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Pre-harvest drop of the McIntosh apple.

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THE PRE-HARVEST DROP OF THE McINTOSH APPLE

INTRODUCTION

One of the most serious and least understood problems in the production of McIntosh apples in Massachusetts is excessive dropping of the fruits just prior to maturity. This difficulty forces the orchardist either to harvest the crop prematurely, before maximum size, color, and quality are obtained, or to delay the harvest thus increasing the percentage of drops. This limits the acreage of McIntosh that can be grown by any one orchardist. Other varieties such as Wealthy, Fameuse, and Gravenstein may exhibit this trait at times. On the other hand, Northern Spy, Rome, and Ben Davis often will hang some time after maturity. As a general rule, the summer and early fall varieties seem more inclined to drop before maturity than late fall and especially winter varieties.

Since McIntosh is the outstanding commercial apple in Massachusetts, it was deemed advisable to use only this variety in this investigation. Many growers in Massachusetts believe that pre-harvest drop is the prime weakness of the McIntosh. Some orchardists experience worse dropping than others. There are orchards in the state where the premature dropping problem is not troublesome, but when the entire McIntosh industry is considered, the problem of pre-harvest dropping assumes great significance.

Massachusetts growers have reported dropping of fifty per cent or even more of the total crop of a tree. In the Experiment Station blocks there are many drop records exceeding one half the tree crop. In the southern apple sections of New Hampshire, which present conditions comparable to those in Massachusetts, pre-harvest dropping of McIntosh in commercial orchards has been reported up to thirty-five per cent of the total crop (58). At Durham, up to eighty per cent drop has been recorded (58). In Maine, estimates vary from one to fifteen per cent (70). In Connecticut, commercial growers experience a twenty to thirty per cent drop (60), in Rhode Island, ten to twenty per cent (13), and in the higher elevations in Pennsylvania, around twenty per cent "though we have run much higher than this occasionally" (3). Some of these percentage figures are estimates and tend to be conservative. The significance of pre-harvest drop of McIntosh is plainly seen. In California and some other sections McIntosh is not recommended for commercial planting and one of the chief reasons given is its premature dropping tendency (2). As far north as Ottawa, Canada, the "greatest fault of McIntosh is dropping" (17). In Minnesota, early dropping of McIntosh is quite common and in recent breeding work this dropping tendency is given prime significance (1). Alderman summarizes the problem forcibly: "It is a serious handicap to the commercial development of a variety of apple if it must depend upon very favorable weather conditions to attain suitable color before dropping" (1). In some locations and in some years some growers are able to market dropped apples profitably. However, the majority of growers realize that there is a wide price differential between drops and hand picked apples. Furthermore the market can absorb only a definite amount of drops at a price level profitable to the grower. Drops are very perishable and must be marketed quickly. This has a tendency to flood the the market and bring about a lower price scale.

In addition to the absolute advantage in price which the hand picked McIntosh apple generally has over the dropped fruit, a further vital consideration is that an apple usually increases in size as long as it remains on the tree. Data from a McIntosh tree in one of the Experiment Station orchards indicate that those apples that hung on the tree until the latter part of September increased more than thirty-five per cent in volume over those that dropped during the first week of the same month. The practical advantage to the grower of such a significant size increase is evident.

The results of an investigation of the causes of McIntosh drop are reported and discussed in this paper. It was assumed that a feasible approach was, first, to ascertain what apples fall and then to find the reason or reasons for this.

REVIEW OF LITERATURE

Considerable investigation concerning the dropping problem in general has been carried out but comparatively little work has been done with pre-harvest drop of McIntosh. The problem has been considered to be a varietal one and hence insurmountable save through variety change. In New Jersey (5) (6) and elsewhere, mulching to prevent severe bruising of drops is sometimes practiced. In Canada, the premature dropping of McIntosh apples is accepted "as one of the inevitables" and they "let it go at that" (19). Gardner in Michigan suggests that the solution of this "most serious fault" may be in the finding of a bud sport that will be an improvement over the parent form in this one respect (25). In California, location is stressed (2). It was observed that McIntosh and some other varieties did not drop as badly at the higher altitudes. This is also notably true in Pennsylvania (3) and in other sections. With oranges in California, excessively high transpiration has resulted in abscission of flowers and fruit (14). Christopher has observed dropping variations due to spray materials (13). Trees with foliage injured by lime sulphur or other strong sprays "...have dropped a larger than average percentage of their fruit". In New Jersey, Blake attributes early dropping to a high temperature at a critical time when "some varieties respire carbohydrates very rapidly" (6).

