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H. V. M.

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THE INFLUENCE OF CHEMICAL THINNERS ON PREHARVEST DROP OF THE MCINTOSH APPLE

INTRODUCTION

In recent years synthetic growth regulators of the naphthaleneacetic acid (NAA) type have been used extensively in the fruit industry for retarding preharvest drop and for reducing the set (thinning) in those years when oversetting is considered probable. Many of the practical problems concerning the use of synthetic growth regulators for preharvest drop control (28, 61) and, to a lesser extent, for thinning (6 66, 67) have been solved. Yet despite the extensive field work that has been carried on since the first report in 1939 (16) that dilute concentrations of NAA and naphthaleneacetamide (NAAmide) effectively reduced preharvest drop and a later report in 1941 (9) that the same materials also could be used for thinning, no entirely satisfactory explanation of the physiological mechanism of these synthetic growth regulators has been forthcoming. This lack of understanding of the mechanism involved has made it difficult to interpret some of the results obtained from chemical thinning experiments.

Luckwill (36) and others (44, 66) have reported that the average viable seed number of fruit is reduced following applications of NAA shortly after full bloom. Earlier work (55, 56, 57) has shown that at harvest time fruit with few seeds tend to abscise earlier than fruit with many seeds. If these observations are correct, i.e., if NAA actually does reduce the viable seed number, then it is conceivable that chemically thinned trees may be more susceptible to preharvest drop than similar hand thinned trees.

In the northeastern United States McIntosh is one of the principal apple varieties grown. In years when growers fear an overset of McIntosh, chemical thinning sprays are applied extensively to this variety. Because of the strong tendency of McIntosh to abscise at harvest time, it would be of economic interest to know whether or not these thinning treatments actually do have any influence on preharvest drop. The objective of this experiment was to determine the influence of chemical thinning treatments on preharvest drop.

REVIEW OF LITERATURE

The McIntosh variety in some years is especially susceptible to preharvest drop, which at times may be high enough to cause crop losses of 20 to 50 per cent (28, 55). Dilute applications of NAA retard preharvest drop long enough to allow a grower to hand pick the fruit (28).

On the other hand, growers are sometimes interested in increasing the rate of apple fruit drop shortly after the bloom period in seasons when a heavy bloom, ideal weather, and effective cross pollination favor excess fruit setting since the bulk of the crop on overset trees never attains sufficient size to bring a premium price.

Equally serious is the problem of biennial bearing. When the set is heavy one year (the "on" year), flower bud formation for the following year (the "off" year) may be limited or nil, resulting in a biennial bearing habit of a heavy crop one year and virtually no crop the next. Hand thinning is expensive and cannot be done early enough to influence the bearing habit of the trees (43). Various cultural practices have had little influence on the bearing habit of apple trees (4, 69). Application of NAA type materials from shortly after full bloom until four weeks thereafter has been found to reduce the set of fruit to a degree that permits development of optimum fruit size and early enough to break the biennial bearing habit of some apple varieties (59).

The observation that the abscission of young fruits is temporarily delayed following the application of synthetic growth regulators (36, 58, 63, 66) partially explains the apparent anomaly that the same material which retards preharvest drop stimulates abscission of young fruits. However, abscission of immature fruits differs physiologically from the abscission of mature fruits (38, 39, 41). In the spring, abscission is preceded by the differentiation of a narrow cell layer, called the abscission layer, across the pedicel through the abscission zone. In the fall, this abscission layer is not formed in the abscission zone (13). Abscission of both young and mature fruits follows the hydrolysis of pectic compounds in the middle lamella and primary walls of the abscission layer (young fruit) or abscission zone (mature fruit) (38, 39, 40, 41). The vascular tissue of the apple flower and young fruit is "undifferentiated procambium with occasional protoxylem strands" (38). Formation of sclerenchyma tissue and differentiated vascular tissue some time later may conceivably define the time limit beyond which chemical thinning treatments are ineffective. In the abscission of mature fruit, the vascular tissues are ruptured following dissolution of the pectic substances. Gawadie and Avery (18) suggest that since abscission of young leaves may proceed "without the intervention of the abscission layer," the effect of synthetic growth regulators on both young and mature fruits is an effect on cell disintegration, independent of cell differentiation. However, Brown and Addicott (8) found that the application of 2,4-D to the pulvinis of excised bean leaves not only stopped abscission but retarded the formation of an abscission layer which characteristically preceded abscission.

<u>Chemical thinning</u>:--In 1941, Burkholder and McCown (9), attempting to increase the set of Starking apples, found that the same materials used to control preharvest drop (NAA and NAAmide) would reduce the set of apples when applied at or shortly after full bloom. Two years later Green (20) confirmed this report. Schneider and Enzie (51, 52) were the first workers to deliberately attempt to thin apples with synthetic growth regulators.

Since these first reports, many papers have been published concerning optimum timing of applications (3, 30, 67), concentration of thinning materials (62, 67), and varietal differences of trees (6, 62).

In the spring, abscission of apple fruits proceeds in three waves (42).[1] The first wave is composed of unpollinated flowers; the second wave (which overlaps the first), of pollinated but unfertilized ovules which have immediately aborted (31, 32, 66, 68); and the third wave, or June drop, of fertilized ovules in which most of the embryos have aborted (12, 23, 25, 48, 49, 50). Seeds as the primary source of auxin in the fruit (21, 34, 35, 37, 46) provide a drawing force for nutrients and water (25, 47) as well as a hormonal stimulus for fruit growth (46). When the seeds abort, the fruit ceases to grow, probably because of a deficiency of nutrients, water, and growth stimulus (45, 66). Since auxins retard abscission, the abortion of auxin-rich seeds also results in abscission of the fruit (36, 45, 66), provided abortion occurs before some definite physiological stage in the development of the fruit (36, 67), which may be marked by the passage of the endosperm from the free nuclear to the cellular state (36, 47).

The natural abortion of fertilized ovules is generally felt to be due to either inherent genetic incompatibilities within the endosperm and embryo (19, 31, 32, 50, 68) or nutrient deficiencies (2, 10, 19, 48).

Because chemical thinners temporarily retard abscission, Struckmeyer and Roberts (63) proposed that the thinning action of synthetic growth regulators was due to increased nutrient competition. These workers

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[1]Murneek (42) has reported that the June drop is composed of two waves. Chandler (10) accepts this hypothesis, but Howlett (19) rejects it. Murneek's conclusion was based on limited data and is unconfirmed.

failed to note that potential June drops cease to grow appreciably prior to abscission and would thus not provide a source of competition for nutrients (66).

Synthetic growth regulators applied shortly after syngamy apparently cause embryo abortion (45). In the tomato (26) and in *Tradescantia* (65) embryo abortion is induced by dilute applications of NAA to the foliage or flower. Whether or not in the case of the apple the influence of NAA and NAAmide is directly on the embryo has not been conclusively demonstrated. However, that these materials do induce the apple embryo to abort seems fairly certain.

There is also some evidence that besides inducing embryo abortion in June drops, NAA may reduce the viable seed number of fruit that persist to maturity. Luckwill (36) has reported, "Seed counts on fruits harvested at the end of the season showed that although the total number of seeds per fruit was about the same for all treatments, there was a marked increase in the percentage of abortive seeds in fruits from branches sprayed between petal-fall and petal-fall plus 25 days." In another experiment on two trees of Crawley Beauty, Luckwill (36) found a greater number of aborted seeds in the June drops of the NAA sprayed tree than in the control (90 per cent versus 12 per cent), but after the June drop, the fruit of the sprayed tree had no more aborted seeds than the fruit of the control.

Murneek and Teubner (44) applied 40 ppm NAA to a number of Wealthy trees 21 days after full bloom. Nine days later examination of the fruit revealed no difference in size of the seeds from the fruit of untreated and treated trees, but the embryos of the seeds from the treated trees were "inhibited considerably," being on the average 2.71 $\pm$ .22 mm versus 3.73 $\pm$ .17 mm for those of the controls.

In a histological study of NAA induced embryo abortion, Teubner and Murneek (66) found that "the 'hormone' accentuated third drop, which was first evidenced by retarded fruit development, was comprised primarily of those fruits in which embryo development had been inhibited at either the 8-celled stage, which was of frequent occurrence at the time of spraying, or at the 16-celled stage, which had been reached in normal ovules by the 19th day (three days after spraying)." This accentuated third drop provided the only significant difference between the drop of the sprayed and control trees. However, embryo abortion did continue after this stage and was evident at the 30- and 60-celled stages of embryo development. Many of the fruit which contained the later aborting embryos persisted throughout the season. Teubner and Murneek's data show that after the June drop, the fruit on the NAA sprayed trees had many more aborted seeds than the fruit on nonsprayed trees.

Similarly, Hartman (24) has reported that the fruit of Golden Delicious trees sprayed with NAA had seeds which weighed less than seeds from the fruits of unsprayed trees.

<u>Preharvest drop</u>:--The demonstration by Gardner and Marth (16, 17) that the synthetic growth regulator NAA would effectively retard preharvest abscission and the subsequent confirmation of this report by other workers (5, 27, 28, 29, 61) has led to the alleviation of the problem of preharvest drop. Other growth regulating materials are being used to control preharvest drop of some apple varieties (54, 60, 61) but NAA effectively controls preharvest drop of McIntosh and often produces less ripening effect than some other materials (54).

Apparently, the abscission retarding effect which NAA has on mature fruit is the same or very similar to the effect synthetic growth regulators have on debladed (1, 7, 8) or defruited (66) petioles, on mature leaves (33), or on some flower petals (70). Evidently NAA supplements the diminishing abscission retarding auxin content of the mature fruit (34, 71, 72).

Such factors as a heavy crop, foliage injury from mites or frost, severe drought, magnesium or potassium deficiencies, nitrogen excesses, and low seed content, as well as warm weather or wind tend to accentuate preharvest drop (10, 29, 57, 61).

With respect to seed content, Heinicke (25) found that on comparable spurs the fruit with many seeds are more apt to survive the June drop and persist to maturity than the fruit with few seeds. The many seeded fruit were believed to have an advantage over few seeded fruit in obtaining nutrients. In the light of the present concept of the role and source of auxin in fruit (34, 37, 47), it would seem that the drawing force of seeds which Heinicke observed in apples is due to auxins originating in the seeds (15).

Since seeds are essential for most pome and stone fruit growth (cf. section on thinning) and seem to provide the auxin which inhibits abscission (35, 36, 72), an investigation of the seed content of mature fruit in relation to preharvest abscission is warranted.

