

Thinning of Spur 'Delicious' Apples by Shade, Terbacil, Carbaryl, and Ethephon

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Abstract. Terbacil applied to whole-spur 'Delicious' apple (*Malus domestica* Borkh.) trees reduced photosynthesis and fruit set. The addition of the surfactant X-77 to terbacil sprays increased fruit thinning and leaf injury. Terbacil sprays applied to leaves only (fruit covered with foil) were as effective as when applied to leaves plus fruit. Dipping fruit alone in a terbacil solution did not cause abscission. Shading trees for 4 days with 92% polypropylene shade material reduced fruit set =50%. Spraying trees with carbaryl reduced fruit set by 25%. The combination of shade + carbaryl spraying reduced fruit set by 89%. Chemical names used: 1-naphthalenyl methylcarbamate (carbaryl); 3-tert-butyl-5-chloro-6-methyluracil (terbacil); 2-chloroethylphosphonic acid (ethephon); alkaryl polyoxyethylene alcohols (X-77).

Spur 'Delicious' apple trees may be thinned with terbacil, carbaryl, ethephon, Vydate, naphthaleneacetic acid (NAA), or naphthaleneacetamide (NAD). Sprays of NAD (50 mg·liter⁻¹) or NAA (10 mg·liter⁻¹ + surfactant) typically increase the number of "pigmy" fruit (abnormally small fruit) of spur 'Delicious' types, particularly at rates needed to cause thinning (Byers, 1978; Rogers and Thompson, 1969; Rogers and Williams, 1977; Unrath, 1978). Combinations of carbaryl plus NAA or NAD have provided excellent thinning in some years, but have caused serious overthinning or pigmy fruit in other years (Byers et al., 1982; Rogers and Thompson, 1969; Rogers and Williams, 1977; Unrath, 1978, 1981). Failure of ethephon thinning to improve fruit size, noted in some experiments (Knight, 1980) with 'Cox's Orange Pippin', has not been investigated thoroughly in spur 'Delicious' strains. Ethephon response has also been reported to be very temperature-dependent (Jones and Keen, 1985).

Carbaryl has not provided adequate thinning of spur 'Delicious' in the eastern United States, even with high rates and multiple applications (Byers, 1978; Byers et al., 1982; Forshey and Hoffman, 1966; Herrera-Aguerra and Unrath, 1980; Rogers and Thompson, 1969; Rogers and Williams, 1977; Unrath, 1981). Combinations of carbaryl plus a non-phytotoxic, highly refined paraffinic, 70-sec superior spray oil have provided additional thinning when applied with a hand gun sprayer (Byers, 1978; Byers et al., 1982). Vydate has provided about the same amount of thinning as carbaryl, but the addition of oil to this systemic

pesticide has not improved thinning (Byers, 1978; Byers et al., 1982). Vydate has also increased russet of 'Golden Delicious' fruit (Byers, 1978; Byers et al., 1982). Pigmy fruit has not been reported with Vydate or carbaryl treatments.

Shading limbs or spraying limbs with terbacil, a photosynthetic inhibitor, has caused thinning if done soon after full bloom (Byers et al., 1985, 1987; Del Vane et al., 1985). Airblast sprays of terbacil at 200 mg·liter⁻¹ almost defruited mature 'Starkrimson Delicious' trees without pigmy fruit or leaf injury occurring (Byers et al., 1985). Some leaf injury occurred when terbacil was applied to limbs with a hand pump sprayer at 400 mg·liter⁻¹. These limb treatments were not as effective as the 200 mg·liter⁻¹ airblast spray to whole trees. This difference suggests considerable compensatory effect when limbs alone are treated or that terbacil translocates out of limbs.

Surfactants have promoted additional thinning by NAA, but not with NAD, Vydate, or carbaryl (Forshey and Hoffman, 1966; Horsfall and Moore, 1961; Byers, 1978; Byers et al., 1982). When a surfactant is recommended, the rate of NAA used is usually half that when NAA is used alone. Since pesticides used in orchards have surfactants in the formulation to improve coverage (Horsfall and Moore, 1961), recommendations that double the rate of a thinner when no surfactant is used could cause more thinning when pesticide applications are made about the same time as thinner application.

