Progress Report on the Use of 4-Thianaphtheneacetic Acid (4-TNA)[1]; a New Chemical for Fruit Thinning and Preharvest Drop Control of Apples[2]

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INTRODUCTION

Since 1941 considerable attention has been focused on plant regulator materials to control fruit abscission in commercial apple orchards. While some materials are now being used commercially to chemically thin apples in the spring and control preharvest fruit abscission in the fall, the response obtained has been too erratic from year to year. Some varieties of apples do not respond to applications of naphthaleneacetic acid (NAA), the most commonly used growth regulator for thinning, so the need is very great for a new compound that would dependably thin most important apple varieties year after year and control preharvest drop of fruit in the fall.

The possibility that 4-thianaphtheneacetic acid (4-TNA) could be used as a thinning agent and as a control for preharvest drop of apples resulted from investigations on the use of this compound to aid in the mechanical harvesting of cherries. Hammer (2) found that the compound caused the cherry fruit stem to stick to the tree and the fruit was more easily broken away from the stem when the trees were subjected to mechanical shaking. Lombard and Mitchell (3) applied 40 ppm of 4-TNA in a spray to individual Wealthy apple limbs just after petal fall

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1 4-thianaphtheneacetic acid supplied by the Upjohn Company, Kalamazoo, Michigan.

2 Information contained in this report to be submitted to the Proceedings of the American Society for Horticultural Science for possible publication.

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and found that the limbs were nearly defruited by the spray treatments.

As a result of these observations it was decided that a study should be made to compare the biological activity of 4-TNA and NAA so as to better judge timing and concentrations when the material was used in field evaluations. Based on the findings from the biological studies, 4-TNA was evaluated as a possible commercial material to chemically thin apples and control preharvest fruit drop.

MATERIALS AND METHODS

The avena straight-growth test and the petiole abscission test using Kentucky wonder beans (Phasealus vulgaris), and small apple seedlings were used to make the biological studies.

For comparing the biological activity of 4-TNA, NAA, and IAA the avena straight-growth test as described by Nitsch and Nitsch (4) was used. The concentrations of the compounds ranged from 5×10^{-8} molar to 10^{-3} molar.

In the abscission test using bean plants, each auxin treatment was applied to 10 replicated plants when two pairs of expanded leaves had formed on the plants. NAA and 4-TNA at 25 ppm concentrations were applied as: (a) a foliage spray, (b) a one ml. soil application, (c) a 10 ml. soil application, and (d) an injection into the main stem 4 mm. below the first pair of expanded leaves. Twenty-four hours after treatment the first pair of petioles were debladed on each plant. Daily counts of dropping petioles were made following treatments. Two weeks after treatment, when most of the debladed petioles had fallen, the plants were cut off at the ground level and the tops weighed. The plant roots were also removed from the growing media and observed for possible injury.

In the abscission test involving apple seedlings, apple seeds were germinated and the seedlings grown in the greenhouse until there were 10 to 12 fully expanded leaves on each plant. The lower four leaves were removed from each plant leaving the leaf petioles intact with the main stem. Twenty-four hours after the leaves were removed, NAA and 4-TNA at 20 ppm concentrations were applied

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to seven replicated seedlings as a foliage spray and as a 25 ml. soil drench. The controls were represented by seven seedlings receiving no chemical treatment. Counts were made daily of petioles dropping from the plants. Forty-two days after treatment the plants were harvested, dried at 70° C for 24 hours, and weighed.

Based on the results from the biological studies, field evaluations were conducted to determine the practicability of using 4-TNA as a chemical thinning agent and as a control for preharvest drop of fruit.

Mature Stayman Winesap and seven-year-old Jonathan apple trees were used to evaluate the thinning potential of 4-TNA and mature McIntosh trees were used for the preharvest drop studies. The chemicals evaluated were sprayed on the trees with an air blast speed sprayer (Meyer Model No. 227). Applications of 10 and 20 ppm of 4-TNA to Stayman Winesap trees were made on May 24, 1961 under fast drying conditions, 73° F and a slight wind. A light frost occurred on May 23, 1961 the day preceding the application date. NAA at 10 ppm and 4-TNA at 5, 10, and 15 ppm concentrations were applied to the seven-year-old Jonathan trees on May 30, 1961 under fast drying conditions, 65° F, sunny, and a slight wind. Applications of NAA, 2,4,5-TP and 4-TNA at 15 ppm concentrations were made to McIntosh trees on September 9, 1961 for the preharvest drop study and drop records were taken until the harvest date of October 9, 1961.