Southwick (55, 56, 57) studied the influence of seed content of the McIntosh apple in relation to time of preharvest abscission. In trees of normal vigor, a significant correlation exists between viable seed number and date of preharvest drop. The correlation coefficient between seed number and date of drop of individual trees ranged from $+.264 \pm .023$ to $+.610$

$\pm$.012. A correlation coefficient of $+$.264, although statistically significant would account for less than 7 per cent of the variation in the time of drop, while a correlation coefficient of $+$.542 would account for approximately 30 per cent (55). Southwick (57) concluded, "The seed influence is manifest . . . and the apples with the most seeds tend to hang on the longest."

MATERIALS AND METHODS

The trees used in this experiment were 29-year-old McIntosh located in the University of Massachusetts Experiment Station Orchard in Amherst. Selection of the trees was based on cross-sectional area of the trunk (73) (Appendix, Table A). A nitrogen analysis of leaves collected in midsummer was made by a modified Micro Kjeldahl method (64) to confirm the uniformity of tree vigor (Appendix, Table A). The selected trees were divided into single tree plots in a randomized block design so that the results could be treated statistically. There were six treatments with six replications.

The sprays were applied from a six-nozzle broom and hydraulic pump. Care was exercised to minimize drifting of spray materials onto adjacent trees.

A spray application of 25 parts per million (ppm) of NAAmide was made at petal fall (PF) to two groups of six trees (Treatments 3 and 4, Table 2). This application was repeated 17 days after petal fall (Treatments 5 and 6, Table 2). The remaining trees served as checks (Treatments 1 and 2, Table 2). After the June drop the checks were hand thinned to the same degree of set as the set on the petal-fall-plus-17-days (PF ≠ 17) application.

Fruit set records were obtained by counting the number of blossoming clusters on three representative limbs per tree. By this method a total of 450 to 600 clusters were counted per tree. Following the June drop, all fruits remaining on these limbs were counted and the fruit set per 100 blossoming clusters determined.(67) (Appendix, Table A).

June drops were collected by gently tapping various limbs with a stick and catching in a sheet the young fruit which fell. It was believed that such a method would yield fruit on the verge of abscission. Fruit which persisted beyond the June drop were collected at random by stripping the fruit from small branches (35).

The average volume and weight, as well as the seed number and size, of these fruit were determined (Appendix, Tables C and D). After the fruit had been weighed and the volume determined (by water displacement) the fruit were cut transversely and the seeds removed. The number and size of the seeds in one-millimeter increments was noted (Appendix, Table B). Some of these seeds were oven dried at 70° C., weighed, and the average dry weight per seed calculated.

When preharvest drop of fruit began in September, 20 ppm of NAA was applied for drop control to one group of six trees in each of the three spring treatments (Treatments 2, 4, and 6, Table 5). A repeat application of NAA was made 11 days later to the same trees so that this phase of the study could be extended over a longer period of time. The drops were collected and counted daily. Each day ten drops were randomly selected from the drops of each tree. These fruit were stored for a seed count at a later date.

A record was kept of the number of bushel boxes harvested from each tree (Appendix, Table A). The average size of the fruit for a tree was estimated by placing an equal number of apples from a corner of each box harvested in an empty box. The number of apples required to fill this box was considered an indication of the average size of the apples from that tree (Appendix, Table A).

The seeds of the preharvest drops were counted and the number of normal and aborted seeds per fruit noted (Appendix, Table F). These seeds were placed in polyethylene bags, moistened, and after-ripened at approximately 40° F. for at least 60 days. One hundred seeds from each tree were planted and the percentage of germination recorded.

RESULTS

Since preharvest drop control materials are extensively used in the apple industry, this experiment was designed to determine the influence of the chemical thinner naphthaleneacetamide (NAAmide) on the preharvest drop of trees treated with the "stop drop" material naphthaleneacetic acid (NAA) as well as those which received no preharvest drop control treatment. Because the amount of reduction in set often varies with timing of the spray applications, two thinning dates were used. The possibility that each application might exert a different influence on the fruit or seeds of the fruit of treated trees was considered also. To provide a control for each phase of the experiment, the treatments were set up as indicated in Table 1.

Table 1.--Arrangement of treatments used in this experiment.

	Treatment	
Treatment no.	Spring	Fall
1	Hand thinned[a]	- - - - - -
2	Hand thinned[a]	"Stop drop"[d]
3	Chemical thinner at PF[b]	- - - - - -
4	Chemical thinner at PF[b]	"Stop drop"[d]
5	Chemical thinner at PF $\neq$ 17[c]	- - - - - -
6	Chemical thinner at PF $\neq$ 17[c]	"Stop drop"[d]

[a]After the June drop, June 24th.
[b]PF = petal fall, May 10th, 25 ppm NAAmide applied but ineffective.
[c]PF $\neq$ 17 = 17 days after petal fall, 25 ppm NAAmide applied, effective.
[d]20 ppm NAA applied on September 6th and 17th.

In the spring Treatments 1 and 2 served as checks for the thinning sprays (Treatments 3, 4, 5, and 6). In the fall Treatments 1, 3, and 5 were the controls for the "stop drop" applications on Treatments 2, 4, and 6, respectively. In the groups of trees which did not receive a "stop drop" spray, Treatment 1 is the control for Treatment 3 (unthinned) and for Treatment 5 (the effect of the chemical thinner NAAmide on preharvest drop). In the groups of trees which did receive a "stop drop" spray, Treatment 2 was the control for Treatment 4 (unthinned) and for Treatment 5 (the effect of the chemical thinner NAAmide on preharvest drop).

<u>Thinning results</u>:--From the fruit set records in Table 2 it is evident that the PF application (Treatments 3 and 4) did not reduce the set. The PF ≠ 17 application (Treatments 5 and 6) reduced the set to 50 per cent of that of the checks. There is no satisfactory explanation for this apparent incongruity within the same block. Since adequate chemical thinning of McIntosh may be accomplished anytime from full bloom to four weeks after petal fall, it is probable that unknown environmental factors altered the susceptibility of the fruit to the thinning action of NAAmide.

Since differences in fruit set might influence the rate and total amount of preharvest drop, it was considered essential that Treatments 1 and 2 (which received no chemical thinning treatment) be hand thinned to the same degree as Treatments 5 and 6. This was done on June 24th and 25th, shortly after the June drop was completed and set records for all treatments were obtained. After finding that NAAmide had failed to thin Treatments 3 and 4, it was decided not to hand thin them so that the influence of no thinning, and consequently larger crop size, on preharvest drop could be determined.

Table 2.--The influence of naphthaleneacetamide applied at petal fall and 17 days later on the set of McIntosh apples.

Treatment	No. of trees	Date applied	Fruits/100 blossoming clusters Before thinning	After thinning
1. Check hand thinned	6	PF[a] + 45	51.0	25.5[e]
2. Check hand thinned	6	PF[a] + 45	56.3	28.1[e]
3. NAAmide 25 ppm	6	PF[b,d]		43.5
4. NAAmide 25 ppm	6	PF[b,d]		51.0
5. NAAmide 25 ppm	6	PF + 17[c,d]		27.1
6. NAAmide 25 ppm	6	PF + 17[c,d]		26.8
L. S. D. at 5 per cent level				10.4

[a]PF = May 10th
[b]Temperature at time of application (8:00 - 9:00 a.m.) was 77° F.
[c]Temperature at time of application (2:00 - 3:00 p.m.) was 75° F.
[d]Minimum temperatures in low area 50 yards northeast of McIntosh block were 32° F. on May 3d and 28° F. on May 20th.
[e]Checks hand thinned 50 per cent after the June drop, June 24th - 25th.

June drops:--Two collections of June drops were made, one on June 9th (PF + 30) and one on June 16th (PF + 37). A cursory examination showed that none of the drops contained viable seeds. It was decided to measure the length of the aborted seeds to see if such data would yield information on the time of abortion. Because of the small size of the seeds of the fruit collected on June 9th, only the drops collected on June 16th were examined. Since Treatments 3 and 4 (25 ppm NAAmide at PF) did not reduce the set, no seed counts were made on the fruit from these trees at any time.

Contrary to the reports of Luckwill (36) and Teubner and Murneek (66), there was only a negligible number of normal seeds in the drops of both sprayed and unsprayed trees (Table 3), nor was any difference apparent in regard to the average size of the fruit, the number of seeds per fruit, or the size of the seeds.

Table 3.--Average diameter of fruit, weight and number of seeds, number of normal seeds, and number of aborted seeds of various sizes in the June drops of chemically thinned and hand thinned McIntosh.[a]

Treat-ment	Fruit diameter (cm)	Wt of seeds (mg)	Number of aborted seeds					No. of normal seeds
			Total	<3 mm	3-4 mm	4-5 mm	>5 mm	
1 and 2	1.93	1.21	6.27	.35	1.40	2.72	1.80	.01
5 and 6	1.87	1.13	6.22	.33	1.37	2.90	1.54	.07

[a]Data based on 752 fruit from seven hand thinned trees and 505 fruit from five chemically thinned trees (cf. Appendix, Table B).

It is possible that the majority of the fruit examined were natural June drops and did not abscise as a result of the NAAmide spray. Teubner and Murneek (66) have pointed out that of the fruit lost in the June drop, those which may be attributed to the action of the chemical thinning sprays abscise in a definite surge sometime after the spray is applied.

In the June drops the limited number of seeds which were not completely aborted appeared to be in the process of aborting. These aborting seeds contained smaller embryos than those of the normal seeds of persisting fruit. The endosperm of the aborting seeds definitely showed signs of collapse. Apparently, under the conditions of this experiment, the June drops did not abscise until all or most of the seeds had aborted.

Fruit collected after the June drop:--Several workers (36, 44, 66) have proposed that chemical thinning treatments may reduce the viable seed number of the fruit which persist to maturity. The data in Table 4 show that there was no difference between the average seed number of the fruit from sprayed and unsprayed trees. However, because no fruit were collected prior to application of the spray materials, we cannot be positive that the seed number was not affected. The average seed number varied considerably from tree to tree and it is possible that this variation would mask a small but significant reduction in the average viable seed number.

The data in Table 4 show that the average viable seed number of the fruit from individual trees ranged from 2.3 to 8.2 seeds per fruit. In general, a low average viable seed number is correlated with a high average aborted seed number. Southwick (55, 57) has reported the average seed number of McIntosh to range from six to nine seeds per fruit. Few of the trees in this experiment had an average seed number over six seeds per fruit.

No reason is apparent for the high rate of seed abortion observed. Abortion occurred in both chemically thinned and hand thinned trees. There was no apparent relation between the average seed number of the fruit and the proximity of the trees to some Wealthy pollinizers.

Many of the fruit contained only aborted seeds (for actual percentage see Tables 13 and 14). But, almost all of these fruit contained some aborted seeds over five millimeters in length, which would indicate that these seeds had not aborted until nearly full grown; i.e., near the end of the June drop.

