been obtained from preharvest application of ethephon made 2 to 3 weeks prior to normal harvest (3, 7, 10), hence, this seems the most appropriate time for ethephon application.

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Mid-summer Applications of Ethephon and Daminozide on Apples. II. Effect on 'Delicious'[1]

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Abstract. **Sprays of (2-chloroethyl)phosphonic acid (ethephon) applied to 'Delicious' apple trees (*Malus domestica* Borkh.) in July at concentrations of 500 to 1000 ppm shortly after the completion of June drop hastened the respiratory climacteric, and increased soluble solids, watercore and preharvest drop. These effects were diminished when 1000 ppm succinic acid-2,2-dimethyhydrazide (daminozide) was included with ethephon. All concentrations of ethephon increased flesh firmness. Two periods of fruit abscission occurred following ethephon application at high concentrations: shortly after application and immediately prior to harvest. After cold storage, fruit which had received 500 or 1000 ppm ethephon had less scald but a greater incidence of brown core. High ethephon concentrations increased bloom the following spring but had no influence on fruit set.**

We have reported the effects of ethephon and daminozide on flower bud initiation and quality of 'McIntosh' apples (3). This communication deals with the effects of mid-summer applications of ethephon and daminozide on 'Delicious' apples which respond somewhat differently from 'McIntosh'.

Materials and Methods

1974. A block of 40-year-old standard 'Delicious' apple trees at the Horticultural Research Center in Belchertown, Mass. was selected. Fourteen trees were used in the experiment with each tree representing 1 replication. Five uniform limbs per tree were tagged and on July 8 (shortly after the completion of June drop) ethephon alone at 250, 500, and 1000 ppm and ethephon at 500 ppm combined with 1000 ppm daminozide were applied with a hand sprayer to the drip point while one limb was left as a control. Fruit diameter measurements were made on July 9 and again on Sept. 23 on 30 tagged fruit per limb. Ten fruit per limb were harvested, cut, and the severity of watercore estimated on Sept. 24 using a scale of 0 to 7 (0 = no watercore; 7 = more than 50% of flesh affected). The remaining fruit on the tagged limbs were harvested on Sept. 30. Flesh firmness was measured on a 10-apple sample from each tagged limb using a Magness-Taylor pressure tested with a 11.1 mm head. Drop of the tagged fruit was recorded at 4- to 5-day intervals from July 15 to Sept. 23. Return bloom and fruit set were taken on each tagged limb in 1975.

1975. A block of 11-year-old 'Delicious' apple trees was selected at the Horticultural Research Center in Belchertown. On July 18 ethephon at concn of 250, 500, and 1000 ppm was applied either alone or in combination with 1000 ppm daminozide with a high pressure sprayer. In addition, 1 group of trees received 1000 ppm daminozide alone. Each treatment was replicated 7 times in a randomized block design. Forty fruit on 2 representative limbs on each tree were tagged prior to treatment. Fruit drop from these tagged fruit was recorded at 3- to 4-day intervals from July 21 to Oct. 2. Fruit diameter measurements were made on 30 tagged fruit per tree prior to treatment and again on September 18. Fruit were harvested at random from the periphery of the tree on Sept. 23 and 30 for determination of flesh firmness, and watercore as in 1974, and for internal ethylene determination and respiration as previously described (2). Soluble solids were determined with a hand refractometer on a 10-apple sample from each tree.

A 1-box fruit sample was stored at 0°C in air for 19 weeks. Upon removal from storage, flesh firmness of 10 fruit from each box was determined. The remaining fruit were examined for storage disorders after 7 days at 21°. Return bloom and fruit

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set were recorded on the tagged limbs in 1976.

Results

Flesh firmness. The application of ethephon in July generally resulted in increased flesh firmness at harvest (Tables 1 and 2), the increase being greater as ethephon concn increased. The only ethephon concn that failed to increase flesh firmness was 250 ppm applied in 1974. Daminozide alone increased flesh firmness, and its addition to the ethephon treatments resulted in flesh firmness values greater than those resulting from the use of either compound alone.

