthate transportation between leaves and fruits has been reported as a thinning-mechanism for some chemical thinners (Dennis, 2002). In 2005 the fruit set reduction caused by chemical thinners was earlier than in 2004 (Tables 1 and 3), probably due to a higher fruitlet sensitivity to chemical thinning during the "off" year (year with a lower yield), as suggested by Lakso *et al.* (2006). Comparing the yield and flower density of the two evaluated years, it can clearly be seen the alternate bearing behavior of 'Golden Delicious' (Tables 1 to 4).

Except for fish oil, all treatments reduced the final fruit set in 'Golden Delicious', and also reduced the time spent for the supplementary hand-thinning practice (Table 3). This time reduction due to supplementary hand-thinning, represent a significant reduction in labor costs for growers, which fulfills one of the objectives estab-

lished for these trials. Treatments with NAA alone and the combinations of Carbaryl with 6-BA or with K-salt resulted in the lowest fruit set, whereas the K-salt by itself reduced fruit set at a similar level to the early hand-thinned trees (Table 3). Adding CB to the solution of 6-BA increased the thinning effect as compared to 6-BA alone. Despite the significative reduction of fruit set, a high yield was obtained with K-salt (Table 4).

The lowest fruit set in 'RedChief Delicious' was obtained with NAA, CB and fish oil treatments (Table 3), which were similar to that obtained by early hand-thinned trees. The mixture of thinning agents reduced the effect of the same agents when applied separately. Marini (2002) also reported a reduction in thinning effect when CB was added to the NAA solution. In spite of the fruit set results, there was no reduction in time spent for the supplementary hand-thinning practice, because the 'RedChief Delicious' trees used in this experiment are compact trees (small size) and easier and faster to thin. Phytotoxicity symptoms, such as fruit russetting or leaf epinasty, were not observed on any treated tree, similar to 2004 evaluations.

Table 4. Thinning effect on yield, and fruit equatorial diameter, firmness and total soluble solid content on 'Golden Delicious' and 'RedChief Delicious' apple trees grown at Cuauhtémoc, Chihuahua, México. 2005.

Treatment	Rate (mg L ⁻¹)	Yield (kg/tree)	Equatorial fruit diameter (mm)	Fruit firmness (N)	Total soluble solids (° Brix)
'Golden Delicious'					
Late hand-thinned control		13.6 d [†]	70.9 a	73.4 ab	15.3 a
Ethephon	540	73.4 ab	63.1 e	72.5 bc	13.2 cd
Carbaryl	480	58.4 bc	66.2 cd	75.6 a	13.3 bcd
NAA (K-salt)	16.6	99.2 a	66.6 cd	69.8 cd	12.4 e
NAA (Fruitone N)	18.6	54.8 bc	68.3 bc	71.2 bc	13.3 bcd
6-BA	95	102.4 a	68.1 bc	65.4 f	11.7 f
Fish oil	6 mL L ⁻¹	35.6 cd	69.1 ab	68.5 de	13.5 bc
6-BA + Carbaryl	95 + 240	55 bc	66.4 cd	71.6 bc	13.1 cd
NAA (K-salt) + Carbaryl	5 + 240	90.8 ab	64.9 de	65.8 ef	12.9 de
Early hand-thinning		56.8 bc	69.2 ab	69.8 cd	13.8 b
LSD		37.0	2.08	2.6	0.55
'RedChief Delicious'					
Late hand-thinned control		41.7 c	72.3 a	67.6 ab	13.9 a
Ethephon	540	33.1 c	67.2 c	63.6 bc	14.0 a
Carbaryl	480	55.9 abc	71.5 a	65.8 abc	11.8 e
NAA (K-salt)	16.6	47 bc	67.6 bc	62.7 c	12.8 cd
NAA (Fruitone N)	18.6	74.9 a	70.3 ab	64.9 bc	11.9 e
6-BA	95	67.2 ab	67.1 c	67.2 abc	12.0 e
Fish oil	6 mL L ⁻¹	78.5 a	70.9 a	65.8 abc	12.1 e
6-BA + Carbaryl	95 + 240	36.2 c	66.7 c	64.5 bc	13.1 bc
NAA (K-Salt) + Carbaryl	5 + 240	42.6 c	66.2 c	65.4 abc	13.6 ab
Early hand-thinning		42.0 c	64.7 c	69.8 a	12.2 de
MSD		24.5	2.9	4.87	0.70

[†] Means with different letter in a column are statistically significant different (Tukey, 0.05). LSD = Least significant differences.

Yield and fruit quality

An alternate bearing behaviour was observed on 'Golden Delicious', especially in late hand-thinned control, Carbaryl and fish oil treated trees. Highest yield was obtained with K-salt and 6-BA treatments, even with the low fruit set observed with K-salt. Similar results were found on 'RedChief Delicious' with Fruitone N and fish oil, which showed the highest yield values despite the low fruit set achieved (Table 4).

Fruit equatorial diameter in 'Golden Delicious' was greatest for the late hand-thinned control. This effect was related to the low yield registered in this treatment. It is well known that there is a negative correlation between the number of fruits per tree and the fruit size (Jackson, 2003). However, the greatest fruit size observed for the late hand-thinned control trees in 'RedChief Delicious' (Table 4) can not be explained in the same manner as with 'Golden Delicious'.

Highest fruit firmness was observed on Carbaryl and the late hand-thinned control treatments, whereas lower values were for 6-BA treated trees (Table 4). Late hand-thinned control produced fruits with higher total soluble solids content (Table 4), probably due to a high leaf:fruit ratio since these trees had a lower crop load. A similar behaviour was observed in 2004, despite a similar crop load (Table 2). Thinning treatments did not induce pygmy fruits at harvest in 'RedChief Delicious' (data not shown).

Return bloom

A high return bloom was observed on late hand-thinned control, Carbaryl and fish oil treatments as a result of the alternate bearing behavior of 'Golden Delicious'. Ethephon and 6-BA failed to produce a satisfactory return bloom in the second year of evaluation, like they did in 2005 (Tables 1 and 3). Even with the effectiveness of the chemical thinning treatments (Table 3), return bloom for 'RedChief Delicious' trees did not show any effect. A reduction in return bloom for all 'RedChief Delicious' trees was observed, may be due to a slightly higher yield per tree in 2005 than in 2004.

General conditions

The late season hand thinning, as commercially done, is an strategy devised to minimize the impact of late season frosts. Therefore, growers thin once in the Spring when frost probabilities are scarce. Some responses were common to both years; for example, time spent in hand-

thinning was 50 % lower in K-salt-treated trees than in late hand-thinned control trees for 'RedChief Delicious' (Table 1). Also, phytotoxicity effects such as fruit russeting or leaf epinasty, neither pygmy fruits were not observed in any of the chemical thinners tested.

CONCLUSIONS

Lowest fruit set was obtained with naphthalene acetic acid sprayed as chemical thinner in cultivars 'Golden Delicious' and 'RedChief Delicious', and sometimes fruit set was similar to that obtained with early hand-thinning. This reduction of fruit set did not affect yield or fruit quality at harvest. In 'Golden Delicious', all chemical treatments except fish oil, reduced the time spent for performing the supplementary hand thinning, and this reduced the cost of hand-thinning in 2005; this occurred in 'RedChief Delicious' in 2004 only when sprayed with K-salt. Alternate bearing observed on 'Golden Delicious' trees was not reduced by the chemical thinners.

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