The relation of seed number to set:--Batjer and Hoffman (6) have suggested that "under conditions of a low average seed content, a postbloom spray of naphthaleneacetic acid may thin heavier than when the average seed content is high following strong cross pollination."

Table 4.--Average seed number of fruit persisting beyond the June drop, collected June 23d.

Tree	No. of fruit	Normal seeds/fruit	Aborted seeds/fruit
Treatment 1. Hand thinned at PF[a] + 45 Preharvest drop control: None			
C-24	54	4.00	2.28
C-12	50	4.84	2.50
C-6	52	4.85	2.23
E-16	51	4.29	2.94
G-16	52	5.86	2.00
G-4	51	5.85	1.78
Ave.		4.94	2.28
Treatment 2. Hand thinned at PF[a] + 45 Preharvest drop control: 20 ppm NAA on 9/6 and 9/17			
A-8	50	5.00	2.01
C-16	51	5.22	1.63
E-2	52	8.17	1.50
E-6	50	4.10	4.01
G-20	51	6.73	2.02
G-6	48	5.13	1.06
Ave.		5.75	2.05

[a]PF = petal fall, May 10th.

Table 4.--Continued

Tree	No. of fruit	Normal seeds/fruit	Aborted seeds/fruit
Treatment 5. Chemically thinned with 25 ppm NAAmide at PF[a] ≠ 17 Preharvest drop control: None			
A-14	50	5.94	.94
C-10	49	4.96	3.96
C-4	49	4.80	1.79
E-12	37	4.19	3.81
G-22	49	5.29	2.84
G-12	51	5.37	2.80
Ave.		5.13	2.54
Treatment 6. Chemically thinned with 25 ppm NAAmide at PF[a] ≠ 17 Preharvest drop control: 20 ppm NAA on 9/6 and 9/17			
A-10	49	6.61	.51
C-22	50	4.40	1.54
E-4	53	2.26	6.55
E-14	52	3.98	2.75
G-18	52	4.15	2.92
G-10	52	3.60	2.09
Ave.		4.14	2.77

The data presented graphically in Figure 1 show that there was no relation between set and seed number of hand thinned trees, but as can be seen in Figure 2, there was a significant positive correlation between set and seed number of chemically thinned trees.

Apparently, the NAAmide thinning spray either reduced the average viable seed number proportionately to the degree of thinning, or thinned those trees with an initially low average seed number to a greater degree than the trees with a high average seed number. At present it is not clear whether this relation is one of cause or of effect.

"Stop drop" application:--The data on the average cumulative percentage of preharvest drop is presented in Table 5 and Figure 3. The adjusted treatment means of cumulative preharvest drop (in bushels) are shown in Table 6. NAA was not as effective in retarding preharvest abscission as it has been in some years (5, 28). Hitchcock and Zimmerman (26) have noted that the effectiveness of preharvest drop sprays often varies from tree to tree. Such was the case in this experiment and may explain why a difference of 14 per cent between Treatments 1 and 2 (Table 5), or of 13 per cent between Treatments 5 and 6 (Table 5) is not statistically significant. However, in the case of the hand thinned trees, the preharvest drop control application, Treatment 2, was significantly better than Treatment 1 at the 5 per cent level when the results were computed by angles rather than by per cent.

The average cumulative percentage of preharvest drop records in Table 5 show that NAA applied to the hand thinned trees (Treatment 2) resulted in significantly less preharvest drop than occurred from trees which were not thinned (Treatments 3 and 4) or from the chemically thinned trees not

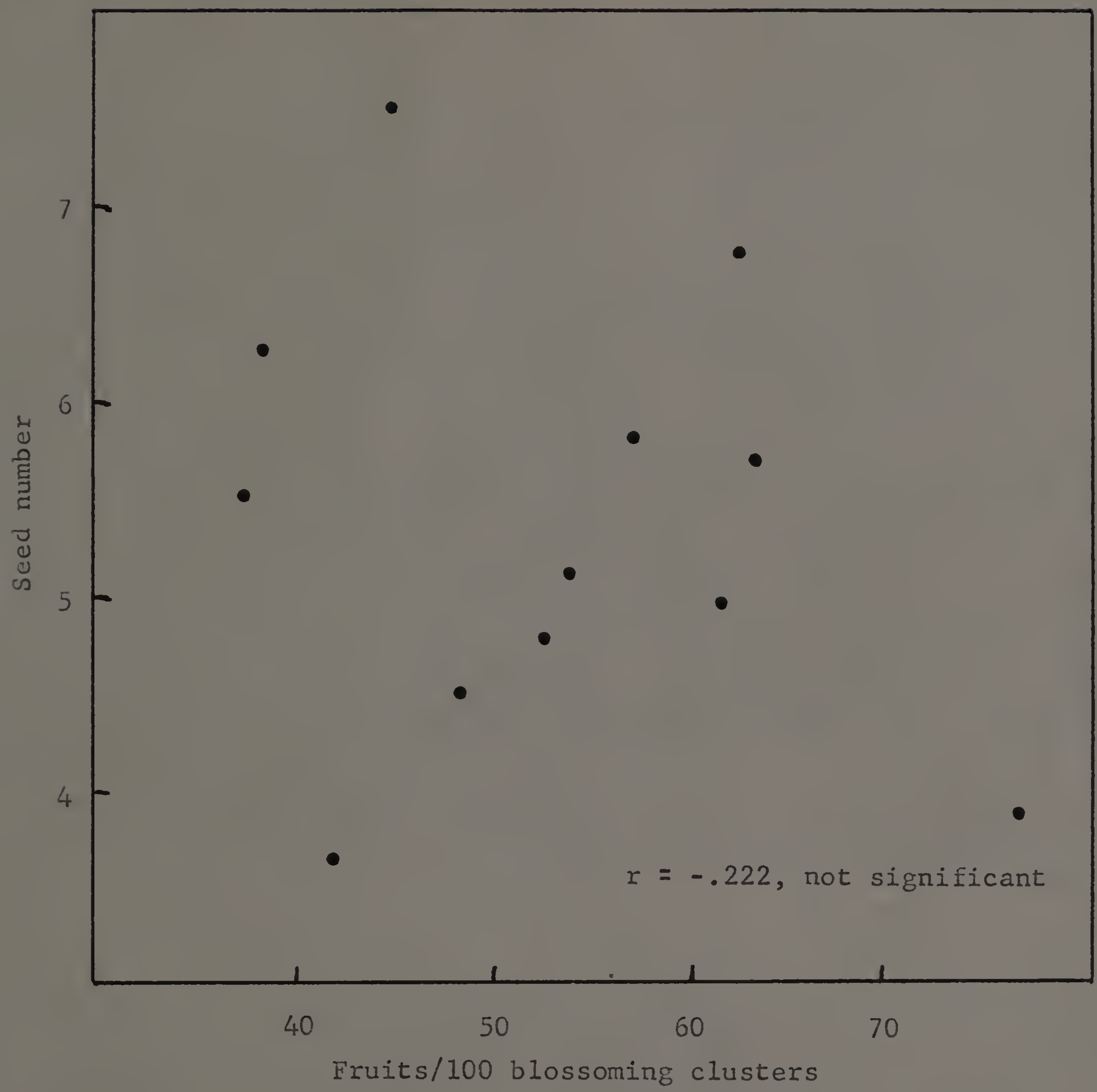

Fig. 1. The relation between seed number[a] and fruits per 100 blossoming clusters of 12 untreated McIntosh trees.

[a]The seed number data is based on the average of the seed number of the persisting fruit collected June 24th and the preharvest drops collected September 19th - 24th.

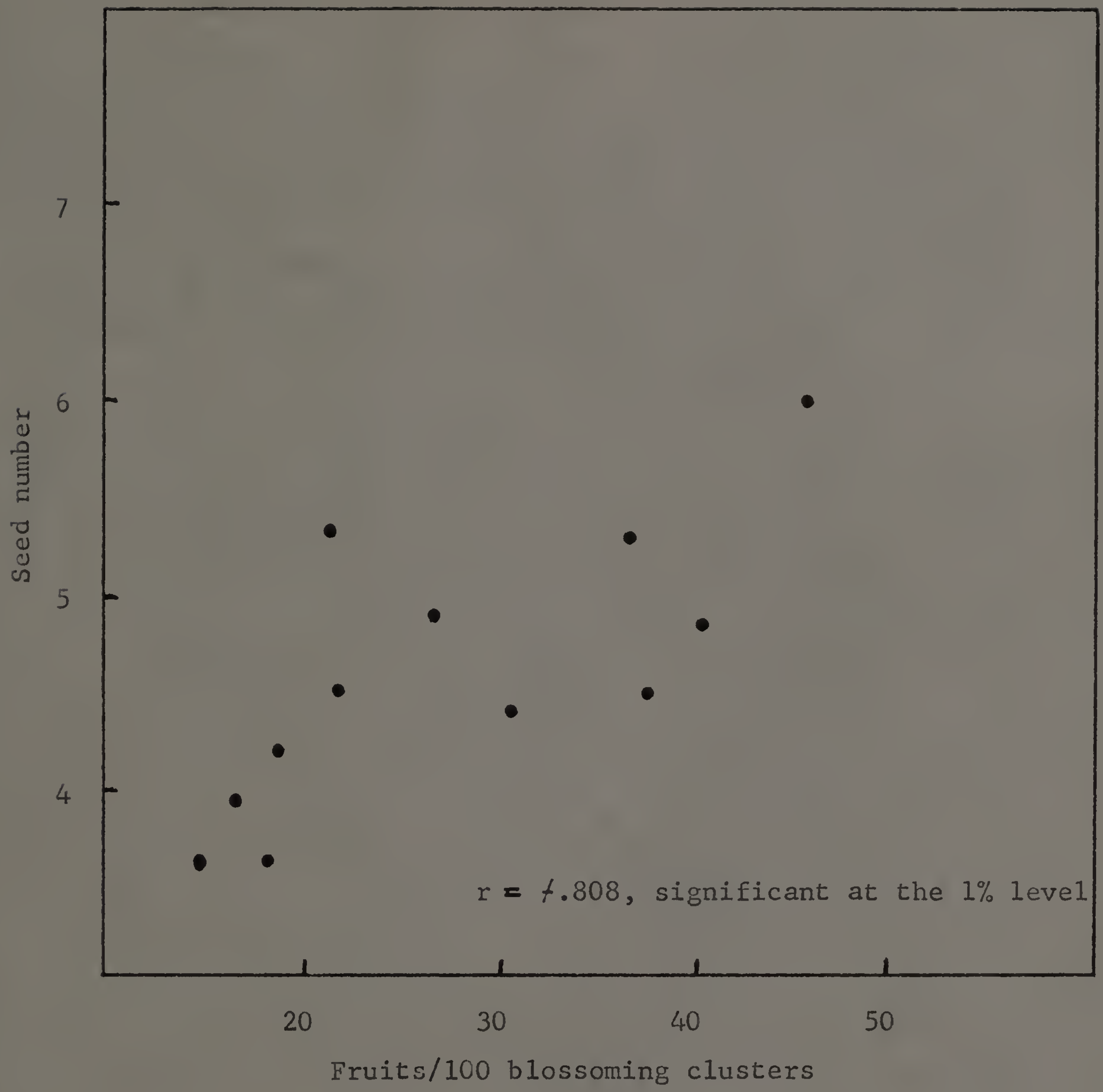

Fig. 2. The relation between seed number[a] and fruits per 100 blossoming clusters of 12 chemically thinned McIntosh trees.

