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Endothall: A Blossom Thinner for Apples

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Summary. Endothall [7, oxabicyclo (2,2,1) heptane-2-3 dicarboxylic acid] is an aquatic herbicide with potential use as a blossom thinner for apples *(Malus domestics* Borkh.). Trials conducted in Washington, New Zealand, and Australia on several apple cultivars indicate that endothall is a safe, consistent blossom thinner. Cultivars treated were 'Golden Delicious', 'Delicious', 'Royal Gala', and 'Granny Smith'. Single and repeat applications were used in the New Zealand and Washington tests. With multiple applications of endothall, no fruit marking occurred on any of the test cultivars. In temperate fruit zones with extended apple bloom periods, multiple applications of endothall at a low rate may be beneficial for reducing fruit set and biennial bearing.

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For more than 40 years, the Washington apple industry used Elgetol as a blossom thinner for reducing biennial bearing of apples. In 1989, Elgetol was removed from the market. Without the use of Elgetol, many cultivars such as 'Golden Delicious', spur 'Delicious', and 'Fuji' become alternate-year fruit bearers. In Washington in 1993, about 50% of 'Golden Delicious' and about 25% of spur 'Delicious' trees were without full commercial crops because of biennial bearing. The biennial bearing pattern continues unless a blossom thinner and an early postbloom thinning spray are applied to the trees during the bearing year (Williams, 1993a, 1993 b).

Since the loss of Elgetol, only one new blossom thinner, sulfcarbamide (Wilthin), has been developed (Williams, 1993a). Wilthin is an effective blossom thinner for apples, but, if applied too late or at too high a concentration, it may cause fruit injury (Williams,1993a). Because of the consumer demand for unblemished fruit. other blossom thinners that do not mark fruit are needed. The following report covers trials with endothall, which has promise as a blossom thinner for apples.

Methods

In 1993, blossom-thinning trials were conducted at Wenatchee, Wash.; Havelock N., New Zealand; and Grove, Tasmania. Australia. -In 1994. commercial trials were conducted in Washington.

The 1993 Wenatchee trial was conducted on 16-year-old spur 'Delicious'- trees on MM. 106 rootstock trained to a central leader. Three uniform trees with full bloom were used for each treatment. and each tree was a single replication in a randomized complete block. The number of blossom clusters on 2-year-old and older wood were counted on each of three uniform middle to upper limbs per tree. The cross-sectional area of each limb was determined. and after Tune drop the number of persisting fruit was recorded and expressed as number of fruit per square centimeter of limb cross-sectional area. This method commonly is used in chemical thinning trials (Byers and Carbaugh, 1991; Forshey and Elfving, 1979). The control trees in all trials were not treated. The data from all trials were analyzed for variance, and the treatment means were compared using the Waller-Duncan K ratio t test at $\alpha = 0.05$.

Table 1. *Effects of endothall on fruit set of 'Delicious' apples at Wenatchee, Wash., 1993.*

Treatment[z]	Fruit/cm² limb cross-sectional area
Control	5.6 a
Endothall K-salt (a.i. 6.75%)	
1.0 ml·liter^{-1}	5.1 a[y]
1.5 ml·liter^{-1}	3.9 bc
2.0 ml·liter^{-1}	2.9 d
Endothall alkylamine salt (a.i. 6.75%)	
1.0 ml·liter^{-1}	3.1 cd
1.5 ml·liter^{-1}	3.2 bcd
2.0 ml·liter^{-1}	3.9 bc
Wilthin (a.i. 79%)	
2.5 ml·liter^{-1} + Regulaid 1.25 ml·liter^{-1}	3.8 bc
3.0 ml·liter^{-1}	4.1 b
LSD 0.05	0.97

[z]*Treatments applied with a high-pressure hand gun at 90% of bloom open following a rapid bloom period.*
[y]*Means within columns with common letters are not different by Wailer-Duncan analysis, K ratio* t *test,* = 0.05.

The chemicals used were the dipotassium salt of endothallic acid (a.i. 6.75%) and the alkylamine salt of endothallic acid (a.i. 6.75%) (ElfAtochem North America, Philadelphia). Wilthin, (a.i. 79%) (Unocal, Sacramento, Calif.) was compared with endothall. The sprays were applied to runoff with a high-pressure hand gun at 90% of blossoms open. The rates of chemicals used are given in Table 1. Day temperatures after spray application were 25 to 30C with no rain.

The Tasmania trials were conducted at the Grove Research Station on 7-year-old 'Golden Delicious' on seedling rootstock and on 7-year-old spur 'Delicious' trees on seedling rootstock trained to a modified central leader. Four uniform trees with full bloom were selected for each treatment in a randomized complete-block design. The number of blossom clusters and fruit set per square centimeter trunk cross-sectional area were recorded. Fruit counts were made after the December drop was complete.