RESULTS AND DISCUSSION

Biological Studies:

In terms of biological activity, as measured by the avena straight-growth test, 4-TNA appears to be more active than NAA or IAA (Figure 1). At concentrations from 5×10^{-8}M. to 5×10^{-6}M., 4-TNA caused a greater elongation of the coleoptiles than NAA or IAA. As the concentration increased from 5×10^{-6}M. to 5×10^{-5}M., NAA and IAA continued to promote elongation of the coleoptiles while 4-TNA at this concentration caused an inhibition in elongation of the coleoptile sections. No elongation of the coleoptile sections occurred with any of

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the three chemicals at 10^{-3}M., indicating complete inhibition in elongation of the coleoptiles at this concentration.

Results from the abscission test also indicated that the biological activity of 4-TNA was quite similar to NAA (Figures 2 and 3). In the bean test, both compounds controlled petiole abscission to about the same degree with the big difference being in the method of application. Petiole abscission was controlled best by injection of the compounds into the main stem. A foliage spray was the next most effective way of controlling petiole abscission followed by a soil drench which was the least effective. NAA did appear to be more effective in controlling abscission than 4-TNA when used as a soil drench which may indicate the compound is more rapidly broken down in the soil than NAA. Both 4-TNA and NAA were found to promote abscission when used as a 1 ml. soil drench. These results appear similar to Gaur and Leopold (1) who found that high concentrations of auxins inhibited abscission while low concentrations have the opposite and promotive effect on abscision.

The results from the study involving the apple seedlings substantiated the work with the bean plants. Results indicated that 4-TNA inhibited abscission of apple leaf petioles slightly longer than NAA when used as a foliage spray but again NAA inhibited abscission longer than 4-TNA when applied as a soil drench (Table 1).

In evaluating the influence of the material on plant growth and foliage injury, 4-TNA was found to be similar to NAA (Tables 2 and 3). Both materials caused an inhibition in vegetative growth of bean plants when used as a 25 ppm foliage spray, but this inhibition was not evident when used as a soil drench. No visable injury was evident to the roots of the treated plants when observed following the experiment.

When applied to apple seedlings as a foliage spray, both compounds increased the size of the root systems over the control plants. Applications of 4-TNA to the foliage resulted in shorter plants but the accumulation of dry matter by the plant tops was greater than the control or NAA treated plants.

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All biological studies indicated that the concentration of 4-TNA for the field evaluations should be similar to concentrations normally used for NAA.

Field Evaluations:

The findings for the use of 4-TNA as a thinning agent for apples are given in Tables 4 and 5. Mature Stayman Winesap trees were thinned by applications of 10 and 20 ppm of 4-TNA. The size of the fruit from the 4-TNA thinned trees was appreciably larger than the fruit from the control trees. Total yield of fruit was less but this is normal and expected in thinning by any method. The harvested fruit from the 4-TNA sprayed trees were not as firm as the fruit from the control trees but this difference in firmness is probably because of differences in fruit size and not to any direct influence of the chemical on the fruit. All fruit were well colored and had a good finish and no differences were evident between fruit that had been sprayed with 4-TNA and those that had not been sprayed. Some flagging and rolling of the leaves were noticeable on the sprayed trees one day after the application of 4-TNA. As the season progressed, it was evident that the terminal growth of the 20 ppm sprayed trees was less than the control or 10 ppm sprayed trees and the slightly rolled appearance of the foliage remained throughout the season. However, no burning, scorching, or yellowing of the foliage was present at any time. The occurrence of a frost the day preceding the application of 4-TNA could have contributed to the amount of leaf rolling brought about by the 4-TNA spray. These findings indicate that the concentration of 4-TNA for Stayman Winesap should be about 15 ppm since the 20 ppm concentration caused slightly more leaf deformity than is desired.