[a]The seed number data is based on the average of the seed number of the persisting fruit collected June 24th and the preharvest drops collected September 19th - 24th.

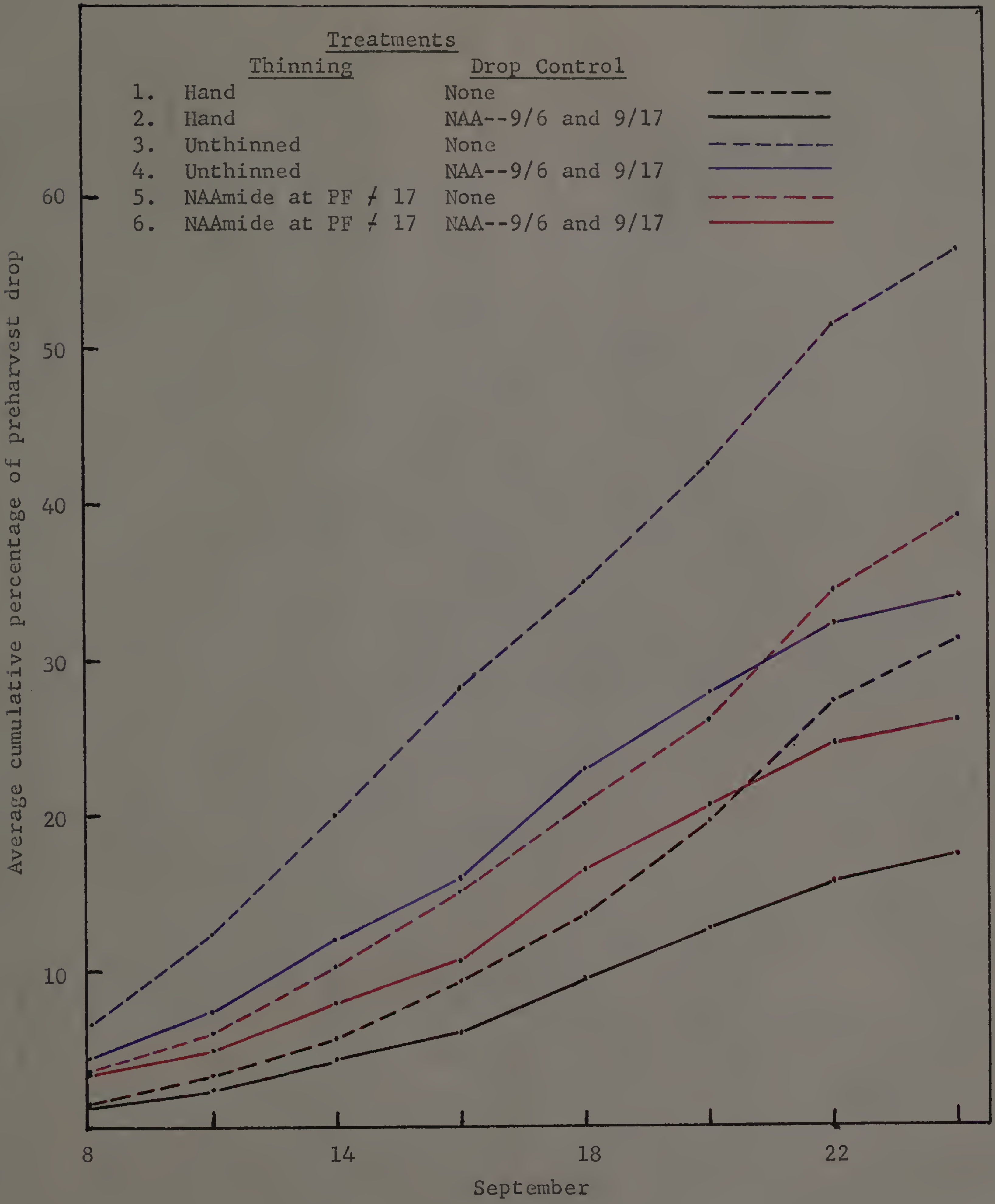

Fig. 3. The average cumulative percentage of preharvest drop of hand thinned, chemically thinned, and unthinned McIntosh trees; sprayed and not sprayed with 20 ppm NAA to control preharvest drop.

Table 5.--Effect of NAA, chemical thinners, and crop size on the preharvest drop of McIntosh apples.

Treatment: Thinning	Treatment: Drop control	No. of trees	Cumulative percentage of drop 9/6 - 9/17	Ave. yield in bu.
1. Hand thinned at PF + 45	None	6	31.4	32.9
2. Hand thinned at PF + 45	20 ppm NAA on 9/6 and 9/17	6	17.4	34.5
3. Unthinned	None	6	56.4	45.9
4. Unthinned	20 ppm NAA on 9/6 and 9/17	6	34.1	45.2
5. 25 ppm NAAmide at PF + 17	None	6	39.3	38.9
6. 25 ppm NAAmide at PF + 17	20 ppm NAA on 9/6 and 9/17	6	26.0	33.1
L. S. D. at 5 per cent level			15.4	10.2
L. S. D. at 1 per cent level			20.7	13.7

sprayed with NAA (Treatment 5). NAA applied to the unthinned trees (Treatment 4) resulted in significantly (at the 1 per cent level) less preharvest drop than occurred from the unthinned trees not sprayed with NAA (Treatment 3).

A comparison of the average cumulative percentage of preharvest drop data (Table 5) shows the chemically thinned trees (Treatment 5) lost 8 per cent more of their crop than did the hand thinned trees (Treatment 1). Where "stop drop" was applied, the chemically thinned trees (Treatment 6) lost 9 per cent more of their total crop than did the hand thinned trees (Treatment 2). These differences are not significant in either case, but they do suggest that chemically thinned trees may be more susceptible to preharvest drop than similar hand thinned trees.

The yield data in Table 5 show that the trees of Treatments 3 and 4, which were unthinned, had a significantly larger crop than trees of the other treatments. The average cumulative percentage of preharvest drop data show that the unthinned trees lost a significantly higher percentage of their total crop than comparable treatments, e.g., the average cumulative percentage of preharvest drop of Treatment 3 was significantly greater than that of Treatments 1 or 5, and the average cumulative percentage of preharvest drop of Treatment 4 was significantly greater than that of Treatment 2.

The size of the total crop was found to have a significant influence on the percentage of preharvest drop (cf. Table 5 and Figure 5). Since the total yield of the replications within treatments fluctuated widely (cf. Appendix, Table A), covariance was utilized to minimize this source of error in determining the effectiveness of the preharvest drop control treatments.

The adjusted treatment means data in Table 6 show that the NAA application significantly retarded the preharvest abscission of the fruit from hand thinned trees (at the 5 per cent level) and from the unthinned trees (at the 1 per cent level) but had no significant effect on the chemically thinned trees. (For method of computation of L. S. D.'s, refer to the Appendix, Table G.) The chemically thinned trees did not lose a significantly greater amount of fruit than the hand thinned trees. (Although the chemically thinned trees sprayed with NAA for preharvest drop control lost 5.21 bushels more than similar hand thinned trees, this difference is not statistically significant.) On the other hand, the influence of the size

Table 6.--The adjusted treatment means of the preharvest drop of McIntosh apples (calculated as bushels of fruit dropped per 38.41 bushels mean total yield).

	Preharvest drop control treatment	
Thinning treatment	None	20 ppm NAA on 9/6 and 9/17
Hand thinned	15.08 bu.	8.92 bu.
Unthinned	20.83 bu.	10.78 bu.
25 ppm NAAmide at PF + 17	16.37 bu.	14.13 bu.

L. S. D. between any two treatments at 5 per cent level: 5.29

L. S. D. between any two treatments at 1 per cent level: 7.17

of the crop is again evident where the 'stop drop' material was not applied to unthinned trees. There is no satisfactory explanation for the apparent anomaly that NAA effectively reduced the preharvest abscission of hand thinned and unthinned trees but had no effect on chemically thinned trees.

The influence of yield on preharvest drop:--The relation of the cumulative percentage of preharvest drop to total yield per tree is shown in Figures 4 and 5. In general, as total yield increased, the percentage of preharvest drop increased.

The data in Figure 4 are a compilation of the yield-percentage of preharvest drop data of all trees sprayed with 20 ppm NAA on September 6th and 17th for preharvest drop control (Figure 4-A) and all trees not sprayed (Figure 4-B). The regression coefficients and correlation coefficients are highly significant. The correlation coefficient and regression equation for the groups of trees not sprayed with NAA are $r = +.827$ and $y = 1.520X - 17.27$. The correlation coefficient and regression equation for the groups of trees sprayed with NAA are $r = +.612$ and $y = 0.936X - 9.35$.