Some growers are seriously considering ways and means of artificially coloring hand picked apples. Since red color development in apples is dependent partly on exposure to direct sunlight, harvested fruit will develop additional color if properly exposed. Magness observed that color development was dependent on several factors; namely, sugar content and associated chemical changes, ultra-violet light, and stage of maturity (47). Pearce and Streeter obtained results more or less contrary to those of Magness (57) but a careful investigation by Arthur at Boyce Thompson Institute conclusively established the fact that "ultra-violet, violet, and blue regions of sunlight were most valuable in producing color on apples after they had been picked" (4). He further proved that color production was a function of living cells. Growers in New York have commercially "ground-colored" McIntosh by placing green fruits on mulch under the trees (61) (68). The time required for development of good color averaged about ten days. Recent coloring work with McIntosh under Amherst conditions brought out the fact that green fruits will develop at least 50% color with a thirty-hour exposure to bright sunshine at a mean temperature of 60° F. (6). Roberts reported that fruit color varied inversely with fruit nitrogen content (59). Other evidence supports this contention.

As to definite effects of fertilizer or cultural practices on pre-harvest abscission, there are few investigational results sufficiently significant to warrant discussion here. The presence of potassium seems required for the initiation of the abscission process (55) but definite cultural data is lacking regarding its effect on premature apple abscission in the orchard.

Harrington reports a possible response to "phosphate fertilizer" in the Bitter Root Valley of Montana (27). Most severe dropping followed a nitrogen alone program. Addition of phosphorus resulted in "much better sticking qualities". This decrease in drop possibly may be explained by the supposition that phosphorus is more of a limiting factor in Montana than in Massachusetts and other regions.

Davis (17) reports increased dropping due to boron deficiency, drought conditions, and excessively high lime conditions. The first and third factors are considered to be associated. Mann (48) also emphasizes the significance of boron.

In 1936, Shaw and Southwick reported definite evidence of increased dropping on heavily mulched plots (64). The outstanding soil difference between the mulched and the cultivated plots was in amount of soil nitrates. These were found to be consistently higher in soil under mulch during the growing season and during the fall and winter as well. More growth was recorded on the mulched trees, as measured by trunk diameter, shoot growth, and size of crown. Yield was likewise better. Just why the mulched trees gave a comparatively severe pre-harvest drop was not determined. It is generally believed that nitrogen tends to decrease dropping early in the growing season (24) and to increase abscission as the fruit approaches maturity. However, Mann (48) reports that with McIntosh in the Okanagan Valley in Summerland, British Columbia, a lack of sufficient nitrogen induces pre-harvest dropping. Although the mulched trees in the Shaw and Southwick experiment outyielded those under cultivation, the records as a whole do not substantiate any relation between size of crop and percentage of dropped fruit. Shaw reported in 1935 a possible effect of rootstock. He suggested that McIntosh trees worked on certain clonal stocks exhibited less pre-harvest dropping of fruit than those worked on others (63).