The response of seven-year-old Jonathan trees to 4-TNA was somewhat different than Stayman Winesap. The concentrations of 5 and 10 ppm of 4-TNA appeared to have been too low, as little thinning resulted from sprays at these concentrations (Table 5). Sprays of 4-TNA at a concentration of 15 ppm thinned comparably to NAA at 10 ppm. No flagging or rolling of the leaves were evident following

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the application of the material to the Jonathan trees. No differences in fruit shape or color could be found at harvest on any of the 4-TNA sprayed trees.

The ability of 4-TNA to control preharvest drop of McIntosh apples is shown by the data in Table 6. Under the conditions of 1961, 4-TNA appeared to more effectively control the drop of fruit than either NAA or 2,4,5-TP. Since 1961 was not a serious preharvest drop year for McIntosh apples, the difference between sprayed and unsprayed trees was not as great as would be expected in a year when McIntosh tends to fall early. There was no apparent influence of any of the chemicals tested on the rate of fruit coloring in 1961. These preliminary results are particularly encouraging since 4-TNA appeared to be more effective in controlling preharvest drop of apples than the materials presently used by commercial fruit growers.

The first year's data, from the field evaluations of 4-TNA, indicated that 4-thanaphtheneacetic acid may prove to be a valuable chemical for fruit thinning and preharvest drop control of apples. While it is imperative that future tests be made to determine proper concentrations, timing, and residue accumulations, the possibility that 4-TNA could be successfully used in commercial fruit production appears to be very good. Information presented in this report should not be considered as specific recommendations for the use of 4-TNA to chemically thin apples and control preharvest fruit drop but only to act as a guide for further research.

SUMMARY

Biological and field comparisons of 4-TNA to NAA revealed the following:

1. Biological studies, using the avena straight-growth test and the petiole abscission test, indicate that 4-TNA is slightly more active than NAA and appears to have about the same influence on plant growth.
2. Fruit thinning investigations revealed that 4-TNA was a very effective fruit thinner on Stayman Winesap and Jonathan apple trees. The preliminary results suggest that the concentration of 4-TNA for Stayman

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should be between 10 and 15 ppm and for Jonathan between 15 and 20 ppm.

3. Preharvest drop studies indicated that 4-TNA controlled the preharvest drop of McIntosh apples better than NAA or 2,4,5-TP, with no undesirable influence on fruit quality.

