Effect of Fall Application of 2-Chloroethylphosphonic Acid on Apple Trees[1]

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Abstract. **Limb units and whole trees of 'Delicious' and 'Golden Delicious' sprayed in the fall with 250 ppm, 500 ppm and 1000 ppm Ethrel significantly decreased fruit set and vegetative growth the following season.**

The growth regulator 2-chloroethylphosphonic acid (Ethrel)[3] induces leaf senescence and abscission (2, 4). In an attempt to induce early defoliation and possibly increase hardiness of apple trees, we applied Ethrel in the fall of 1968. Earlier defoliation was induced on sprayed trees or limbs, however, there was no increase in hardiness. In the spring of 1969, we observed a retardation of flowering and vegetative growth on treated trees and limbs. Responses in the spring following application of Ethrel are reported here.

Individual limb units were selected on bearing 'Delicious' apple trees at Wenatchee, Washington. Whole trees of bearing 'Delicious' trees on EM IX and MM 26 rootstocks were also selected and treated in the same orchard. Young bearing 'Golden Delicious' trees on EM VII rootstock were also selected and treated. The whole tree treatments were replicated 4 times. Sprays were applied until "run-off" with a knap-sack sprayer. We also hand defoliated complete limbs to compare the effects of defoliation and Ethrel. After "June drop" was over, we determined the effect of Ethrel on fruit set by counting the number of fruit per 100 blossoming clusters. Vegetative shoot growth was measured after the terminal buds were set.

'Delicious' limbs and whole trees sprayed on September 30, and 'Delicious' limbs sprayed on October 16, 1968, with 250 and 500 ppm Ethrel had significantly less fruit set than the unsprayed branches, while at 1000 ppm no fruit was set (Table 1). Hand defoliation on October 16, decreased fruit set on limbs of 'Delicious'. Application of 250 ppm Ethrel reduced the fruit set to one-sixth that of untreated limbs. Hand defoliation and Ethrel at 250 ppm, and 500 ppm on whole trees significantly decreased fruit set the following spring. On 'Golden Delicious' trees, Ethrel at 500 and 1000 ppm significantly reduced fruit set the following year (Table 1). Defoliation occurred on November 1 on the untreated limbs and Ethrel limbs treated on October 16. Limbs treated with Ethrel on September 30 lost their leaves on October 20.

The florets on tree and limb units of 'Delicious' treated with 1000 ppm Ethrel never reached full bloom but developed only to the stage illustrated on Figure 1. Most of the florets abscissed, but a few subsisted in the undeveloped stage until the "June drop" period. Abscission of the 'Delicious' flowers treated with 250 and 500 ppm Ethrel did not occur until after full bloom. Flower abscission on 'Golden Delicious' trees treated with Ethrel occurred after full bloom.

Vegetative growth was greatly retarded on 'Delicious' limb units and 'Golden Delicious' trees treated with Ethrel. Growth was retarded by 250 ppm and 500 ppm Ethrel but to a lesser degree than with the 1000 ppm treatment. (Table 2).

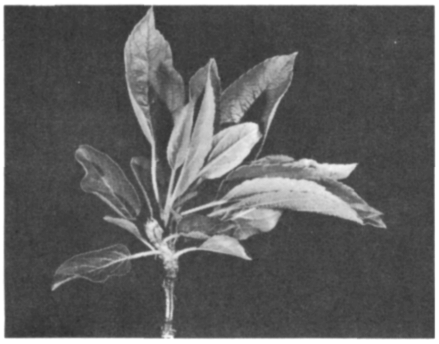

Fig. 1. 'Delicious' fruit spur treated with 1000 ppm Ethrel on September 30, 1968. Picture was taken June 3, 1969, one month after full bloom. Note aborted flower cluster on spur.

We found that Ethrel either eliminates or reduces fruit set when applied in the previous fall. Edgerton and Greenhalgh (3) on different varieties obtained similar results by applying Ethrel at periods between pre-bloom and harvest. Because of the significantly less fruit set on the Ethrel treated limbs and trees than the hand defoliated, there is an indication that an action of the chemical itself and not the process of early defoliation causes the decrease in fruit set. Cummins and Fiorina (1) delayed and retarded shoot growth in nursery stock by an autumn application of Ethrel. Our results were

Table 1. Fruit set in 1969 on apple trees treated with Ethrel in fall of 1968.

Type of Unit	Concn of Ethrel applied (ppm)	No. fruits/100 blossoming clusters		
		Date applied		
		9-20-68	9-30-68	10-16-68
Delicious Limbs	0		198a[1]	200a
	0 Hand defoliated			113b
	250		39c	49c
	500		8d	11d
	1000		0d	0d
Delicious Trees	0		155a	
	0 Hand defoliated		96b	
	250		109b	
	500		52c	
	1000		0d	
Golden Delicious Trees	0	82a		
	500	54b		
	1000	26c		

[1]Unlike letters in the same column indicate significant difference at the 1% level.