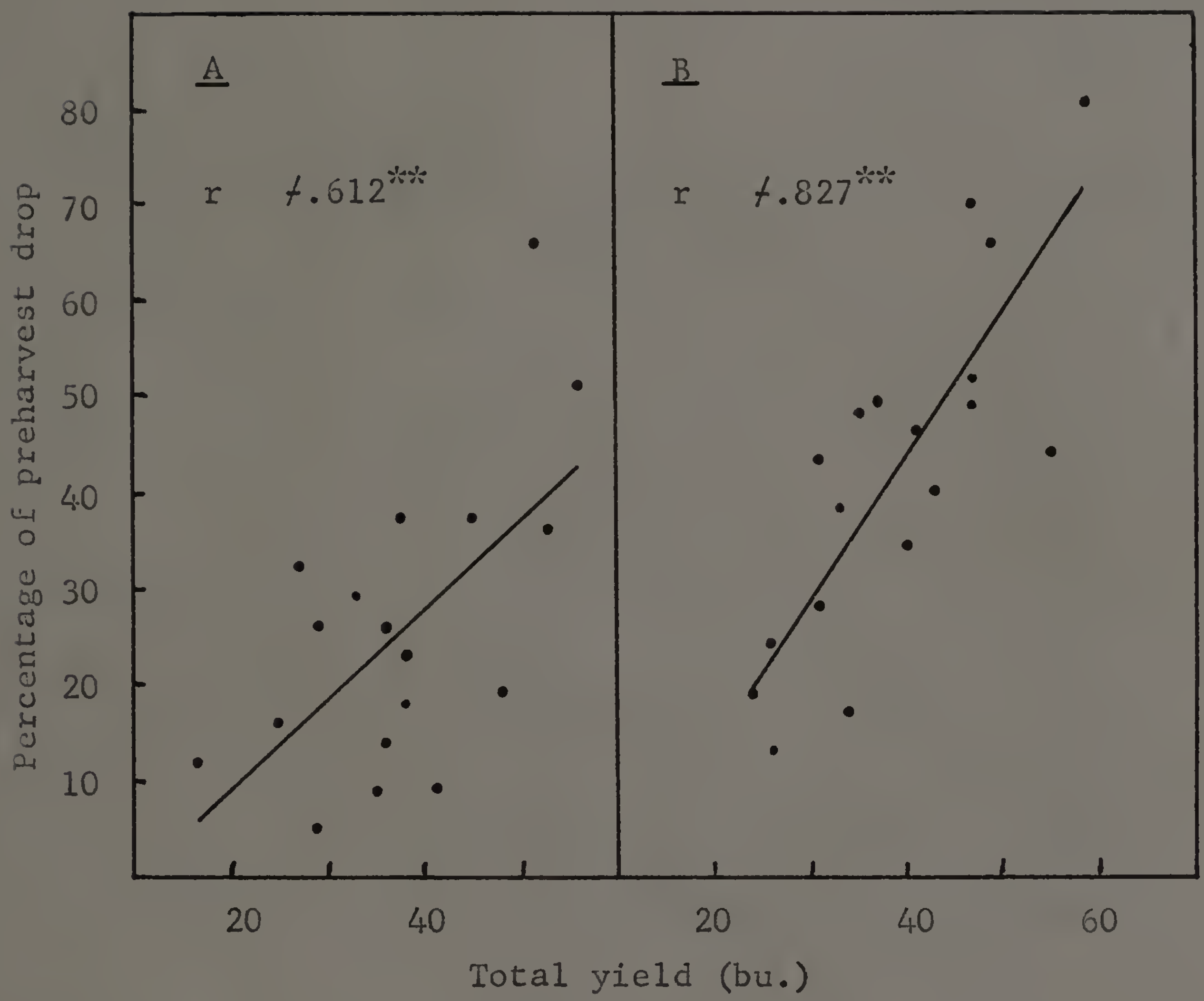

Fig. 4. The relation of crop size to percentage of preharvest drop. A. Trees sprayed with 20 ppm NAA on September 6th and 17th to control preharvest drop. B. Trees not sprayed to control preharvest drop.

**Significant at 1 per cent level.

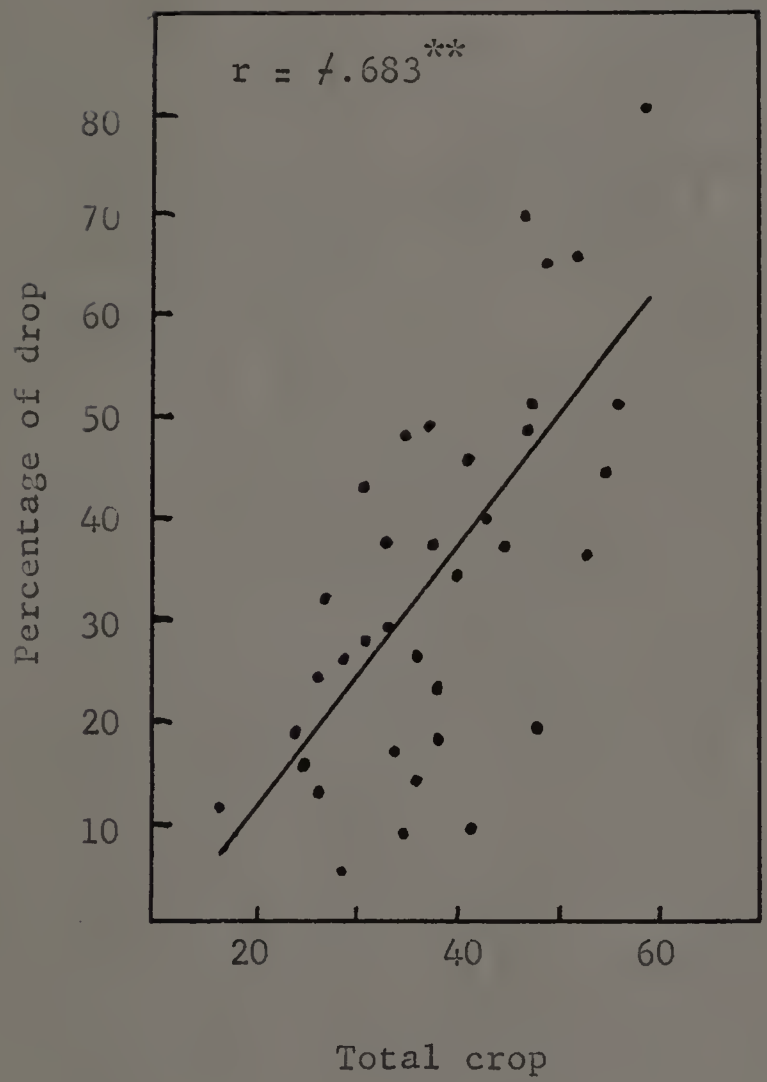

Fig. 5. The relation of crop size to preharvest drop. Hand thinned, chemically thinned, and unthinned trees sprayed and not sprayed with 20 ppm NAA to control preharvest drop are included.

**Significant at 1 per cent level.

The calculated data in Table 7 show that no more fruit may be hand picked from unthinned trees than from thinned trees if a preharvest drop control spray is not applied, although the unthinned trees may have a total yield ten bushels greater than the thinned trees. If a preharvest drop control spray is applied, less than four more bushels may be hand picked from unthinned trees than from thinned trees.

Table 7.--The calculated amount of hand picked fruit which may be harvested from thinned and unthinned trees, treated and not treated with 20 ppm NAA for preharvest drop control.

	Thinned trees		Unthinned trees	
Preharvest drop control treatment	Average total yield[a] (bu.)	No. of bu. of fruit hand picked[b]	Average total yield[a] (bu.)	No. of bu. of fruit hand picked[b]
None	35	22.5	45	22.0
20 ppm NAA on 9/6 & 9/17	35	26.8	45	30.2

[a]Average total yield based on yield data in Table 5.
[b]Number of bushels of hand picked fruit determined by subtracting from the average total yield the calculated percentage of drop obtained from the regression equation y = 1.520X - 17.27 (no preharvest drop control) and y = 0.936X - 9.35 (20 ppm NAA for preharvest drop control).

The yield and percentage of preharvest drop data of all trees in the six treatments are shown in Figure 5. The correlation coefficient and regression equation are r = +.683 and y = 1.284X - 14.13. The correlation coefficient and regression coefficient are significant at the 1 per cent level.

In comparable treatments of this experiment, therefore, crop size exerted a greater influence on the rate of preharvest abscission than the chemical thinning treatments did.

The effect of seeds on the time and severity of preharvest drop:--Southwick (57) has reported that on mature McIntosh trees of normal vigor the viable seed number of the fruit influenced the relative time of abscission. Fruit with many viable seeds tended to remain on the tree longer than the fruit with few viable seeds.

In this experiment, ten fruit were collected at random from the preharvest drops every day from September 6th through September 24th. (During the first part of the preharvest drop, some trees did not lose ten fruit.) The drops thus collected were examined for normal and aborted seeds. The data from individual trees were grouped according to treatment and date of abscission. The correlation between date of drop and the average seed number of the grouped data was calculated. As Luckwill (36) has noted, when the normal and aborted seeds are summed, little or no difference exists between the average number of seeds between individual trees. Therefore, only the normal seed data are presented in detail (Tables 9 through 12).

The data in Table 8 show that where a preharvest drop control spray was applied, there was no apparent relation between seed number and date of preharvest drop. However, where "stop drop" was not applied, there was a significant correlation (.576 necessary for significance at the 5 per cent level). The seed distribution diagrams (Tables 9 through 12) show that although the correlation may be significant, many fruit with very few or no normal seeds may persist late in the season, just as many fruit with a high seed number may be lost early in the preharvest drop. Southwick (54) has noted that even a highly significant correlation may account for only 30 per cent of the variation in time of abscission and concluded that there are factors other than seed number which influence preharvest drop. It is

Table 8.--The relation of normal and aborted seed numbers to date of preharvest drop.[a]

Preharvest drop treatment	Average no. of fruit samples/day	Correlation coefficient Normal seeds	Correlation coefficient Aborted seeds
Treatments 1 and 2. Hand thinned at PF[b] + 45			
None	51.2	+.837**	-.634*
20 ppm NAA on 9/6 and 9/17	48.6	-.290	+.320
Treatments 5 and 6. Chemically thinned with 25 ppm NAAmide at PF[b] + 17			
None	54.2	+.566	-.732*
20 ppm NAA on 9/6 and 9/17	51.5	+.188	-.084

[a] Expanded data in Appendix, Table F.
[b] PF - petal fall, May 10th.
* Significant at 5 per cent level.
** Significant at 1 per cent level.

interesting to note, however, that the "stop drop" application of NAA apparently annulled any influence the seeds might have had on the time of abscission.

Luckwill (33, 34, 36) has shown that seeds are a rich source of an auxin which appears to inhibit the abscission of apples. Fruit with few or no viable seeds could therefore be expected to abscise early in the preharvest drop. If a tree had many fruit which lacked a normal complement of viable seeds, this tree could be expected to lose a significantly large portion of its crop in the preharvest drop. However, the data in Tables 13 and 14 show that there is little relation between the percentage of fruits with no viable seeds and the severity of preharvest drop. The number of trees in each group is too small for the data to be treated statistically; however, a comparison of the trees within groups is interesting.

Table 9.--The relation[a] of normal seed number to the date of drop of hand thinned trees which did not receive a spray for preharvest drop control in September.

Date	Number of fruit	Number of seeds														No. of
Sept.		0	1	2	3	4	5	6	7	8	9	10	11	12	13	samples
6		16	2	3	8	2	2	3	3	4	3	1	0	0	0	47
8		9	4	1	5	1	5	5	1	4	5	0	1	0	0	41
9		21	4	1	3	6	1	3	2	2	2	0	1	0	0	46
10		20	3	4	7	1	2	1	1	2	2	2	0	1	0	46
11		19	2	4	7	5	5	2	3	3	2	2	0	0	0	54
13		16	1	3	4	3	2	3	6	5	2	2	0	0	0	47
15		14	4	4	8	3	4	1	4	1	1	1	0	0	0	46
19		9	6	9	11	2	7	0	5	5	5	1	0	0	0	60
20		8	4	5	1	7	2	4	5	6	3	4	1	0	0	50
22		13	2	5	8	6	4	4	9	4	1	4	0	0	0	58
23		6	5	7	9	4	4	3	4	7	4	6	1	0	0	60
24		7	2	11	5	1	8	8	3	5	8	1	0	0	0	59

[a]Correlation between date of drop and average seed number: +.837

Table 10.--The relation[a] of normal seed number to the date of drop of hand thinned trees which received a spray to control preharvest drop in September.