Carbaryl is not considered a systemic chemical (Byers, 1978; Williams and Batjer, 1964). Williams and Batjer (1964) noted that carbaryl-induced thinning was not transmitted from one spur to adjoining untreated spurs and that fruit must be contacted directly. Knight (1983), however, found that carbaryl applied to the rosette plus bourse leaves or to the pedicel caused thinning, but not if applied only to rosette leaves. When ¹⁴C-labeled carbaryl was applied to the pedicel, a considerable portion moved to the fruitlet, but not if applied to rosette leaves. No ¹⁴C-labeled carbaryl was applied to the bourse shoot leaves in that study.

Our objectives were to determine: 1) the sites of terbacil and carbaryl absorption and subsequent effect as fruit thinners; 2)

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if surfactants increased efficacy of terbacil as a thinning agent; 3) if shading increased efficacy of carbaryl applications made to leaves, fruit, or both; 4) efficacy of the combination of carbaryl and ethephon; and 5) the commercial potential of terbacil applied with an airblast sprayer as a chemical thinner for spur 'Delicious' and 'Golden Delicious'.

Materials and Methods

Trees in all experiments were selected for uniformity of tree size and flowering. Limbs or trees were tagged when trees were in bloom because the potential for crop could be better assessed than if tagged after petal fall.

Experiment 1. Trees in Expts. 1, 2, and 3 were \approx 6 m high and 1.5 m in diameter and were sprayed with \approx 1.1 liter of spray solution with a hand pump sprayer. Each of four treatments was applied to single, whole 5-year-old 'Redchief Delicious'/MM.111 trees that were randomized in a complete-block design of six blocks. The spray treatments of terbacil (50 mg·liter⁻¹ + X-77 (1.25 ml·liter⁻¹), were applied to all fruit or leaves on each tree as follows: 1) control (no treatment), 2) fruit and leaves sprayed to drip, 3) leaves sprayed (fruit and pedicel covered with foil), and 4) fruit dipped. Full bloom occurred 19 Apr. 1985. Treatments were applied 6 May and fruit were counted 22 May. Fruit set was expressed as fruit/cm² of trunk cross-sectional area (TCSA). Photosynthesis was measured in the field on a clear day with a portable ADC infrared CO₂ gas analyzer (LCA-2) equipped with a Parkinson leaf chamber that exposed 6.25 cm² of the leaf to sunlight (Analytical Development Co. PK Morgan Instruments, North Andover, Mass.). Photosynthesis of three leaves on each of two trees per treatment was measured 3 days after treatment.

Experiment 2. Each of eight treatments was applied to single, whole 6-year-old 'Redchief Delicious'/MM.111 trees in a randomized block design of six blocks. The treatments were: 1) control (no treatment); 2-4) terbacil at 50, 75, or 100 mg·liter⁻¹ + X-77 each at 1.25 ml·liter⁻¹, respectively; 5) hand-thinning 36 days after full bloom (DAFB). Full bloom occurred 22 Apr. 1986. Treatments were applied with a hand pump sprayer on 6 May. On 28 May, hand-thinning was done and fruit counts were taken. Fruit set was expressed as fruit/cm² of TCSA. Leaf injury was rated from 0 to 10, with 0 = no injury, 4 = severe interveinal yellowing, 5 = some interveinal necrosis, and 10 = complete defoliation and twig injury or death.

Experiment 3. Each of nine treatments was applied to single, whole 6-year-old 'Redchief Delicious'/MM.111 trees in a randomized complete-block design of six blocks. Carbaryl 50WP (900 mg·liter⁻¹) was applied with a hand pump sprayer to point of drip and all treatments contained X-77 (1.25 ml·liter⁻¹). The treatments were applied to all fruit or leaves as follows: 1) control (no treatment); 2-4) carbaryl: fruit dipped, leaves sprayed and fruit covered with foil, or fruit and leaves sprayed; 5) 92% polypropylene shade over the entire tree; 6-8) same as carbaryl treatments 1-3, but were shaded for 4 days, as was treatment 5; and 9) hand-thinning at 34 days. Spray treatments were applied 9 May with a hand pump sprayer. Trees were shaded 9 to 13 May. Fruit set was expressed as for Expt. 2.