Fruit size. Ethephon at all concn reduced fruit size increase in 1974 (Table 1). In 1975 ethephon or daminozide alone did not restrict fruit size increase but when ethephon and daminozide were combined fruit size increase was reduced (Table 2). The excessive fruit drop within a week after application of 1000 ppm ethephon (Fig. 1) probably accounts for greater fruit size increase on the remaining fruit than on trees receiving the other treatments.

Fruit drop. Ethephon at 1000 ppm in 1974 caused 2 stages of abscission; 22% of the crop abscissed between July 15 and August 2 and another 51% from early Sept. through Sept. 23 (Table 1). Ethephon at 500 ppm caused 14% abscission between early Sept. and Sept. 23 and daminozide overcame this effect. In 1975, ethephon at 1000 ppm virtually eliminated the crop soon after application but the remainder of the data in Fig. 1 confirm the 1974 results, including the 2 stages of fruit abscission and the ability of daminozide to reduce ethephon-induced preharvest drop.

Watercore. Ethephon increased watercore at harvest and its severity was proportional to the concn applied (Tables 1 and 2). The addition of daminozide reduced watercore severity but did not eliminate it.

Soluble solids. Ethephon treatments of 500 and 1000 ppm increased soluble solids (Table 2) whereas the addition of daminozide either reduced or eliminated this response.

Respiration. Ethephon cuased an earlier climacteric rise in respiration (Fig. 2A) and appeared to increase respiration rate. The addition of daminozide reduced, but failed to offset these effects (Fig. 2B).

Internal ethylene. Ethephon at 250 ppm applied alone or with daminozide did not influence internal ethylene levels of the fruit (Table 2). Internal ethylene was increased in fruit receiving higher ethephon concn but the addition of daminozide either reduced or eliminated this response.

Storage. Following storage, flesh firmness of fruit receiving ethephon or daminozide alone was comparable to that of check fruit (Table 3). Fruit that received both ethephon and daminozide were firmer. Scald was reduced with ethephon at 500 ppm or 1000 ppm plus daminozide whereas brown core was increased when fruit were treated with ethephon at 500 ppm, and ethephon at 1000 ppm plus daminozide.

Return bloom and fruit set. Ethephon at 500 and 1000 ppm alone and ethephon at 500 ppm plus daminozide in 1974 increased bloom in 1975 (Table 4). In 1975 only 1000 ppm ethephon alone or with daminozide increased the bloom in 1976. However, neither year did the increased bloom result in increased total fruit set. In 1976 almost 20% of the total bloom on the 1000 ppm ethephon and the 1000 ppm ethephon plus-daminozide treated trees was due to lateral bloom on 1-year-old wood. The fruit set resulting from these flowers was significantly greater than that on the check trees.

Discussion

Ethephon at 1000 ppm alone or in combination with daminozide applied within 2 weeks after the completion of June drop

Table 1. Effects of July 8, 1974 applications of ethephon and ethephon plus daminozide on fruit size, preharvest drop, flesh firmness and watercore of 'Delicious' apples.

Treatment (ppm)		Fruit diam increase July 9-Sept. 23 (cm)	Fruit drop (%)		Flesh firmness Sept. 30 (kg)	Watercore Sept. 24 (%)
Ethephon	Daminozide		July 15-Aug. 2	Early Sept.-Sept. 23		
0	0	3.02a[z]	1b	4c	8.35c	2d
250	0	2.84b	0b	3c	8.39c	32c
500	0	2.84b	0b	14b	8.76b	73b
500	1000	2.64c	0b	3c	9.53a	30c
1000	0	2.76b	22a	51a	–[y]	95a

[z]Mean separation, within columns, by Duncan's multiple range test, 5% level.

[y]Insufficient fruit because of drop.

Table 2. Effects of July 18, 1975 applications of ethephon, and ethephon plus daminozide, on fruit size, fruit quality, and internal ethylene level of 'Delicious' apples.