Date	Number of fruit	Number of seeds														No. of
Sept.		0	1	2	3	4	5	6	7	8	9	10	11	12	13	samples
6		0	2	3	1	6	2	5	3	1	8	2	1	0	0	34
8		9	4	3	2	6	9	6	2	7	4	4	0	0	1	57
9		3	4	2	1	5	9	5	1	2	2	2	1	0	0	37
10		1	2	4	3	6	3	1	4	3	2	0	1	0	0	30
11		5	2	4	3	7	2	4	3	1	2	6	0	1	0	40
13		7	4	6	7	7	3	6	4	5	5	3	0	1	0	58
15		5	3	5	7	3	6	6	3	4	4	1	0	1	0	48
19		4	2	4	6	4	13	7	5	3	6	3	1	0	0	58
20		3	3	4	11	7	6	0	7	6	4	7	0	1	0	59
22		6	2	4	4	3	6	7	3	5	6	4	0	0	0	50
23		4	2	5	11	8	8	5	6	0	5	2	1	0	0	57
24		0	5	9	11	7	5	4	5	5	3	2	0	0	0	56

[a]Correlation between date of drop and average seed number: -.290.

Table 11.--The relation[a] of normal seed number to the date of drop of chemically thinned trees which did not receive a spray for preharvest drop control in September.

Date	Number of seeds														No. of
Sept.	0	1	2	3	4	5	6	7	8	9	10	11	12	13	samples
	Number of fruit														
6	13	1	2	3	2	6	3	6	1	3	2	1	1	0	44
8	5	2	7	4	4	2	2	3	8	3	0	0	0	0	40
9	15	0	4	10	7	1	3	7	3	2	1	0	1	0	54
10	17	5	6	6	3	8	3	5	6	3	1	0	0	0	63
11	17	4	9	5	8	1	2	3	4	5	0	1	0	0	59
13	9	3	8	15	6	6	3	4	2	2	0	0	1	0	59
15	4	4	6	9	8	4	2	5	6	8	1	0	1	0	58
19	4	4	8	10	5	7	9	2	2	3	3	0	1	0	58
20	7	9	6	14	13	8	4	2	1	2	3	1	0	0	70
22	6	6	6	9	5	5	7	2	6	2	2	1	1	1	59
23	3	3	4	8	8	5	6	8	5	5	2	1	0	0	58
24	2	3	4	11	10	4	6	6	7	4	3	0	0	0	60

[a]Correlation between date of drop and average seed number: +.566

Table 12.--The relation[a] of normal seed number to the date of drop of chemically thinned trees which received a spray to control preharvest drop in September.

Date	Number of seeds														No. of
Sept.	0	1	2	3	4	5	6	7	8	9	10	11	12	13	samples
	Number of fruit														
6	7	0	5	6	5	6	2	6	9	3	0	0	0	0	49
8	1	2	3	8	7	8	5	3	5	3	3	1	0	0	49
9	7	2	3	5	4	4	3	3	1	2	2	0	0	0	36
10	9	7	9	9	5	2	2	4	1	0	1	0	0	0	49
11	6	2	8	4	7	6	2	4	6	1	3	0	0	0	49
13	10	6	3	6	7	4	8	4	1	6	2	1	1	1	60
15	3	4	7	7	6	4	3	2	0	6	1	0	0	1	44
19	6	4	8	5	6	9	5	8	2	5	1	1	0	0	60
20	2	4	8	8	9	6	5	4	6	2	3	2	0	0	59
22	3	3	4	14	7	9	4	6	4	4	1	1	0	0	60
23	5	4	16	7	5	4	7	2	4	3	2	1	1	0	61
24	1	5	1	7	6	7	3	1	7	4	0	0	0	0	42

[a]Correlation between date of drop and average seed number: +.188

Table 13.--The influence of yield and seedless fruit on the preharvest drop of hand thinned McIntosh apples.

	June persists		Preharvest drops			
Tree	No. of samples	Percentage of fruit with no viable seeds	No. of samples	Percentage of fruit with no viable seeds	Yield (bu.)	Cumulative percentage of preharvest drop
		Treatment 1. Hand thinned at PF[a] ≠ 45 Preharvest drop control: None				
C-24	54	7.4	102	31.4	24.1	19.4
C-12	50	14.0	110	36.0	31.1	43.7
C-6	52	9.6	104	21.2	32.9	37.6
E-16	51	29.5	74	48.6	26.4	13.0
G-16	52	7.7	111	15.3	40.4	34.4
G-4	51	0.0	111	6.3	42.7	40.3
		Treatment 2. Hand thinned at PF[a] ≠ 45 Preharvest drop control: 20 ppm NAA on 9/6 and 9/17				
A-8	50	4.0	117	1.7	27.2	32.3
C-16	51	0.0	91	23.1	36.0	14.4
E-2	52	0.0	107	2.8	37.8	17.9
E-6	50	16.0	110	11.8	36.3	25.6
G-20	51	0.0	85	1.2	40.6	9.3
G-6	48	4.2	73	6.8	29.0	5.1

[a]PF = petal fall, May 10th.

Trees C-4 and C-10 (Table 14) had exactly the same yield and a nearly equal percentage of preharvest drop. However, 25 per cent of the fruit from C-4 had no viable seeds, whereas few of the fruit from C-10 lacked viable seeds. Similarly, Trees A-10 and C-22 (Table 14) may be compared. A-10 had a yield more than twice as great as C-22 and lost three times the

Table 14.--The influence of yield and seedless fruit on the preharvest drop of chemically thinned McIntosh apples.

Tree	June persists: No. of samples	June persists: Percentage of fruit with no viable seeds	Preharvest drops: No. of samples	Preharvest drops: Percentage of fruit with no viable seeds	Yield (bu.)	Cumulative percentage of preharvest drop
Treatment 5. Chemically thinned with 25 ppm NAAmide at PF[a] ≠ 17 Preharvest drop control: None						
A-14	50	2.0	119	8.4	49.3	66.3
C-4	49	26.6	120	25.0	46.9	52.1
C-10	49	0.0	121	3.3	46.9	48.8
E-12	37	16.2	103	20.4	26.0	23.9
G-12	49	3.9	94	24.5	30.6	27.7
G-22	51	4.1	93	1.1	33.5	17.1
Treatment 6. Chemically thinned with 25 ppm NAAmide at PF[a] ≠ 17 Preharvest drop control: 20 ppm NAA on 9/6 and 9/17						
A-10	49	0.0	120	0.8	55.9	50.8
C-22	50	2.0	82	2.4	25.0	15.7
E-4	53	49.0	119	31.0	29.4	26.6
E-14	52	20.0	70	13.0	17.3	12.0
G-10	52	13.5	119	6.0	32.5	28.7
G-18	52	2.0	101	5.0	38.3	22.5

[a]PF - petal fall, May 10th.

amount of its crop, but neither tree had a significant number of fruit without viable seeds. However, trees with a large crop did not always lose the most apples. Tree G-20 (Table 13) had a large yield, but a very low rate of preharvest drop.

Table 15.--Germination of seeds from the fruit of trees sprayed with synthetic growth regulators and unsprayed trees.

Treatment 1. Hand thinned at PF ≠ 45
Preharvest drop control: None

Tree	Percentage of Germination
C-24	58
C-12	69
C-6	65
E-16	87
G-16	70
G-4	83
Ave.	73.0

Treatment 2. Hand thinned at PF ≠ 45
Preharvest drop control: 20 ppm NAA on 9/6 and 9/17

Tree	Percentage of Germination
A-8	67
C-16	70
E-2	64
E-6	65
G-20	74
G-6	74
Ave.	69.0

Treatment 5. Thinned with 25 ppm NAAmide at PF ≠ 17
Preharvest drop control: None

Tree	Percentage of Germination
A-14	73
C-10	47
C-4	60
E-12	85
G-22	72
G-12	75
Ave.	68.6

Treatment 6. Thinned with 25 ppm NAAmide at PF ≠ 17
Preharvest drop control: 20 ppm NAA on 9/6 and 9/17

Tree	Percentage of Germination
A-10	82
C-22	80
E-4	50
E-14	62
G-18	76
G-10	73
Ave.	70.5

Seed germination:--Crane and Bradley (11) have reported that germination and growth of apricot seeds and seedlings may be adversely affected by preharvest sprays of certain synthetic growth regulators. To measure the effect of preharvest drop control materials or chemical thinning materials on seeds, 100 seeds from each tree were after-ripened and germinated. The germination data in Table 15 show no significant difference between any of the treatments, nor is there any apparent correlation between germination and preharvest drop or fruit set. This is in agreement with the findings of Hemphill (26), who has reported that although NAA may reduce the viable seed number of tomatoes, it has no effect on the germination of seeds which do mature.

DISCUSSION

The failure of the NAAmide spray to affect fruit set when applied at petal fall but its ability to reduce set satisfactorily 17 days later is an illustration of the variable results which may be expected when thinning with synthetic growth regulators, even within the same block of trees in the same year. Since the stage of development of the fruit is probably not a factor in thinning with synthetic growth regulators (3, 57, 66), it is possible that environmental factors are responsible for the variable results. Harley et al (21) have shown that exposure of the foliage to a light frost prior to application of the spray materials increases absorption and, therefore, might be expected to increase the amount of thinning. However, in this experiment light frosts occurred seven days prior to the application of both sprays, yet the treatment at petal fall failed to thin.

Luckwill (33) has reported that apple endosperm tissue is the source of an auxin which inhibits abscission of the fruit. According to Luckwill, periods of low concentration of this auxin are correlated with high rates of abscission in both the spring and the fall. Wright (71) has reported a similar auxin in the seeds of the black currant which apparently inhibits abscission of the berry.

In this experiment, the June drops did not abscise until all of the seeds had aborted. It is possible that the endosperm tissue of McIntosh is such a rich source of auxin that abscission is inhibited until nearly all of this tissue has degenerated. However, the auxin content of the seeds was not determined and therefore the role of the seed as a source of auxin cannot be evaluated.