Experiment 4. Each of five treatments was applied to single, whole 11-year-old 'Oregon Spur Delicious'/seedling trees in a randomized complete-block design of six blocks. Treatments were applied 5 May 1985 with an airblast sprayer calibrated at 1683 liter·ha⁻¹ for a calculated tree-row-volume of 45% of a mature standard tree size (40,600 m·ha⁻¹, (Byers et al., 1984), Trees were spaced 5.5 × 7.9 m with a tree width of 3.7 m and

a height of 4.0 m. Treatments were as follows: 1) control (no treatment), 2) hand thinned 39 DAFB, 3) terbacil (50 mg·liter⁻¹) + X-77 (1.25 ml·liter⁻¹), 4) carbaryl (900 mg·liter⁻¹) + 70-sec viscosity superior oil (2.5 ml·liter⁻¹), 5) ethephon (450 mg·liter⁻¹) + carbaryl (900 mg·liter⁻¹).

Six limbs per tree, 1.5 to 2.5 cm in diameter with a uniform initial fruit set, were tagged 3 days before spraying. Fruits remaining on these limbs 39 DAFB were counted and expressed as fruit/cm² of limb cross-sectional area. Visual observation of crop load on whole trees was made 43 DAFB and was expressed as percentage of a full crop. Trees expected to produce a full crop of fruit of acceptable fruit size were equivalent to 100% crop load. If thinning were required to obtain adequate fruit size, maintain tree structure, or for return bloom, the tree received a rating of > 100% that was equivalent to the full crop (100%) plus an estimate of the percent of fruit needed to be removed (i.e., 200% crop would be equivalent to the need for removal of 50% of the fruit). Diameter of 10 fruits per tree was measured with a band caliper at 125 DAFB. Photosynthesis was measured with instruments described above on three leaves per tree for all six blocks for the control and treatments that contained terbacil.

Experiment 5. Each of seven treatments was applied to single, whole 12-year-old 'Starkrimson Delicious'/seedling trees or three treatments to 12-year-old 'Golden Delicious'/seedling trees that were in a randomized complete-block design of six blocks. The 'Golden Delicious' trees were pollenizer trees in the 'Starkrimson Delicious' planting. Treatments were applied 7 May 1986 with a Swanson airblast sprayer (Durand-Wayland Machinery, LaGrange, Ga.) calibrated at 2618 liters·ha⁻¹ for a calculated tree-row-volume of 70% of a mature standard tree (40,600 m·ha⁻¹) (Byers et al., 1984). Trees were spaced 5.8 × 8.2 m with a tree width of 4.6 m and a height of 5.0 m. Treatments for 'Delicious' trees were: 1) control (no treatment), 2) hand-thinned 51 DAFB, 3) terbacil (50 mg·liter⁻¹) + X-77 (1.25 ml·liter⁻¹), 4) carbaryl (900 mg·liter⁻¹) + 70 sec superior oil (2.5 ml·liter⁻¹), 5) ethephon (450 mg·liter⁻¹) + carbaryl (900 mg·liter⁻¹). Treatments for 'Golden Delicious' were: 1) control (no treatment), 2) hand-thinned 51 DAFB, 3) terbacil (75 mg·liter⁻¹) + X-77 (1.25 ml·liter⁻¹). Photosynthesis was measured as in Expt. 4 at 2 and 6 days after treatment for all six blocks of 'Delicious' trees. Diameter of 10 fruits per tree was measured with a band caliper 122 DAFB. Leaf injury was visually rated from 0 to 10, as described for Expt. 2. Crop load ratings were made as described in Expt. 4.