Treatment (ppm)		Fruit diam increase July 9-Sept. 18 (cm)	Flesh firmness Sept. 30, 1975 (kg)	Watercore severity Sept. 30, 1975 (0-7)[y]	Soluble solids Sept. 25 (%)	Internal ethylene Oct. 1, 1975 (ppm)
Ethephon	Daminozide					
0	0	2.84b[z]	8.12f	0.4d	10.1de	0.07d
0	1000	2.76bc	8.58de	0.1d	9.7e	0.11d
250	0	2.76bc	8.48e	1.6c	10.3d	3.98cd
250	1000	2.61c	8.89bcd	0.4d	10.1de	1.90d
500	0	2.84b	8.80cde	3.5b	11.0bc	21.70ab
500	1000	2.71c	9.08bc	1.4c	10.6cd	2.56d
1000	0	3.02a	9.17ab	5.1a	12.6a	22.90a
1000	1000	2.66c	9.44a	4.2b	11.3b	12.84bc

[z]Mean separation, within columns, by Duncan's multiple range test, 5% level.

[y]Scale of 0 = no watercore to 7 = more than 50% of flesh affected.

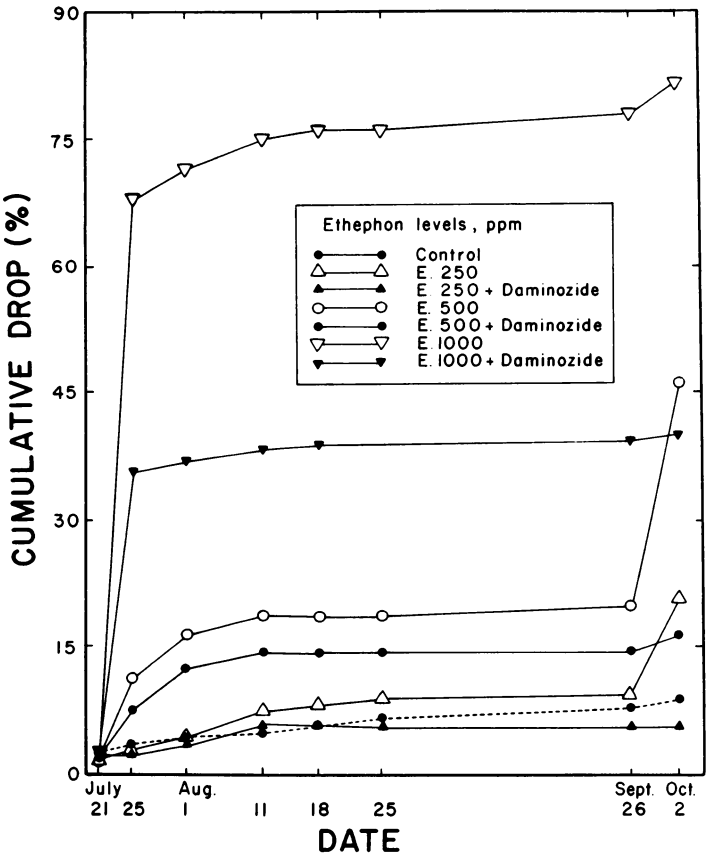

Fig. 1. Influence of ethephon and daminozide treatments applied on July 18, 1975, on cumulative drop of 'Delicious' apples.