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[3]This chemical has been released in a formulation identified as Amchem 66-329. It contained, in addition to the acid, the mono-2-chloroethyl ester of the acid and the anhydride. Mention of a trademark name or proprietary product does not constitute a guarantee or warranty of the product by the U. S. Department of Agriculture, and does not imply its approval to the exclusion of other products that may also be suitable.

Table 2. Average length of vegetative shoots in 1969 on 'Delicious' limb units and 'Golden Delicious' trees treated with Ethrel in fall of 1968.

	Concn of Ethrel applied (ppm)	Length of vegetative shoots (cm)		
		Date applied		
		9-20-68	9-30-68	10-16-68
Delicious	0		32a[1]	33a
	250		15b	17b
	500		11b	13b
	1000		7c	7c
Golden Delicious	0	44a[1]		
	250	46a		
	500	33b		
	1000	21c		

[1]Unlike letters in the same column indicate significant difference at the 5% level.

similar to theirs but more pronounced, and may have been intensified by the cold temperature in the fall and winter of 1968, and different age trees.

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Ethylene Levels in Tomato Fruits Following Treatment with Ethrel[1]

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Abstract. **Internal ethylene concentrations in green tomato fruits rose to a maximum of 30 to 70 ppm within 2 to 5 hours of dipping in a 10,000 ppm solution of Ethrel (2-chloroethylphosphonic acid), then fell to approximately 5 ppm after 24 hours. A second rise in ethylene concentration was associated with fruit ripening, and was observed both in treated fruits and in untreated fruits which ripened as a result of removal from the plant. Incubation of Ethrel with homogenates of green tomato fruits likewise resulted in evolution of ethylene. Autoclaving or boiling the homogenates did not affect activity, indicating that release of ethylene from the chemical was non-enzymatic.**

Recent experiments by ourselves and others (6,8,9) have shown that 2-chloroethylphosphonic acid (Ethrel) stimulates ripening of banana and tomato fruits. The similar effects of this chemical and of ethylene, and the production of ethylene by Ethrel-treated pea stem sections, led Warner and Leopold (10) to conclude that Ethrel promoted ripening by stimulating ethylene production. Cooke and Randall (3) subsequently reported that Ethrel induced flowering in pineapple, and they attributed activity to non-enzymatic release of ethylene from the chemical itself. Hartmann, et al. (5) noted the evolution of ethylene from Ethrel-treated olive leaves, and Edgerton and Blanpied (4) and Warner and Leopold (11) have reported the gradual release of ethylene from aqueous solutions of Ethrel when the pH is raised to 4.9 and above. Our investigations were designed to determine the effects of Ethrel upon ethylene levels in treated tomato fruits, and to assess the role of fruit enzymes in the release of ethylene.

Experiments with intact fruits. Six plants of a tomato breeding line closely related to the 'Fireball' cultivar were grown in a greenhouse until the fruits on the second cluster were 4 to 6 cm in diameter. The plants were then transferred to the laboratory (23 C) where the fruits were treated and analyzed for ethylene. One green fruit was removed from each of the first 2 clusters on each plant, leaving a similar fruit attached. One of the 2 detached fruits and 1 of the 2 attached fruits from each plant were then held for 2 min in a 10,000 ppm solution of Ethrel (Amchem formulation 66-329), containing 0.1% Tween 20 as a surfactant. Detached fruits were left in the laboratory during the course of the experiment, while the plants with attached fruits were returned to the greenhouse after the first 24 hours, and moved to the laboratory only during sampling.

Fruits of the 'Fireball' cultivar were used in a second experiment. Mature green fruits were harvested from vines growing in a field plot at Geneva, and were taken directly to the laboratory for treatment and ethylene analysis. Ethrel was again used at 10,000 ppm.

Internal ethylene concentrations were determined as described by Burg and Burg (1), with minor modifications. Gas samples (0.2 to 1.0 cc per fruit) were withdrawn from the interior of the fruits with a gas-tight syringe while holding the fruits under water, and were chromatographed on a Beckman GC-5, using a 2-foot column of aluminum oxide at 50 C. Helium was used as carrier gas at a flow rate of 20 cc per min, and ethylene was detected with a flame ionization detector. With this system, the retention time of ethylene was 1.12 min, and less than 0.1 ppm was detectable in a 1 cc sample of gas. Reagent grade ethylene was used as a standard by preparing appropriate dilutions with air and plotting log peak height vs. log concentration. Before concluding that an observed peak was ethylene, gas samples were tested by injection into bromine water, which absorbs ethylene, and into 0.1 N NaOH, which does not (1).

Internal concentrations of ethylene in control and treated fruits (experiment 1) are graphed in Figure 1A. Ethylene levels did not exceed 3 ppm in untreated fruits during the first 5 days, while the levels in treated fruits

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