One phase of the problem has been investigated rather more thoroughly than those reported above. This is the influence of seeds. There are plants that can set and mature fruit if pollinated and fertilized though embryo abortion takes place almost at once. Other plants require varying degrees of seed development in order to properly mature their fruit. Finally, there are those that require the maturing of viable seeds along with fruit development in order that premature fruit dropping will not occur. In general, the cultivated apple falls into this last group. Parthenocarpic fruits do not seem to occur as often in the apple as it was once believed (52). The ovarian tissues and the fleshy portion of the apple develop along with the enclosed ovules, and important differences in this development are often associated with varying seed number and distribution. The first striking influence of seed formation on the development of the apple fruit is in size. According to Chandler, fertilization is dependent on pollination and generally fruit development is dependent on fertilization and subsequent seed development (12). His evidence points to the conclusion that seedless apples and pears are usually smaller than seed containing specimens. He says further: "... in fruits normally containing a number of seeds considerable correlation is likely between the size of the fruit and the number of seeds developing". Sturtevant (66) peculiarly, seemed to find more seeds in small than in large fruits. Lewis and Vincent (37) noted that with the increase in apple weight, there was a proportional increase in weight of seeds. Crandall (15) examined over 31,000 fruits of a number of apples varieties and found more seeds in large than in small apples. Murneck and Schowengerdt found a high correlation between fruit weight and seed number (53). Morris (49) further emphasized that many-seeded apples were able to develop more rapidly, and he believed the higher seed content stimulated growth throughout the entire season. Latimer found a "strong correlation" between the number of seeds in a fruit and the size of the fruit on a McIntosh tree (33). Bryant, also working with McIntosh in New Hampshire came to the same conclusion (10), as did Sax in a study of several varieties (62). Brown (9) working with Wealthy claimed that large and small apples had practically the same number of seeds. In fact he found that large fruits from young trees contained the fewest seeds. On the other hand he discovered that the seeds from the large apples were much heavier than seeds from the small specimens. Roberts (59) supports this finding: "While the larger apples have larger seeds than small apples ..... apples of both sizes with the fewer seeds have the largest seeds". Seeds borne singly in a carpel were about ten per cent larger than when there were two seeds. This probably was due to the fact that seeds practically fill the seed cavity up to the time seed growth ceases. One seed in a carpel naturally has more room to expand than if two or more seeds are developing. Whitehouse (71) supported the theory that as the larger apples are larger in the early growing period, they have larger seed cavities when young and so, larger seeds when mature. Roberts (59) claimed that seed growth is completed shortly after the June drop period. Latimer, after considerable recent work on the problem in New Hampshire is still undecided on this question (36).

Roberts (59) concluded that fruit size and seed content are due principally to a common cause, "The nutritional conditions under which the blossom and fruit is produced". Latimer (34)(34_a) also emphasized the importance of proper moisture and nitrogen relations. He found, however, that despite optimum conditions as regards these, fruits resulting from ineffective pollination usually develop very few seeds. Waite in 1898 was one of the first investigators to show definitely that cross pollination results in more and larger seeds and larger and more uniform fruit (69). In one of Latimer's experiments he reduced the number of functioning pistils and observed a definite decrease in the number of seeds per fruit (35). In short an increase in seed number in McIntosh apples is very closely correlated with more effective pollination. In fact, Crane and Lawrence state that "the best measure of fertility and incompatibility is doubtless provided by the number of viable seeds produced per fruit" (16).

It is clear from the above discussion that seed development plays a vital role in fruit growth initiation and its successful continuance. But seed development is dependent on proper pollination and effective fertilization. I have mentioned this in preceding paragraphs but believe that its importance merits further consideration. Byrant observed that different varieties may vary considerably in the number of seeds required to develop normal fruit (10). Latimer concluded that under average orchard conditions in New Hampshire McIntosh requires about seven or eight well developed seeds to produce fruits of normal shape and of good size (36). There was noted further a difference in the ability of different pollens to cause seed to develop in McIntosh fruit (10) (34). A significant correlation was found between variety of pollen and per cent of lop-sided fruit. Seed content varied from 2.3 (Gravenstein pollen) to 9.5 (Delicious pollen). In the first case, a very poor crop would be expected, whereas with Delicious as a pollinator a good crop should result. Consider, for instance, the results of Burrell and Parker in the Champlain Valley (11). In McIntosh pollination work they found that the effectiveness of pollen varied absolutely with variety. Yield and number of seeds per apple were affected and these two factors were associated. Bryant (10) also found a correlation between the effectiveness of a variety of pollen and the number of female gametes developing. The increased size and vigor of gametes was thought to be due to an earlier and accelerated growth rate. Of course, successful fertilization is dependent upon many individual factors acting separately or in combination. Besides a suitable variety of pollen, there must be enough and that properly distributed. Environmental conditions such as rain, sunshine, wind, and temperature must be taken into consideration. Growth status as influenced by available soil moisture and plant nutrients, is particularly significant.

If pollination and fertilization are below normal in effectiveness, there occurs blossom or fruit abscission. However, abscission is a complex phenomenon probably brought about by a multitude of diverse factors besides these two. In the early stages of fruit growth, dropping has been attributed to one or more of these causes: lack of pollination, faulty fertilization, pistil and embryo abortion, abnormal environmental factors, faulty nutrition of fruit spur and embryo, incompatibility, impotency of pollen, and other evolutionary causes. According to Detjen's work (18) those factors that brought about embryo abortion were chiefly responsible for the premature shedding of young fruits of apple, plum, and peach. He stated further: "Whether the percentage of well developed seeds or the lack of them in a fruit forms in itself a basis for predicting the chances of the falling of such fruits, seems not definitely established".