All data were averaged for each single-tree replicate before performing single-degree-of-freedom analysis, Duncan's multiple range procedures, or regression analysis. Where comparisons of dose-response relations of terbacil and the addition of X-77 to terbacil treatments were made, linear and quadratic relationships and curve comparisons were conducted by General Linear Model (GLM) procedures of the Statistical Analysis System (SAS) program package (SAS Institute, 1982) using dummy variables.

Results

Experiment 1. Spraying 'Redchief Delicious' trees with terbacil 17 DAFB (fruit size: 12.54 ± 0.47 mm) induced fruit abscission, as indicated by a reduced number of fruit/cm² of TCSA, and reduced leaf photosynthesis by 87% (Table 1). Spraying terbacil only on the leaves (rosette + bourse leaves: fruit covered with foil) caused fruit abscission. Dipping fruit did not cause thinning. These data are consistent with the hy-

Table 1. Effect of application site of terbacil on 'Redchief Delicious' apple fruit set and photosynthesis (Expt. 1, 1985)

Treatment ^{xy} (FB + 17 days)	Fruit/cm ² trunk cross-sectional area ^x (FB + 31 days)	Photosynthesis ^w (mg CO ₂ /dm per hr) ' FB + 20 days)
Control, no treatment	4.8 a	26.0 a
Fruit + leaves sprayed	2.9 b	3.4 b
Leaves sprayed	2.6 b	---
Fruit dipped	4.9 a	---

^xTerbacil (50 mg-liter⁻¹) + X-77 (1.25 ml-liter⁻¹).

^yFull bloom (FB) occurred 19 Apr. 1985. Fruit diameter was 12.5 ± 0.47 mm on 20 May (FB + 31 days).

^wMean separation by Duncan's multiple range test ($P = 0.05$).

^vMean separation by analysis of variance ($P = 0.05$).

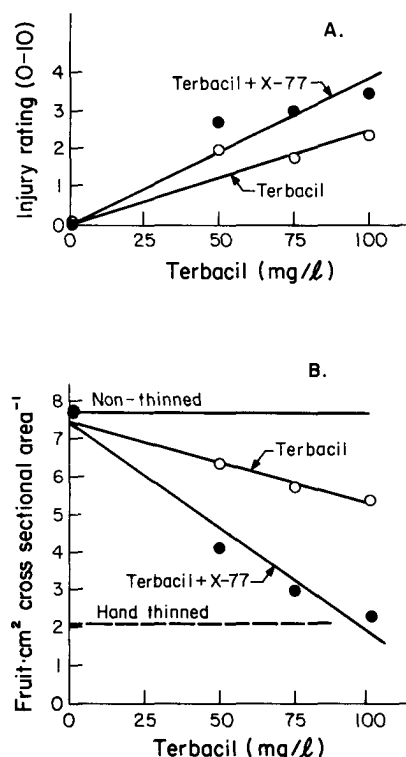


Fig. 1. Effect of terbacil on leaf injury (A) and fruit/cm² of limb cross-sectional area (B). The addition of X-77 surfactant significantly increased the effect of terbacil on injury and fruit thinning. A: terbacil- $y = 0.025x$, $R^2 = 0.95$; terbacil + X-77 = $y = 0.039x$, $R^2 = 0.93$ B: terbacil- $y = 7.56 - 0.023x$, $R^2 = 0.21$; terbacil + X-77- $y = 7.33 - 0.54x$, $R^2 = 0.64$.

pothesis that thinning caused by terbacil is due to a limitation of leaf photosynthesis (Byers et al., 1985, 1987; Del Vane et al., 1985).

Experiment 2. The addition of the surfactant X-77 caused leaf injury and increased thinning when added to terbacil sprays of 50, 75, and 100 ppm applied 15 DAFB (fruit size 8.79 ± 0.41 mm) with a hand pump sprayer [Fig. 1, as indicated by a statistical difference in slope of the two regression lines using dummy variable analysis (SAS Institute, 1982)]. No quadratic relationship was found with either terbacil or terbacil plus X-77.