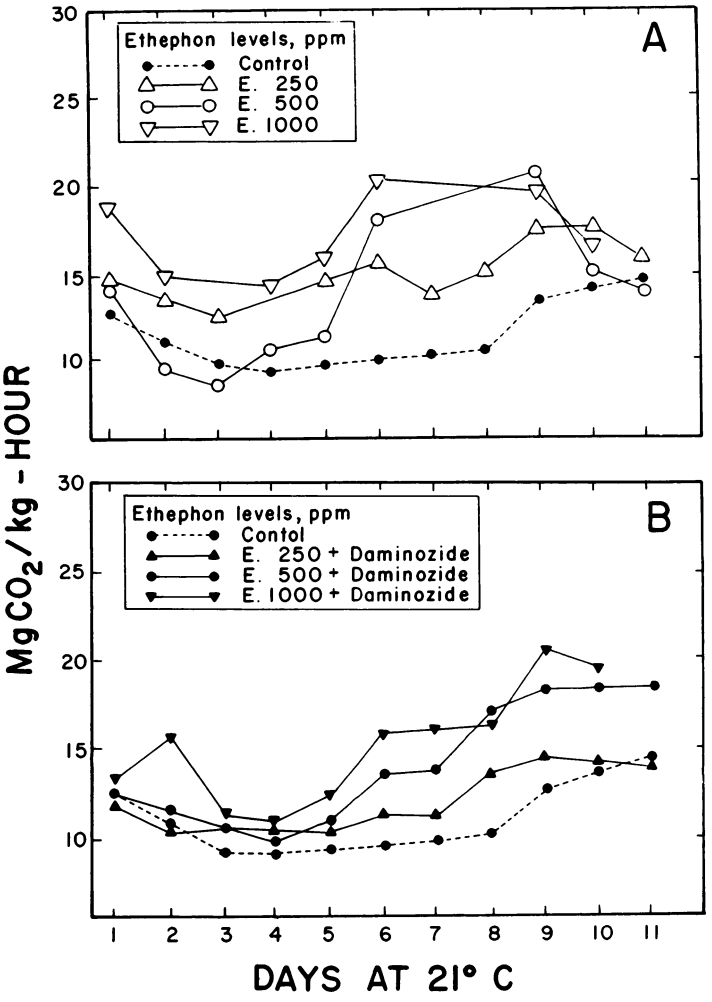

Fig. 2. Respiration rates of 'Delicious' apples treated with (A) ethephon or (B) ethephon and 1000 ppm daminozide on July 18, 1975, and harvested on Sept. 23, 1975.

caused fruit abscission shortly after application (Fig. 1, Table 1). We previously suggested that it might be possible to avoid fruit abscission from ethephon sprays by waiting until the completion of June-drop (6) but it is obvious that the response is too erratic. In 1973, an early post-June-drop application of 200 ppm ethephon caused no fruit abscission (6), but 250 ppm eliminated the crop in 1974 (2). In 1974, 1000 ppm ethephon caused all the fruit to abscise from 'McIntosh' trees, no abscission on 'Cortland' trees (2) and 22% crop loss on 'Delicious' within approximately a month of application (Table 1). In 1974, ethephon at 500 ppm caused no early fruit abscission (Table 1) but in 1975, 18% of the crop was lost within 2 weeks after application (Fig. 1).

We suspect that fruit abscission shortly after spraying is due primarily to high concn of ethylene liberated from ethephon and the second phase of drop in September (Table 1, Fig. 1) is caused by hastened maturation induced by the ethephon treatments applied 2½ to 3 months before normal harvest. Advancement of the climacteric (Fig. 2), high internal ethylene levels (Table 2), increased soluble solids (Table 2) and watercore (Tables 1, 2), reduced storage scald (Table 3) and increased brown core (Table 3) are all evidence of earlier maturation.

Whenever ethephon has been used as a preharvest treatment to advance the maturity of 'Delicious', a reduction in flesh firmness has been reported (4, 8). However, in this investigation ethephon treatments caused a flesh firmness increase (Tables 1, 2). At least part of the increase in flesh firmness was due to the presence of watercore because we selected additional samples of similar size fruit and found a correlation coefficient of 0.68 existed between flesh firmness and watercore severity. Daminozide alone increased flesh firmness and this has been reported by many. Although the effects of ethephon and daminozide were not additive, nor would they be expected to be, the firmest fruit were those that received both ethephon and daminozide (Tables 1, 2) probably due to the presence of watercore and/or fruit size reduction by daminozide. After cold storage flesh firmness differences caused by ethephon or daminozide alone had disappeared, but not that caused by the ethephon-plus-daminozide treatments (Table 3).

Application of relatively high concn of ethephon 53 to 60 days after full bloom resulted in increased flowering the following year (Table 4). Often, it is difficult to determine whether increased flower bud initiation following an ethephon application is a direct effect or due to thinning. In this investigation,

Table 3. Influence of July 18, 1975 application of ethephon and daminozide on flesh firmness and storage disorders of 'Delicious' apples following air storage at 0°C for 19 weeks.