The so-called June drop has received the attention of many workers. Kraus (32) Muller-Thurgau (50) Dorsey (20) and others have found that embryo abortion is a significant causal factor in determining the extent or severity of this drop. Murneek found four distinct waves of abscission of immature fruits (52) (54). Here, too, embryo abortion was thought to be the chief cause of the dropping of the enlarging fruits. Later in the season, competition among the fruits was a factor. Bryant (10) found that without seed production, young fruits failed to grow and soon dropped. Further, a low seed count resulted in abscission soon or later. A late drop (August) in New Hampshire was explained on the basis of poor seed production (34).

It is significant that a great portion of the work on fruit abscission has been concerned with the dropping of young fruits. The account just given emphasizes this point. Nevertheless, the results as summarized and interpreted are believed to have sufficient bearing on pre-harvest abscission as such as to be included as a basis for studying this later drop. Further observations that tend to tie together those different aspects of apple abscission follow. Heinicke (28) observed that spurs that hold fruit until after the June drop are heavier (grams) than spurs that drop their fruit before this time. He also found that seed number in some instances compensated for spur weight. That is, spurs bearing fruit with many seeds were not as vigorous as spurs produced on the same limb but bearing fruits with few seeds. The smaller the spur, the greater the number of seeds required to produce a fruit of a given size. Furthermore, embryo size was important. A fruit might attain a good size on a relatively small spur if its seeds contained large embryos. It was also found that apples which dropped early had fewer seeds, on the average, than apples that remained on the tree. However, many fruits which did not drop had few seeds while others that abscissed early contained many seeds.

Roberts (59) observed that the number of seeds per apple is greatly affected by the percentage of blossoms setting. For instance, in the case of very heavy blossoming and light setting even small fruits would have many seeds. On the other hand, with light blossoming and a high percentage set, the fruits would have relatively few seeds "as fewer of the young fruits with few seeds drop".

Murneek (51) and Murneek and Schowengerdt (53) came to the conclusion that with shaded trees and branches a relatively high number of seeds will result in larger apples, whereas with non-shaded trees or branches comparatively larger fruits may be formed in the presence of fewer seeds due to greater average leaf area per spur, per branch, and a high photosynthetic efficiency of the leaves.

Brittain's observations in Nova Scotia are pertinent (8). Extensive counts from several apple varieties generally revealed a higher average seed count in apples that remained on the tree than in those that came off in the June drop. "It is generally believed that seed production is so intimately associated with the physiological processes of the fruit, that apples with developed seeds have an advantage in the competition for water and organic nutrients over those that have fewer or no seeds". Ewert before 1910 favored this interpretation (22) (23) as have other more recent workers. According to Heinicke (28), Osterwalder in Germany attributed fruitfulness to nutrient conditions, on the number of fertilized fruits, and on the tendency of the variety to develop fruits parthenocarpically.

Now just why the few seeded fruits are handicapped in the competition for water and nutrients is explained, at least in part, by Heinicke's observations (28). He found that fruits with many seeds have a denser sap which enables them to exert a pull on the sap flow. With fruits on weak spurs seeds are particularly important in helping to secure sufficient food and water because "the sap must pass through a poorly developed conducting tissue". The amount of conducting tissue is directly related to spur weight and vigor. "If a fruit with a seedless cavity happens to develop on a weak spur, the side without seeds suffers first and falls behind in growth. Soon or later the poorly pollinated fruit on the weak spur drops, and hence many of the drops are one-sided." According to Sax (62), seedless carpels are generally accompanied by irregularity in fruit shape. "This correlation is more striking in 'June drop' apples than in the mature fruits." Young (72) reported that apples and pears injured by frost often remained on the tree and matured, but such fruits were misshapen and more or less seedless. Latimer found a very high correlation between seed content and per cent of misshapen fruit (35). It is evident that the poorly pollinated fruits that do not drop are usually borne on the vigorous spurs and may develop asymmetrically. Thus seed influence may be only secondary.