LITERATURE CITED

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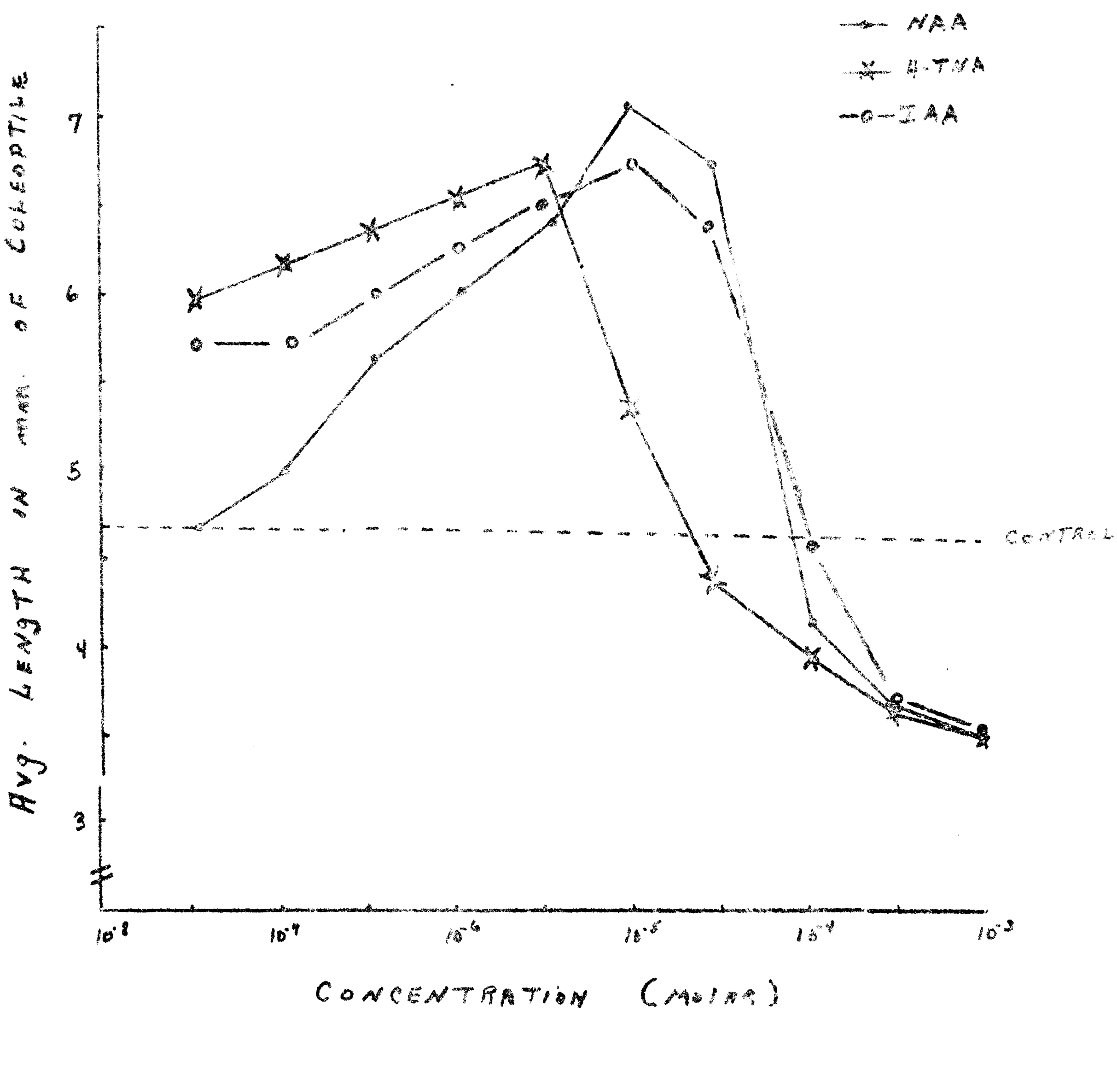

Figure 1. Biological activity of NAA and 4-TNA