Treatment (ppm)		Flesh firmness	Scald	Brown core
Ethephon	Daminozide	(kg)	(%)	(%)
0	0	6.47c[z]	20.0ab	1c
0	1000	6.72bc	25.1a	0c
250	0	6.63bc	3.4bc	4c
250	1000	7.32a	13.7abc	3c
500	0	6.61bc	5.7bc	23b
500	1000	7.29a	2.3c	9c
1000	1000	6.94ab	2.3c	35a

[z]Mean separation, within columns, by Duncan's multiple range test, 5% level.

Table 4. Effects of July applications of ethephon, and ethephon plus daminozide, on repeat bloom and fruit set of 'Delicious' apple trees.

Treatment (ppm)		Applied in 1974		Applied in 1975			
		Blossom clusters 1975	Fruit 1975	Blossom clusters 1976		Fruit 1976	
Ethephon	Daminozide	(per cm limb circumference)		Total	Lateral	Total	Lateral
				(per cm limb circumference)			
0	0	8.3c[z]	3.7ab	7.1c	0.1b	4.1a	0.1c
0	1000	–	–	7.5c	0.4b	5.0a	0.2bc
250	0	10.4bc	5.8a	8.4c	0.6b	4.1a	0.1bc
250	1000	–	–	8.8c	1.0ab	5.6a	0.5ab
500	0	11.6ab	5.1ab	9.0bc	0.3b	5.3a	0.1bc
500	1000	14.3a	5.8a	9.8bc	1.0ab	5.2a	0.4abc
1000	0	13.6b	3.6b	13.1a	2.2a	5.5a	0.7a
1000	1000	–	–	12.1ab	2.2a	5.3a	0.7a

[z]Mean separation, within columns, by Duncan's multiple range test, 5% level.

increased flower bud initiation cannot be solely attributed to thinning since ethephon alone or in combination with daminozide caused no fruit abscission until September (Table 1 and Fig. 1) but did increase flower bud initiation (Table 4). One would not expect increased flower bud initiation the following year from fruit removal or growth regulator sprays in September.

The increased flower bud initiation from ethephon alone or combined with daminozide was not accompanied by a corresponding increase in fruit set (Table 4). It is well established that under similar conditions per cent fruit set on trees with a "snowball" bloom is less than on those with a lighter bloom. Since the data for bloom and fruit set were taken on the same tagged limbs and data are expressed on a per cm limb circumference basis, our comparisons are valid. There are at least 2 possible explanations for the absence of increased fruit set. First, fruit set may be reduced because of increased competition due to more rapid vegetative growth during the spring and early summer of the year following growth regulator application (7). Since there was no difference in terminal growth in August, 1976, from treatments applied in July, 1975, (data not presented) this possibility may be eliminated. Secondly, there may be a carry-over effect of ethephon that may reduce fruit set. It has been shown that fall applications of ethephon can reduce set the following year (5) and ethephon applications even earlier in the season may result in smaller and less true-to-type 'Delicious' fruit shape (9). Unpublished results from this laboratory have shown elevated levels of ethylene in spur-bearing wood of 'McIntosh' over a year after the application of 1000 ppm ethephon. However, internal ethylene levels in the trees used in the present study were not different from the check trees when examined in early June, 1976. Thus, we have no satisfactory explanation for this result.

Preharvest application of ethephon to advance ripening of 'Delicious' has not been widely used commercially in the Northeast. The effectiveness of ethephon may be greatly reduced by the cool weather likely to occur when it is normally applied (1). Therefore, there may be some potential for summer applications of ethephon at low concn to advance ripening of 'Delicious' to avoid damaging freezes that sometimes occur in early Oct. However, there appears to be no commercial value of post-June drop ethephon treatments if the major goal is to increase repeat bloom and fruit set. Although significant increases in bloom can be achieved by application of high ethephon concn, the probability of excessive fruit drop that year is great with no corresponding increase in fruit set the following year.

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