A definite relation was found to exist on individual trees between the degree of chemical thinning obtained and the average seed number of the fruit persisting beyond the June drop. Evidently, seeds are in some way associated with the thinning action of synthetic growth regulators. Murneek and Teubner (43) have suggested that NAA applied shortly after petal fall has an adverse effect on the development of the young seed and thins by causing embryo abortion which results in abscission of the young fruit. Teubner and Murneek (65) in a later paper suggested the possibility that NAA might reduce the viable seed number of the fruit not lost in the June drop. However, the results reported herein show no difference in the average seed number of persisting fruit between the chemically thinned and the hand thinned group of trees.

On the other hand, Batjer and Hoffman (6) suggest that low seeded fruit may be more susceptible to chemical thinners than many seeded fruit. But if chemical thinners preferentially remove low seeded fruit, then the average seed number of persisting fruit should increase following chemical thinning. Such was not the case in this experiment.

No conclusions can be drawn from these data until the seed number-set relationship is again demonstrated and the seed number of the individual trees prior to chemical thinning, as well as the seed number after the June drop, is known.

Of the fruit collected shortly after the June drop which lacked viable seeds, almost all contained at least one, two, and often more, aborted seeds over five millimeters in length. This would indicate that at least the seed coat and probably the nucellus and endosperm tissues had continued to develop until sometime near the end of the June drop. These aborted seeds were not examined for embryos, but it is possible that embryo development had been retarded. The aborting seeds in the June drops were found to have smaller embryos than the embryos from normal seeds of persisting fruit. It is probable that up to a certain stage of development of the fruit, abortion of all seeds results in cessation of growth and subsequent abscission. In some varieties late applications of chemical thinners cause seed abortion but not abscission, although growth of the fruit is retarded (67).

The results of this experiment suggest that covariance rather than analysis of variance would yield more precise information on the effects of preharvest drop control treatments. Crop size has been shown to exert a significant influence on the percentage of preharvest abscission. This is in accord with general field observations (61).

There is no evidence that thinning McIntosh with synthetic growth regulators may increase the rate of preharvest abscission. Although the time of abscission of fruit during the preharvest drop period may be regulated in part by seed number, viable seeds do not appear necessary for preharvest drop control sprays to be effective. In addition, seed number did not appear to be reduced by synthetic growth regulators applied in the spring, nor did the presence of many fruit lacking viable seeds increase the total amount of preharvest abscission of either the trees sprayed with NAA or those not sprayed.

NAA significantly reduced the preharvest drop of hand thinned and unthinned McIntosh trees, but was apparently ineffective on chemically thinned trees. The implication that a chemical thinning treatment can have a negative influence on preharvest drop control materials should be viewed with caution. NAAmide was applied in the spring to the trees referred to as "unthinned". Further, it is probable that synthetic growth regulators lose their activity a few weeks after application to the plant (5, 16).

From a practical standpoint, there is no reason for disregarding chemical thinning. Trees which overset frequently do not mature fruit of marketable size and may tend to flower and bear fruit in alternate years. Furthermore, a grower may harvest only slightly more hand picked fruit from unthinned McIntosh trees since the severity of preharvest abscission increases as the size of the crop increases.

Since it appears that auxins are necessary for fruit growth (45), and yet we observed that some fruit lacking viable seeds do develop to maturity and reach marketable size, it is reasonable to conclude that auxins originating elsewhere than in the seeds are translocated to the fruit to stimulate growth and retard abscission. This hypothesis might explain how seedless fruit are able to reach maturity and, further, why McIntosh trees can retain only a limited number of fruit at maturity. The abscission-retarding auxin content of the seeds is nil (33), and if abscission is to be retarded the auxin must be externally supplemented. This supplement could be in the form of synthetic growth regulators applied for preharvest drop control and/or auxin from the leaves. If the fruit-to-leaf ratio was high, there might be insufficient natural auxin to inhibit abscission of many fruits.

Eaton and Ergle (13), working with cotton, found that "within varieties and environments, the number of bolls per 100 grams of fresh stem and leaves remains rather constant even though nutritional factors may cause marked differences in plant growth." These authors suggest that abscission of cotton bolls is inhibited by some substances, perhaps auxin, originating in the leaves, and that should the maximum ratio of bolls to leaves be exceeded, some bolls will abscise because of an insufficient supply of this substance.

Luckwill (37) has shown that the mature terminal leaves of the Cortland apple contain similar auxins to those which are present in the seeds of some apple varieties. It is conceivable that these auxins are translocated from the leaves to the fruit.

Trees which mature a high percentage of fruit lacking viable seeds may be atypical of McIntosh. However, under the conditions of this experiment the phenomenon was evidently possible. From this work with McIntosh there is no evidence that chemical thinning reduces the viable seed number and, further, the presence or absence of seeds does not appear to influence the total amount of preharvest abscission.

SUMMARY

1. The chemical thinner, naphthaleneacetamide, had no significant influence on the preharvest drop of McIntosh apples.
2. The percentage of preharvest drop of the fruit from mature McIntosh trees increased as the size of the crop increased.
3. Preharvest drop control materials in this experiment were effective on hand thinned and unthinned trees, but not on chemically thinned trees.
4. Under the conditions of this experiment, the June drops did not abscise until all of their seeds had aborted.
5. There was a highly significant positive correlation between the fruit set of chemically thinned trees and the number of viable seeds per fruit after thinning. A similar relationship did not exist between the set and seed number of hand thinned trees. No studies were made of the seed numbers before chemically thinning.
6. Chemical thinning did not appear to reduce the viable seed number of the McIntosh fruit persisting to maturity.
7. Some McIntosh trees were found to have a high percentage (25 to 33 per cent) of mature fruit lacking viable seeds. These trees lost no more fruit during preharvest drop than similar trees with a low percentage (0 to 10 per cent) of fruit lacking viable seeds.
8. A significant positive correlation was found between the date of preharvest abscission and the average number of seeds per fruit of the groups of trees not treated with naphthaleneacetic acid. However, naphthaleneacetic acid apparently annulled the effect of seed number on the relative time of abscission.
9. Mature McIntosh apple seed germination was not affected by either chemical thinning treatments or preharvest drop control treatments.

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APPENDIX

Table A.--Summary of data: Trunk area, nitrogen, set, yield, drop.

Tree no.	Trunk area (cm^2)	Leaf N per cent	Fruit/100 blossoming clusters[a]	Yield (bu.)	Cumulative percentage of preharvest drop[b]	Fruit /bu.
		Treatment 1. Hand thinned at PF[c] ≠ 45 Preharvest drop control: None				
C-24	741.0	1.92	38.9	24.1	19.4	101
C-12	1034.2	1.75	26.9	31.1	43.7	119
C-6	968.1	1.73	18.8	32.9	37.6	119
E-16	907.7	1.74	21.0	26.4	13.0	117
G-16	989.3	1.85	28.6	40.4	34.4	107
G-4	1080.0	1.85	19.0	42.7	40.3	114
Ave.	953.4	1.81	25.5	32.9	31.4	113
		Treatment 2. Hand thinned at PF[c] ≠ 45 Preharvest drop control: 20 ppm NAA on 9/6 and 9/17				
A-8	706.1	2.04	31.8	27.2	32.3	108
C-16	1098.6	1.93	24.2	36.0	14.4	112
E-2	860.7	2.17	22.5	37.8	17.9	104
E-6	1136.4	1.96	26.3	36.3	25.6	124
G-20	928.2	1.78	31.4	40.6	9.3	97
G-6	1013.8	1.81	30.8	29.0	5.1	108
Ave.	957.3	1.95	27.8	34.5	17.4	109

[a] Treatments 1 and 2, after hand thinning 50 per cent.
[b] Total preharvest drop, September 6th - 24th, 1957.
[c] PF = petal fall, May 10th.

Table A.--Continued

Tree no.	Trunk area (cm^2)	Leaf N per cent	Fruit/100 blossoming clusters[a]	Yield (bu.)	Cumulative percentage of preharvest drop[b]	Fruit /bu.
Treatment 3. Chemically thinned with 25 ppm NAAmide at PF[c] Preharvest drop control: None						
A-20	877.3	2.04	61.7	47.4	70.3	113
C-18	869.0	1.97	39.1	37.0	48.9	124
C-8	1149.8	2.08	40.2	58.6	81.4	119
E-10	911.1	1.91	38.9	36.7	47.7	110
G-14	1126.9	1.77	37.3	41.0	45.9	108
G-2	966.4	2.01	43.9	54.7	44.3	110
Ave.	983.4	1.96	43.5	45.9	56.4	114
Treatment 4. Chemically thinned with 25 ppm NAAmide at PF[c] Preharvest drop control: 20 ppm NAA on 9/6 and 9/17						
A-6	1026.9	2.03	64.2	51.0	65.9	107
C-14	1052.4	1.73	39.0	38.2	37.1	128
C-2	897.5	1.80	52.0	48.4	18.8	117
E-8	1074.5	2.04	50.2	45.4	37.1	131
E-24	803.8	2.10	60.1	35.4	8.9	100
G-8	1093.0	1.97	40.9	52.7	36.3	116
Ave.	991.3	1.95	51.1	45.2	34.1	116

Table A.--Continued

Tree no.	Trunk area (cm^2)	Leaf N per cent	Fruit/100 blossoming clusters[a]	Yield (bu.)	Cumulative percentage of preharvest drop[b]	Fruit /bu.
Treatment 5. Chemically thinned with 25 ppm NAAmide at PF[c] ≠ 17 Preharvest drop control: None						
A-14	877.3	2.11	20.6	49.3	66.3	93
C-10	1180.5	1.88	39.9	46.9	48.8	119
C-4	966.4	1.70	26.1	46.9	52.1	103
E-12	1007.2	1.96	18.3	26.0	23.9	123
G-22	860.7	1.90	36.4	33.5	17.1	111
G-12	962.9	1.63	21.2	30.6	27.7	108
Ave.	975.8	1.86	27.1	38.9	39.3	109
Treatment 6. Chemically thinned with 25 ppm NAAmide at PF[c] ≠ 17 Preharvest drop control: 20 ppm NAA on 9/6 and 9/17						
A-10	1052.4	2.07	45.8	55.9	50.8	111
C-22	832.8	1.73	37.2	25.0	15.7	103
E-4	966.4	1.96	14.2	29.4	26.6	107
E-14	795.8	1.79	17.7	17.3	12.0	105
G-18	857.4	1.87	30.0	38.3	22.5	106
G-10	899.2	1.79	15.9	32.5	28.7	121
Ave.	900.6	1.87	26.8	33.1	26.0	109

Table B.--Average diameter of fruit, average weight and number of seeds, number of normal seeds, and number of aborted seeds of various sizes in the June drops of hand thinned and chemically thinned McIntosh, collected June 16th.