Experiment 3. Spraying 'Redchief Delicious' fruit + leaves with carbaryl 17 DAFB (fruit size: 9.95 ± 0.41 mm) reduced

fruit set by 25% (Table 2). When only the leaves were treated (fruit covered with foil before spraying), or fruit only dipped in a carbaryl solution, no significant thinning occurred when compared to the control. Shading trees for 4 days caused more thinning than any of the carbaryl treatments (reduced fruit set by 50%) and gave fruit set the same as hand thinning 34 DAFB. Carbaryl-treated trees shaded for 4 days reduced fruit set by 89% and were thinned more than either carbaryl or shading treatments alone (Table 2).

Experiment 4. In 1985, airblast application of terbacil (50 mg-liter⁻¹, + X-77 to 'Oregon Spur Delicious' trees caused significant fruit thinning on fruit/cm² of limb cross-sectional area and on visual estimates of percent crop load (Table 3). No chemical treatment provided adequate fruit thinning or increased fruit size. Photosynthesis was reduced 65% by terbacil (50 mg-liter⁻¹) + X-77 when measured 3 days after treatment. Since carbaryl or ethephon plus carbaryl did not depress photosynthesis, all replicates were not measured for those treatments and data are not presented. No leaf yellowing or necrosis was noticed on any treatment. Visual rating of trees in full bloom the following spring indicated that only ethephon + carbaryl produced increased flowering relative to the control (Table 3).

Experiment 5. In 1986, airblast applications of carbaryl + superior oil and ethephon + carbaryl to 'Starkrimson Delicious' slightly overthinned the crop, but terbacil at 50 mg-liter⁻¹ + X-77 reduced the crop to 9.5% of a desirable crop load (Table 4) and caused serious leaf injury, yellowing, and interveinal necrosis in 'Starkrimson' and 'Golden Delicious'. This was the same concentration that did not adequately thin in 1985 (123% crop load).

Discussion

Limitation of photosynthesis by shading trees or by application of a chemical photosynthetic inhibitor has been shown to cause fruit abscission in the period soon after bloom (Byers et al., 1985, 1989; Del Vane et al., 1985). Application of terbacil or terbacil combined with carbaryl to fruit only did not cause thinning, which suggests that fruit photosynthesis may not be important for fruit retention. Preliminary data suggest that a cloudy or rainy day may reduce light levels by 90% or more and photosynthesis of leaves by 60% or more (R.E.B., unpublished data). Since as little as 3 days of shade can cause 45% reduction in fruit set (Byers et al., 1989), the combined effect of environmental shading and chemical thinner application could be a very significant factor and should be studied extensively. Results reported here showed that carbaryl was more effective when leaves were shaded. Since it is not unusual to have 2 to 3 consecutive days of either cloudy or rainy weather sometime during the thinning period, variability of thinning action could be more related to light levels during cloudy, rainy weather than rewetting and subsequent chemical absorption. Variability of results in experiments reported here may have been affected by their timing in relation to cloudy weather. Experiments involving shading and photosynthetic inhibitor effects could be more reliable if done in geographic locations that do not have clouds during the course of the experiment. However, in regions where clouds may be a regular occurrence, a smaller reduction in photosynthesis may be required to cause thinning than in regions with continuous high-light conditions.

Williams and Batjer (1964) reported that ¹⁴C-labeled carbaryl was mainly fruit-absorbed and that application of carbaryl to

Table 2. Effect of shading and carbaryl applications on thinning of 'Redchief Delicious' apple (1986).

Treatment ^{z,y} (FB + 17 days)	Treatment applied			Fruit/cm ² trunk cross-sectional area (FB -t- 34 days)
	Fruit dipped	Leaves sprayed	Fruit + leaves sprayed	
Control				5.3
Carbaryl	x			4.3
Carbaryl		x		5.8
Carbaryl			x	4.0
Shaded (4 days)				2.7
Shaded (4 days) + carbaryl	x			0.4
Shaded (4 days) + carbaryl		x		1.0
Shaded (4 days) + carbaryl			x	0.6
Hand-thinned (34 days AFB)				2.5
LSD (<i>P</i> = 0.05)				0.85

^zCarbaryl 50WP, a.i., 900 mg·liter⁻¹. All chemical solutions contained X-77 at 1.25 ml·liter⁻¹.