compared to IAA as measured by the Avena straight-growth test

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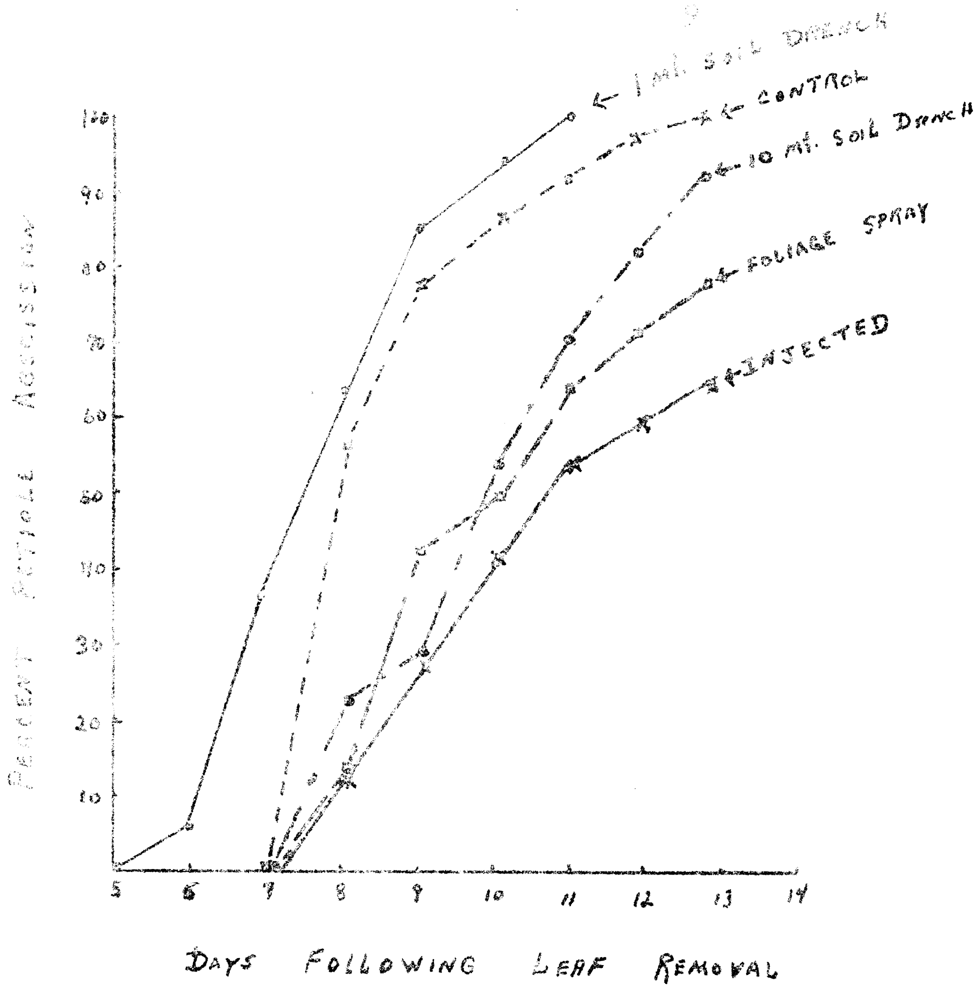