Heinicke further observed that short-stemmed fruits often set with fewer seeds than those with long stems (28). The latter are developed from lateral flowers while the short-stemmed fruits come from the central flower on the spur. The central flower opens first, "...and it is possible that priority of pollination may be an advantage in causing a set with fewer seeds." In addition, the central fruit in a cluster is obviously in the most desirable position from the standpoint of sap supply. Latimer also recognized the significance of flower position in the cluster (34).

In a series of experiments directly concerned with the so-called abscission layer (28) Heinicke found that such a layer of cells was formed as a result of definite stimuli. Working with young fruits, he observed that removal of a fruit from its stem induced the formation of a definite layer between the stem and the spur, and the shorter the stem, the more quickly was it formed. But when water was pulled through the pedicel stub by means of a suction pump separation was delayed (29). A drop of concentrated sugar solution placed on the cut surface of the stem produced the same effect. The suction thus developed was believed to act as a substitute "for the osmotic force which is a factor in holding fruits with a high seed value." It was also observed that water forced into the ends of excised twigs would exude from the cut surfaces of the pedical stubs and separation would be delayed. "Abscission is delayed longest where the flow of water is greatest." From this evidence the importance of spur characteristics as related to fruit abscission is emphasized because the more vigorous the spur, the better is it adapted to conduction of sap, etc. It was further found that when an excised spur with fruit was immersed in water and sealed in a container containing air or illuminating gas, abscission was delayed (29). On the other hand, coating the fruit with vaseline or grafting wax or saturating the atmosphere immediately surrounding an apple with water vapor both hastened fruit drop (28). On the basis of this work it seems that the causes that excite the peculiar changes in the abscission zone, which necessarily precede natural fruit dropping, are associated with the water and nutrition supply.

MacDaniels believes abscission of maturing fruit is largely a chemical process which takes place very quickly once it is started (46). "This differs from leaf abscission, at least in some species in which the cork layer is laid down..." but where abscission is delayed until the layer becomes weakened by moisture, frost, or some other irritant. Heinicke found that fruits which were nearly mature held on much longer than younger fruits when coated with grafting wax (29). It seems that a stimulus sufficiently strong to initiate the abscission process early in the life of the apple may be too mild to disrupt normal growth behavior in the abscission zone of older fruits. It is probable that identical stimuli may function to bring about the formation of the abscission layer before and after the June drop. It is also probable that, to a variable extent, different stimuli are most effective at the different critical periods in the fruit growth and maturity cycle.

Fruit abscission is axial. Data from a number of sources (10) (21) (26) (29) (38) (39) (40) (45) (65) indicate that in the case of axial abscission the separation layer is located at or near the base of an internode. According to Heinicke (29) this layer may become a millimeter wide before abscission finally occurs. Working mainly with flowers and young fruits, in a humid atmosphere, he noted that an abscission band of "glistening tissue" appeared around the pedicel base sometime before actual detachment took place. Other workers have noted this zone as a definite visible line and Heinicke has described it "... as a green line in contrast to the brown bark." It is a rim of a plate of cells that lies between the pedicel and the cluster base, as a general rule. In some cases, the layer will cut across the cluster base itself without reference to pedicel attachment (29). In pre-harvest abscission MacDaniels (45) has recently traced the split through the epidermis at the pedicel base, "... through the living collenchyma and vascular tissues of the abscission zone and through the abscission layer of the sclerenchyma in the pith area." "The line of fracture is smooth through the collenchyma and somewhat rough through vascular tissue and sclerenchyma...".

It is important to understand the modifications which make the abscission zone of the normal pedicel structurally weak. They are essentially as follows (after MacDaniels):

(a) A reduction in the diameter of the pedicel. Such construction is pronounced with McIntosh.

(b) The presence of abundant specialized collenchyma immediately underneath this constriction instead of fibers and stone cells.

(c) Less sclerenchyma in the cortical region.

(d) Partial replacement by parenchyma of the fibers and vessels of the vascular cylinder.

(e) The modification of the vessel from the normal porous type with round pits to the scalariform type with scalariform pits.

(f) The modification of constriction epidermal cells to form cushions of elongate cells which easily separate.

Thus, the abscission zone is more or less plainly set off from the adjacent normal tissues. The abscission layer, or layer of cells through which abscission takes place,is obscure, however. MacDaniels compared the abscission zone of the McIntosh with that of varieties like Rome and Spy which do not drop so easily. The zone of the McIntosh was more clearly defined, relatively free from sclerenchyma tissues, fibers, and stone cells, smaller in cross-sectional area and more deeply constricted. However, in comparing the abscission zones of fruits from McIntosh trees that show marked differences in fruit dropping severity, no marked structural differences were found.