^yFull bloom (FB) occurred 22 Apr. 1986. Treatments were applied by spraying with a hand pump sprayer or by dipping fruit. Fruit diameter was 9.95 ± 0.41 mm when treated 9 May (FB + 17 days). Treatments shaded FB + 17 to + 21 days.

Table 3. Effect of apple thinners and terbacil on fruit thinning and photosynthesis of 'Oregon Spur Delicious' (1985).^z

Treatment ^{y,x} (FB + 16)	Concn (a.i.)	Fruit/cm ² limb cross- sectional area (FB + 39)	Percent crop load ^w (FB + 43)	Fruit diam ^w (cm) (FB + 125)	Photosynthesis mg CO ₂ /dm per hr (FB + 19)	Return bloom ^w (0-10)
Control		9.3 a	188 a	6.62 b	26.4 a	6.3 bc
Hand-thinned (FB + 39)		4.0 b	88 c	7.01 a	---	5.4 c
Terbacil 80WP + X-77	50 mg·liter ⁻¹ 1.25 ml·liter ⁻¹	6.7 bc	127 b	6.76 b	9.3 b	7.1 bc
Carbaryl 50WP + superior oil	900 mg·liter ⁻¹ 2.5 ml·liter ⁻¹	8.8 a	148 b	6.50 b	---	8.6 ab
Ethephon + carbaryl 50WP	450 mg·liter ⁻¹ 900 mg·liter ⁻¹	7.6 a	143 b	6.60 b	---	9.8 a

^zMean separation within columns by Duncan's multiple range test (*P* = 0.05).

^yFull bloom occurred on 19 Apr. 1985.

^xAll treatments were applied with an airblast sprayer at 1683 liter·ha⁻¹ 5 May (FB + 16) when fruit size was 10.7 ± 0.2 mm in diameter.

^wTrees with a full crop were equivalent to 100% crop load. Fruit size was taken near harvest. Return bloom rated 0 = no bloom, 4 = adequate for full crop, 10 = all spurs flowering.

leaves did not cause fruit thinning. Knight (1983), however, showed that ¹⁴C-labeled carbaryl may be translocated to the fruit from the pedicel but not from rosette leaves. However, he did not apply ¹⁴C-labeled carbaryl to bourse leaves. Carbaryl applied to bourse leaves in another experiment caused slight, but significant, fruit thinning. The significance of leaf absorption of carbaryl on thinning is still a question. Knight (1983) suggested that Williams and Batjer (1964) probably treated only rosette leaves, not the newly forming bourse leaves, which may be a major site of absorption. In our trials, shading trees previously treated with carbaryl was used to enhance the fruit thinning effect of carbaryl applied to fruit and leaves in an attempt to make the tree more sensitive to carbaryl thinning. Carbaryl applied to leaves (bourse leaves + rosette leaves) thinned as effectively as when carbaryl was applied to fruit only or to fruit and leaves under shade conditions. Our results support those of

Knight (1983) that leaves contribute to carbaryl absorption and action in addition to fruit absorption.

In the 1985 and 1986 airblast experiments, the chemical solution rate per hectare was increased from 1683 liters·ha⁻¹ to 2618 liters·ha⁻¹, respectively, since tree sizes were different [40% tree row volume (TRV) in 1985; 70% TRV in 1986]. Previous data indicated that chemical deposits are inversely related to tree size and canopy density (Byers et al., 1984) and that more uniform chemical thinning can be obtained by adjusting rates according to TRV calculations. The chemical rates per hectare were chosen in an attempt to apply equivalent chemical rates per unit area to tree leaves and fruit. The trees used in 1986 were larger and taller and the spray pattern was distributed more vertically than in 1985. Also, in 1986, the daytime high temperatures were 31, 32, 31, and 27C the day of the application and the following 3 days, respectively. In 1985, the