The chemical used in Tasmania was the dipotassium salt of endothallic acid (a.i. 6.75%). The trees were sprayed to runoff with a high-pressure hand gun at either 60% or 80% of blossoms open. The chemical rates used are given in Table 2. Day temperatures after spray applications were 15 to 20C, and light rain occurred 6 h after spraying the 80% bloom application on 'Delicious' and after the 60% application on 'Golden Delicious' trees.

The Havelock N., New Zealand, trials were conducted on 'Royal Gala' and 'Delicious' trees that were 5 and 6 years old, respectively, on MM. 106 rootstock trained to a central leader. Four uniform trees with fill bloom were selected per treatment in a randomized complete-block design. The blossom clusters and fruit on three limbs per tree were counted and fruit number was expressed as number per square centimeter of limb cross-sectional area. Fruit counts were made after the December drop.

The chemicals used in New Zealand were the dipotassium salt of endothallic acid and Wikhin. Sprays were applied with a commercial air-blast sprayer using enough spray to moderately wet the foliage (2200 liters·ha^{-1}). The rates of chemical used are given in Table 3. Two applications at a low rate (0.75 ml·liter^{-1}) were compared to a single application of three different rates (0.5, 1.0, and 1.5 ml·liter^{-1}). The single applications were applied at 80% of blossoms open and the double sprays were applied at 60% and 80% of blossoms open. Day temperatures after spray application were 15 to 20C with no rain.

The 1994 trials in Washington were in commercial orchards of trelised 10-year-old 'Delicious' and 12-year-old 'Granny Smith' on M.26 rootstock. Sprays were applied to 150 trees per treatment by air-blast sprayer to drip. Before spraying in each treatment block, 10 single-tree replicates with fill bloom were selected at random for data collection. Blossom clusters were counted on whole trees, and fruit set was expressed as number of

Table 2. *Effects of endothall on fruit set of 'Delicious' and 'Golden Delicious' at Grove, Tasmania, 1993.*

	Fruit/cm² limb cross-sectional area	
Treatment[z]	Delicious	Golden Delicious
Control	6.1 a[y]	12.6 a
Endothall K-salt (a.i. 6.75%)		
0.5 ml·liter^{-1} 60% bloom	6.0 a	6.4 bc
1.0 ml·liter^{-1} 60% bloom	5.3 ab	5.3 bc
1.5 ml·liter^{-1} 60% bloom	4.9 b	1.7 d
0.5 ml·liter^{-1} 80% bloom	4.7 b	7.3 b
1.0 ml·liter^{-1} 80% bloom	4.4 b	6.7 b
1.5 ml·liter^{-1} 80% bloom	3.2 c	3.5 cd
LSD 0.05	0.91	2.73

[z]*Treatments applied with a high-pressure hand gun following an extended bloom period.*
[y]*Means with common letters are not different by Waller-Duncan analysis, K ratio* t *test,* $\alpha = 0.05$.

Table 3. *Effects of endothall on fruit set of 'Delicious' and 'Royal Gala' apples at Havelock N., New Zealand, 1993.*

	Fruit/cm² limb cross-sectional area	
Treatment[z]	Delicious	Royal Gala
Control	6.5 a[y]	5.8 a
Endothall K-salt (a.i. 6.75%)		
1 × 0.5 ml·liter^{-1}	5.7 b	5.0 bc
1 × 1.0 ml·liter^{-1}	5.4 bc	5.2 b
1 × 1.5 ml·liter^{-1}	5.0 c	3.8 cd
2 × 0.75 ml·liter^{-1}	4.2 c	2.9 d
LSD 0.05	1.32	1.39

[z]*Single applications applied at 80% of bloom open, two applications applied at 60% and 80% of bloom open with an airblast sprayer.*
[y]*Means within columns with common letters are not different by Waller-Duncan analysis, K ratio* t *test,* $= 0.05$.

Table 4. *Comparison of one and two applications of endothall and Wilthin as blossom thinners on apple, Wenatchee, Wash., 1994.*

	No. of fruit set/100 flower clusters	
Treatment	Delicious	Granny Smith
Control	67 a[z]	101 a
Wilthin (a.i. 79%)		
2.5 ml·liter^{-1} + 1.25 ml·liter^{-1} Regulaid (80% bloom)	49 bc	72 bc
Wilthin (a.i. 79%)		
2.5 ml·liter^{-1} + 1.25 ml·liter^{-1} Regulaid (65% + 80% bloom)	40 c	54 c
Endothall (a.i. 7%)		
1.0 ml·liter^{-1} (80% bloom)	46 bc	51 bc
Endothall (a.i. 7%)		
1.0 ml·liter^{-1} (65% + 80% bloom)	38 c	44 c
LSD 0.05	10.9	20.5

[z]*Means within columns with common letters are not different by Wailer-Duncan analysis, K ratio,* t *test* $= 0.05$.

fruit per 100 blossom clusters. Wilthin was applied as single and double applications to compare with a single and double application of endothall. The chemical rates used are given in Table 4. The double spray applications were applied at 65% and 80% of blossoms open and the single application of each chemical was applied at 80% of blossoms open.