Tree	No. of fruit	Fruit diameter (cm)	Wt. of seeds (mg)	Number of aborted seeds					No. of normal seeds
				Total	<3 mm	3-4 mm	4-5 mm	>5 mm	
			Treatments 1 and 2. Hand thinned at PF[a] + 45						
A-8	101	1.93	1.20	6.03	.38	1.36	2.50	1.78	.02
E-2	107	2.08	1.22	9.00	.19	1.09	3.36	4.35	.02
C-16	103	1.89	1.21	6.21	.40	1.89	2.83	1.09	.00
E-16	102	1.94	1.25	5.46	.39	1.06	2.51	1.48	.02
C-24	110	1.84	1.28	5.43	.31	1.32	2.57	1.23	.00
C-6	125	1.85	1.18	6.29	.44	1.96	2.70	1.18	.00
E-6	104	1.98	1.11	5.50	.33	1.12	2.55	1.50	.00
Ave.		1.93	1.21	6.27	.35	1.40	2.72	1.80	.01

[a]PF = petal fall, May 10th.

Table B.--Continued

Tree	No. of fruit	Fruit diameter (cm)	Wt. of seeds (mg)	Number of aborted seeds					No. of normal seeds
				Total	<3 mm	3-4 mm	4-5 mm	>5 mm	
Treatments 5 and 6. Chemically thinned with 25 ppm NAAmide at PF[a] + 17									
A-14	125	1.85	1.05	6.23	.21	1.34	3.09	1.52	.07
A-10	100	1.81	1.12	6.08	.36	1.56	3.13	1.03	.00
G-18	103	1.91	1.30	6.39	.20	1.17	3.07	1.82	.14
C-22	106	1.75	.99	6.13	.71	1.83	2.08	1.48	.03
E-14	71	2.03	1.21	6.27	.18	.97	3.13	1.87	.11
Ave.		1.87	1.13	6.22	.33	1.37	2.90	1.54	.07

[a]PF = petal fall, May 10th.

Table C.--Average weight and volume of June drops.

Fruit collected on June 9th

Treatments 1 and 2 Hand thinned at PF[a] + 45				Treatments 5 and 6 Chemically thinned with 25 ppm NAAmide at PF[a] + 17			
Tree	No. of fruit	Weight (gm)	Volume (ml)	Tree	No. of fruit	Weight (gm)	Volume (ml)
G-20	121	1.69	1.78	G-12	142	1.57	1.68
E-2	117	1.43	1.53	G-22	118	1.75	1.84
C-12	105	1.02	1.10	G-10	128	1.43	1.51
G-6	106	1.39	1.48	E-4	121	1.27	1.36
G-4	113	1.33	1.42	C-10	108	1.07	1.16
G-16	114	1.53	1.62	G-18	140	1.49	1.57
C-16	108	1.07	1.16	C-4	106	1.02	1.08
Ave.		1.35 ± .24	1.44 ± .24	Ave.		1.37 ± .27	1.46 ± .27

Fruit collected on June 16th

Treatments 1 and 2 Hand thinned at PF[a] + 45				Treatments 5 and 6 Chemically thinned with 25 ppm NAAmide at PF[a] + 17			
Tree	No. of fruit	Weight (gm)	Volume (ml)	Tree	No. of fruit	Weight (gm)	Volume (ml)
C-6	126	3.24	3.57	G-22	106	4.43	4.81
E-16	105	3.63	4.00	E-12	76	3.47	3.68
E-6	105	2.93	4.33	C-4	113	3.77	4.16
C-16	102	3.33	3.68	E-14	71	4.37	4.79
E-2	106	4.62	5.05	G-18	104	3.69	4.04
G-20	106	4.64	5.09	C-10	112	3.12	3.44
C-12	106	3.49	3.82	E-4	102	4.67	5.10
Ave.		3.70 ± .67	4.22 ± .63	Ave.		3.93 ± .57	4.29 ± .63

[a]PF = petal fall, May 10th.

Table D.--Average weight and volume of fruit persisting beyond the June drop, collected on June 23d.

Tree	No. of fruit	Weight (gm)	Volume (ml)
Treatments 1 and 2. Hand thinned at PF[a] + 45			
C-12	26	17.38	19.62
E-6	26	17.42	19.81
C-6	26	18.58	20.96
E-2	26	21.92	24.81
C-16	26	16.42	18.65
E-16	26	16.54	18.65
C-24	26	16.23	18.46
Ave.		17.78 ± 1.99	20.14 ± 2.24
Treatments 5 and 6. Chemically thinned with 25 ppm NAAmide at PF[a] + 17			
E-4	53	17.15	19.53
A-14	25	18.56	21.60
C-10	26	18.54	21.35
E-14	24	20.25	23.54
E-12	26	16.81	18.85
A-10	26	20.04	23.08
C-22	26	19.12	22.12
Ave.		18.64 ± 1.32	21.44 ± 1.73

[a]PF = petal fall, May 10th.

Table E.--The average number of normal seeds in the early and late preharvest drops.

Tree	September 6th - 11th		September 19th - 24th	
	Number of fruit	Number of seeds/fruit	Number of fruit	Number of seeds/fruit
Treatment 1. Hand thinned at PF[a] + 45 Preharvest drop control: None				
C-24	33	2.94	40	3.10
C-12	51	1.49	50	4.64**
C-6	35	3.71	49	5.43
E-16	19	2.16	50	2.32
G-16	52	3.15	49	5.10**
G-4	44	5.55	49	5.92
Ave.		3.17		4.42
Treatment 2. Hand thinned at PF[a] + 45 Preharvest drop control: 20 ppm NAA on 9/6 and 9/17				
A-8	49	5.51	49	5.67
C-16	22	2.59	49	2.98
E-2	37	6.73	50	6.14
E-6	50	4.44	40	4.75
G-20	26	6.27	42	6.05
G-6	14	3.50	49	4.04
Ave.		4.84		4.92

[a]PF = petal fall, May 10th.
*Significant at 5 per cent level.
**Significant at 1 per cent level.

Table E.--Continued

Tree	September 6th - 11th		September 19th - 24th	
	Number of fruit	Number of seeds/fruit	Number of fruit	Number of seeds/fruit
Treatment 5. Chemically thinned with 25 ppm NAAmide at PF[a] + 17 Preharvest drop control: None				
A-14	49	4.31	50	4.70
C-10	50	4.74	51	4.75
C-4	51	2.75	49	5.02*
E-12	34	3.59	49	4.27
G-22	30	5.87	45	5.33
G-12	26	2.54	49	3.73*
Ave.		3.97		4.63
Treatment 6. Chemically thinned with 25 ppm NAAmide at PF[a] + 17 Preharvest drop control: 20 ppm NAA on 9/6 and 9/17				
A-10	49	4.92	51	5.39
C-22	35	5.80	39	4.62
E-4	49	2.59	50	5.02**
E-14	17	2.76	42	3.24
G-18	32	4.28	50	4.68
G-10	50	4.62	50	4.24
Ave.		4.16		4.53

Table F.--The relation of seed number to the date of preharvest drop (September 1957).

	Treatment 1. Hand thinned at PF[a] ≠ 45 Preharvest drop control: None			Treatment 2. Hand thinned at PF[a] ≠ 45 Preharvest drop control: 20 ppm NAA on 9/6 & 9/17			Treatment 5. Chemically thinned with 25 ppm NAAmide at PF[a] ≠ 17 Preharvest drop control: None			Treatment 6. Chemically thinned with 25 ppm NAAmide at PF[a] ≠ 17 Preharvest drop control: 20 ppm NAA on 9/6 & 9/17		
	Number	Average number of seeds/fruit		Number	Average number of seeds/fruit		Number	Average number of seeds/fruit		Number	Average number of seeds/fruit	
Date Sept.	of fruit	Normal	Aborted	of fruit	Normal	Aborted	of fruit	Normal	Aborted	of fruit	Normal	Aborted
6	47	3.40	3.98	34	6.09	1.35	44	4.32	3.80	49	4.67	2.27
8	41	4.27	2.71	57	4.91	2.51	40	4.45	2.10	49	5.27	1.29
9	46	2.63	5.04	37	4.81	2.89	54	3.74	3.17	36	4.00	3.22
10	46	2.72	5.20	30	4.83	2.23	43	4.35	3.05	49	2.86	3.41
11	54	3.17	4.48	40	5.00	2.70	59	3.31	3.46	49	4.39	2.41
13	47	3.81	4.30	58	4.67	3.26	59	3.64	3.47	60	4.53	3.17
15	46	2.91	3.85	48	4.65	2.69	58	4.90	2.71	44	4.34	2.86
19	60	3.75	3.03	58	5.26	2.78	58	4.45	1.84	60	4.52	2.95
20	50	4.80	2.78	59	5.37	1.81	59	3.81	2.92	59	4.85	1.85
22	58	4.28	4.16	49	5.33	3.29	58	4.62	2.34	61	4.64	2.57
23	60	4.85	2.28	57	4.65	2.42	58	5.17	1.79	60	4.07	2.70
24	59	4.64	2.68	56	4.55	2.71	60	5.07	2.12	42	4.86	1.93
Correlation Coefficient		≠.837**	-.634*		-.290	≠.320		≠.566	-.732*		≠.188	-.084

[a]PF = petal fall, May 10th

*Significant at 5 per cent level.

**Significant at 1 per cent level.

Table G.--The preharvest drop (in bushels) of McIntosh apples: Analysis of covariance--(y-cx)--and calculation of L. S. D.'s.

	d.f.	s.s.	m.s.	F	Significance
Replications	5	430.26	86.05	4.360	**
Treatments[a]	5	537.81	107.56	5.450	**
$T_{1,2}$ vs. $T_{3,4}$	1	87.28	87.28	4.423	*
$T_{1,2}$ & $T_{3,4}$ vs. $T_{5,6}$	1	14.57	14.57	.738	n.s.
$T_{2,4,6}$ vs. $T_{1,3,5}$	1	340.83	340.83	17.271	**
Remainder	2	91.15	45.57	2.309	n.s.
Error	24	473.62	19.734		

L. S. D. between any two adjusted treatment means: d.f. = 24

5 per cent level: $\sqrt{\frac{2 \times 19.734}{6}} \times 2.064 = 5.29$

1 per cent level: $\sqrt{\frac{2 \times 19.734}{6}} \times 2.797 = 7.17$

[a]Treatments:

T_1: Hand thinned at PF ≠ 45, preharvest drop control: None.
T_2: Hand thinned at PF ≠ 45, preharvest drop control: 20 ppm NAA on 9/6 and 9/17.
T_3: Unthinned, preharvest drop control: None.
T_4: Unthinned, preharvest drop control: 20 ppm NAA on 9/6 and 9/17.
T_5: Chemically thinned with 25 ppm NAAmide at PF ≠ 17, preharvest drop control: None.
T_6: Chemically thinned with 25 ppm NAAmide at PF ≠ 17, preharvest drop control: 20 ppm NAA on 9/6 and 9/17.

*Significant at the 5 per cent level.
**Significant at the 1 per cent level.

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