Table 4. Effect of thinners and terbacil on fruit thinning and photosynthesis of 'Starkrimson Delicious' and 'Golden Delicious' (1986).²

Treatment ^{yx} (FB + 16)	Concn (a.i.)	Fruit/cm ² limb cross- sectional area (FB + 51)	Percent crop load ^w (FB + 56)	Fruit diam ^w (cm) (FB + 122)	Injury rating (0-10)	Photosynthesis mg CO ₂ /dm per hr		Return bloom ^w (0-10)
						(FB + 18)	(FB + 22)	
<i>Starkrimson Delicious</i>								
Control		11.4 a	188.0 a	6.07 C	0.0 b	30.4 a	26.9 a	
Hand-thinned (FB + 51)		4.5 b	---	6.50 b	0.0 b	---	---	1.5 c
Terbacil 80WP + X-77	50 mg-liter ⁻¹ 1.25 ml-liter ⁻¹	0.7 c	9.5 c	7.59 a	3.3 a	14.7 b	10.9 b	9.8 a
Carbaryl 50WP + superior oil	900 mg-liter ⁻¹ 2.5 ml-liter ⁻¹	5.8 b	86.5 b	6.71 b	0.0 b	---	---	6.7 b
Ethephon + carbaryl 50WP	450 mg-liter ⁻¹ 900 mg-liter ⁻¹	5.2 b	86.5 b	6.65 b	0.0 b	---	---	7.4 b
<i>Golden Delicious</i>								
Control		12.4 a	196.0 a	6.32 b	0.0 a	---	---	
Hand-thinned (FB + 51)		5.8 b	---	6.71 b	0.0 a	---	---	0.0 a
Terbacil + X-77	75 mg-liter ⁻¹ 1.25 ml-liter ⁻¹	2.4 C	20.0 b	7.37 a	6.8 b	---	---	3.7 b

^zMean separation within columns by Duncan's multiple range test ($P = 0.05$).

^yFull bloom (FB) occurred on 21 Apr. 1986.

^xAll treatments were applied with an airblast sprayer at 2618 liters·ha⁻¹ 6 May (FB + 15) when fruit diameter was 9.9 ± 0.32 mm ('Starkrimson') and 9.2 ± 0.39 mm ('Golden Delicious').

^wTrees with a full crop were equivalent to 100% crop load. Fruit size was taken near harvest. Return bloom rated 0 = no bloom, 4 = adequate for full crop, 10 = all spurs flowering.

respective values were 26, 26, 18, and 23C. In 1986, serious leaf injury, yellowing, and interveinal necrosis occurred when 'Starkrimson Delicious', and 'Golden Delicious' were sprayed with terbacil (50 mg-liter⁻¹, + X-77 (1.25 ml-liter⁻¹). No injury had previously occurred when terbacil at 200 mg-liter⁻¹ had been applied with an airblast sprayer or where 200 mg-liter⁻¹ defruited trees (Byers et al., 1985). Injury had been seen in several experiments where terbacil had been applied with a hand pump sprayer, but this was the first time we observed an airblast application injuring leaves.

The 1986 airblast spray application of terbacil resulted in much more thinning and leaf injury than expected from previous work. We suspect that temperatures averaging 9C higher for the 4 days following the application in 1986 than 1985 might have been responsible for the increased thinning effects of terbacil. The ethephon and carbaryl treatments also caused more thinning in 1986 than 1985. The chemical rates per hectare in 1986 were higher than in 1985 and may have contributed to the increased thinning, but rates were applied on a TRV basis in an attempt to obtain similar chemical deposits per unit area. The importance of evaluating chemical thinning response in relation to environmental interactions of temperature, shade, re-wetting, and tree physiology cannot be overemphasized (Forshey and Hoffman, 1966; Hennerty and Forshey, 1972; Jones and Keen, 1985; Unrath, 1981).

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