Results and discussion

All of the 1993 Washington endothall treatments, except the low rate of the K-salt formulation, significantly reduced 'Delicious' fruit set (Table 1). The 1.0-ml·liter^{-1} rate of the alkylamine salt of endothall thinned more than the 1.0-ml·liter^{-1} rate of the K-salt formulation. The reason for the above likely was because of the increased wetting action of the alkylamine formulation. Some slight curling of primary spur leaves occurred with the K-salt formulation, whereas, more severe leaf curling resulted when the alkylamine formulation was used. To reduce the potential for leaf damage, all further trials were made with the K-salt formulation of endothall. No fruit marking occurred with any of the endothall treatments.

Wilthin also reduced fruit set; however, the high rate of Wilthin without surfactant caused some fruit marking.

The results of the endothall trials conducted in Tasmania on 'Delicious' and 'Golden Delicious' showed that all endothall treatments, except the low rates at 60% bloom on 'Delicious', resulted in significantly reduced fruit set (Table 2). The 1.5-ml rate was the most effective at either timing. The 1.0- and 1.5-ml·liter^{-1} rates of endothall caused some leaf and bud damage on 'Golden Delicious'. There was considerably less leaf curl on 'Delicious' than on 'Golden Delicious'. More leaf curl was present on the Tasmania 'Delicious' than on the Washington or New Zealand 'Delicious'. The rain after treatment in Tasmania could account for the increased leaf curl. The new leaves that developed after spraying were not affected. Even with more leaf curl, there was no fruit damage on 'Delicious' or 'Golden Delicious' in Tasmania.

In the New Zealand trials, the 0.5-,1.0-, and 1.5-ml·liter^{-1} single application rates significantly thinned 'Royal Gala' and 'Delicious' (Table 3). The two applications at the 0.75 - ml·liter^{-1} rate also significantly reduced fruit set. Even with two applications, there was only slight leaf curling. The lack of leaf damage in the New Zealand trial likely was related to the low rate of chemical used and less spray coverage (2200 liters·ha^{-1}) with the commercial air-blast equipment. Also, the smaller droplet size from the air-blast sprayer could be a factor in reduced leaf injury. No fruit damage was evident in any of the endothall treatments.

In the 1994 Washington commercial orchard trials, endothall significantly reduced fruit set on 'Delicious' and 'Granny Smith' (Table 4). One application at 80% of blossoms open reduced set by about 30% and two applications reduced set by about 50%. There was no fruit marking with the endothall sprays. Primary leaf curling with marginal leaf necrosis occurred on both cultivars treated with endothall. Wilthin also caused some marginal leaf necrosis on both cultivars. All leaves that developed after spraying with endothall or Wilthin were normal and the treatments did not appear to affect growth. This trial confirmed the 1993 New Zealand results in that lower fruit set occurred when two applications of endothall were applied. There was no attempt to compare the effects of rootstock or apple strains on the efficacy of endothall as a blossom thinner.

Endothall presumablv acts as a desiccant on the flower parts to prevent pollination and fertilization. The stage of bloom and the number of flowers open and fertilized compared to the number recently opened and not fertilized at the time of spray application are important considerations. The concentration of chemical also is important: it must be high enough to damage the style of the pistil but not damage the receptacle, which forms the fruit. Multiple applications of endothall were used in the New Zealand trials because flower opening occurred over a period of 2 weeks or more, and few flowers were open and susceptible to endothall damage at any one spray time. In some years in Washington, the bloom period is extended and multiple applications of a blossom thinner are needed.

Endothall was an effective blossom thinner on all of the cultivars treated and warrants further testing. The use of multiple applications at low rates can increase fruit thinning without seriously damaging leaves. In apple areas with extended bloom periods, repeat applications could be safe for effective early fruit removal. Some cul - tivars such as 'Golden Delicious' appear to be sensitive to endothall and may actually lose some spur leaves when chemical rates are too high. There were no observed adverse effects of endothall on fruit size or quality. Where significant fruit thinning occurred in 1993, return bloom in 1994 was adequate for a commercial crop.

The optimum time of application appears to be at 70% to 80% of blossoms open and after the king bloom, or strongest flower in the cluster, is pollinated and fertilized. Further trials with endothall are needed to determine the optimum time and rate of chemical application on other apple cultivars.

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