In summation of this study of the abscission zone, it seems worthwhile to quote MacDaniels's interpretation. "In the abscission process at harvest time there is apparently no proliferation of cells in the abscission layer as is found in the early season abscission but rather, a change in the chemical nature of the cell walls which permits easy fracture.

Before maturity the tissues of the abscission zone resist fracture and must be torn apart leaving a rough surface..... The chemical change which causes the collenchyma to split easily apparently takes place very rapidly in some varieties and more slowly in others accounting in part for varietal differences in abscission." (45)

This review of literature has revealed some definite clues bearing on the specific problem of this thesis: i.e. the pre-harvest abscission of McIntosh apples. A few of the points brought out follow. In the first place, it is evident that very little of the investigational work has dealt with pre-harvest drop. Research results have emphasized the importance of seeds to the early set and development of the fruit. The abscission curve has been shown to oppose in a general way the curve of seed value. In other words the fruit abscission tendency is negatively correlated with number of seeds per apple under a definite set of conditions. The presence of seeds seems to be a stimulus to the sap flow, and in the competition for food the many-seeded apples have the advantage. It is thought that seed content influences vascular tissue formation. In general, flowers and fruits have a poorer chance than leaves to obtain water and nutrients when the supply is limited. Dropping of young fruits occurs in more uniform waves than later dropping and it is important to realize that those factors initiating fruit abscission up to and including the June drop are not necessarily identical with those causing the later fruit drop. As summed up by MacDaniels and Heinicke, "The flowers and young fruits have no strong connecting tissues which attach them to the tree, but on the contrary they are readily separated from it at the slightest provocation" (43). Further, "In fruits that remain after the June drop, the connecting tissues have been strengthened and thenceforth there is little, if any, response to conditions that previously caused abscission." There is no uniformity of argument on this point, however, and in the above literature review evidence to the contrary is not entirely lacking.

The literature reveals little concrete data to support the general supposition that climatic and cultural factors play an important role in pre-harvest fruit abscission although numerous research men have expressed opinions based on personal observations. In a general way, the evidence emphasizes the importance of location, temperature, humidity, water and nutrient availability, soil type, and cultural procedure. But as MacDaniels says: "Over a period of years there seems to be no one factor that controls the earliness or lateness of McIntosh drop as related to color or apparent maturity." (44). Severity of pre-harvest drop has been observed to vary tremendously from year to year, from section to section, from orchard to orchard, from tree to tree in the same block, and from limb to limb in the same tree. It seems probable that many factors acting in unison, determine dropping severity and that these factors may differ in their causal potentialities from one tree to the next. It is on this basis that the problem of this thesis has been attacked.

MATERIALS AND METHODS

Records on File

Extensive dropping data already available in the Pomology Department files were analyzed. These data were obtained from the usual yield records covering a considerable period, the exact number of years varying with each particular block. Four blocks subdivided variously into plots were studied. Possible effects on dropping severity of plot fertilizer treatment, soil management, understock and tree age were determined. The role of weather conditions was also studied.

Orchard Observations

It was decided to study pre-harvest dropping intensively using a small number of trees. In contrast to analysis by plots and whole blocks, individual tree and even small branch behavior were studied. Furthermore, instead of elucidating trends over variable long time periods, the basis for study was for the most part a single season. The purpose of this rather intensive investigation was to determine if possible just what apples fall prematurely. In relation to its location on the tree and possibly to its own characteristics, it was important to determine the ability of an apple to hang on. Only when it is known what apples drop can the question of "why" be answered with any assurance.

In August, 1936, six trees located in three plots in two blocks were chosen for detailed study. In Block E, two trees in each of two plots were selected on the basis of their past history and the crop that was then on the trees. J-10 and H-20 had, over a period of years, exhibited more pre-harvest dropping than J-12 and J-18. However, individual year fluctuations were so violent that the differences were not always significant when tested by Fisher's method. From 300 to 400 apples on each tree were numbered with India ink and calipered. In each case, detailed spur and leaf data were taken.