Figure 2. Influence of NAA placement on petiole abscission

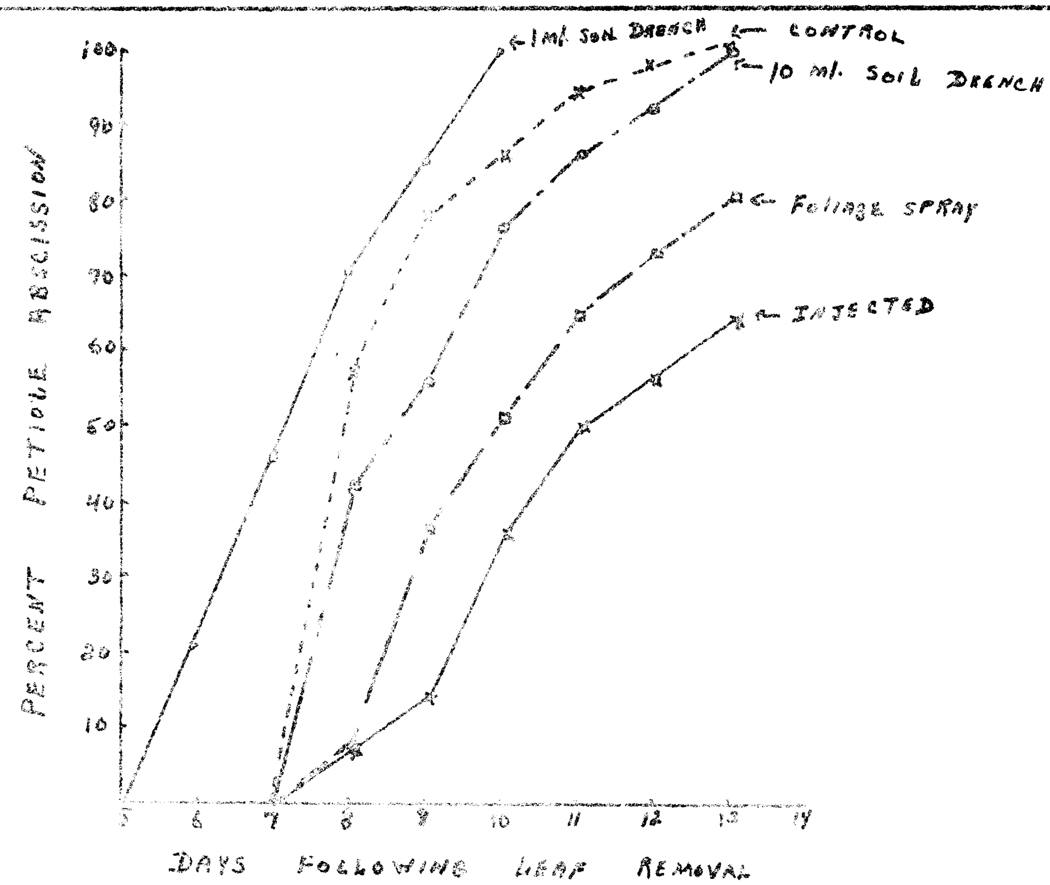

Figure 3. Influence of 4-TNA placement on petiole abscission

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Table 1

Comparison of 4-TNA and NAA when used as a Foliage Spray and as a Soil Drench to Control Leaf Petiole Abscission of Small Apple Seedlings

Treatment	Number of Days Required for 50% Abscission	Number of Days Required for 100% Abscission
Control	11*	19
NAA - Foliage Spray	21	35
4-TNA - Foliage Spray	25	42
NAA - Soil Drench	17	28
4-TNA - Soil Drench	16	25

* Number of days required for 4 petioles per plant to drop. Seven plants per treatment.

Table 2

Comparison of 4-TNA and NAA to Influence the Top Growth of Bean Plants

Treatments[a.]	Top Growth[b.*]
Control	6.4
NAA - Foliage Spray	5.1
4-TNA - Foliage Spray	5.3
NAA - Injected into main stem	6.0
4-TNA - Injected into main stem	6.0
NAA - 10 ml. Soil Drench	6.3
4-TNA - 10 ml. Soil Drench	6.8
NAA - 1 ml. Soil Drench	7.6
4-TNA - 1 ml. Soil Drench	6.7

a. The concentration of NAA and 4-TNA was 25 ppm.

b. Average fresh weight in grams. Ten plants per treatment.

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Table 3

Comparison of 4-TNA and NAA when used as a Foliage Spray and as a Soil Drench to Influence Growth of Small Apple Seedlings

	Size of Plants 42 Days After Treatment			
Treatment[a.]	Height (mm)	Top Dry Wt. (g.)	Root Dry Wt. (g.)	Shoot/Root Ratio
Control	22.7[b.]	2.38	.97	2.5
NAA - Foliage Spray	22.0	2.38	1.13	2.1
4-TNA - Foliage Spray	19.4	2.50	1.17	2.1
NAA - 10 ml. Soil Drench	22.8	2.62	1.03	2.5
4-TNA - 10 ml. Soil Drench	21.2	2.38	1.07	2.2

a. The concentration of 4-TNA and NAA was 20 ppm.

b. Average of 7 seedlings.

Table 4

Influence of 4-TNA on Fruit Set, Fruit Size, Yield, and Fruit Firmness of Stayman Winesap Apples

Treatment[a.]	No. Fruit per 100 Fruiting Clusters	Size cm.[b.] (Dia. of Fruit)	Yield Crate/Tree	Firmness[b.] lbs.
Control	100.1	7.6	15.7	18.2
4-TNA (10 ppm)	78.5	8.0	13.7	17.2
4-TNA (20 ppm)	41.5	8.4	9.7	16.4

a. Three trees per treatment.

b. Average of 20 fruit per tree.

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Table 5

Influence of 4-TNA and NAA on Fruit Set and Yield of Seven-year-old Jonathan Trees

Treatment*	Avg. No. Fruit 100 Fruiting Clusters	Avg. Yield Tree (lbs.)
Control	41	124
NAA (10 ppm)	27	110
4-TNA (5 ppm)	39	120
4-TNA (10 ppm)	34	105
4-TNA (15 ppm)	27	97

* Eight trees per treatment.

Table 6

Influence of 4-TNA, 2,4,5-TP, and NAA on Preharvest Drop of McIntosh Apples. 1961

Treatment*	Average Cumulative Percentage of Drop			
	9/28/61	10/2/61	10/6/61	10/9/61
Control	8.7	16.0	26.5	48.0
NAA (15 ppm)	7.1	12.7	20.9	40.3
2,4,5-TP (15 ppm)	5.9	11.7	20.2	40.1
4-TNA (15 ppm)	5.0	9.8	17.3	35.2

* Four trees per treatment. Average yield per tree 26.0 boxes.

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