From September 8 to October 14 the "drops" were gathered at least once a day, marked for identification, and placed in cold storage for later study. In Block P, one thousand apples, representing the greater part of the crop of one tree, were numbered as above and tags bearing identical numbers in each case were attached to the respective spurs. Spur and leaf data were taken as before and the drops handled in the same way. Part of the crop of another tree in this block was also labeled.

In August, 1937, two trees in Block D and one in Block E were chosen for study. The tree in the latter block was one of those used in the previous year's study. In 1937 all of the apples on the three trees were labeled and the drops were handled as in 1936. A few hundred apples on the two trees in Block D were calipered cross-wise and length-wise at weekly intervals from June 10 to September 1 for growth studies in connection with dropping severity. Tree F-25 in this block was also used for preliminary direct nutrient injection studies.

The apples from these experimental trees were examined during the winter and certain measurements and other data were recorded for statistical study. These included maximum cross and length diameters, stem lengths, cavity depths, and seed numbers and sizes. Sugar, acid, and pectin determinations were run on three samples of fruit which dropped at different times as well as partial chemical analyses to show amounts of certain ash constituents.

PRESENTATION AND DISCUSSION OF DATA

Plot Data

It has been claimed by some pomologists and intimated by others that the fertilizer balance plays a major role in apple growth and abscission. The review above suggested certain possibilities and with these in mind it was decided to analyze certain records available in the Pomology Experiment Station files to see if any association between plot treatment and dropping severity could be found.

In harvesting fruits in the Massachusetts Experiment Station plots, weight records of dropped fruit as well as hand picked fruit are obtained and filed. These records cover variable periods of time depending on the block. The weights as recorded are accurate, but the individual tree differences revealed in dropping percentage may be more apparent than real. That is, the significance of calculations based on these records may not be always the same. This is brought about by variable practices incident to time and manner of harvesting. However, it is believed that relatively long-period trends can be analyzed from this necessarily rather gross data, because, as length of period increases, the minor variations tend to be equalized. Considering this idea on the basis of a curve, time interval increase smooths out minor but often rather violent fluctuations and the true trend is emphasized. In 1936 and 1937 special precautions were taken to so supervise the harvesting operations that the yield records of dropped apples might give a better picture of pre-harvest drop severity of McIntosh trees particularly in certain blocks.

Block E

Block E consists of seven plots of .404 acre each. There are ten twenty-five year old McIntosh trees on each plot. During the winter of 1936-37 the interplanted Baldwin trees were removed leaving the McIntosh trees 40 x 40 feet apart. A report of the behavior of the trees in this block was published in 1934. A brief summary of plot treatment since 1921 is presented in Table 1.

Table 1

Fertilizers and Amounts Applied per Plot, Block E, 1921-1937

	1921-1926	1927-1931	1932-1937
Plot 1	0	0	150# $(NH_4)_2SO_4$ 47# KCl 150# superphosphate
2	120# $NaNO_3$	120# 80# $NaNO_3$*	200 # 80# $NaNO_3$*
3	0	0	0
4	120# $NaNO_3$	120# $NaNO_3$	200# $NaNO_3$
5	0	120# $NaNO_3$	200# $NaNO_3$
6	120# $NaNO_3$	120# $NaNO_3$ 60# K_2SO_4	200# $NaNO_3$ 60# K_2SO_4
7	0	0	150# $(NH_4)_2SO_4$ 47# KCl 150# superphosphate

Note: In 1922 nitrogen cut one-half. Also even-numbered plots in sod; others cultivated.

* Two separate applications - May and July.

In Table 2 yield and drop data are computed by four-year periods from 1922 through 1937. They are also figured for the entire period of sixteen years.

Table 2

Total Yield and Total Drops (pounds) and Per Cent Drop, Block E

	Dates (inclusive)	Average Annual Tree Yield	Average Tree Drop	Per Cent Drop
	1922-25	233	23	10
	1926-29	214	29	13
Plot 1	1930-33	495	118	24
	1934-37	565	229	41
	1922-37	377	100	26.5
	1922-25	271	46	17
	1926-29	171	34	20
Plot 2	1930-33	304	52	17
	1934-37	369	121	33
	1922-37	279	63	22.6
	1922-25	173	26	15
	1926-29	119	14	12
Plot 3	1930-33	270	43	16
	1934-37	371	124	33
	1922-37	233	52	22.2
	1922-25	268	50	19
	1926-29	170	34	20
Plot 4	1930-33	245	38	16
	1934-37	314	77	25
	1922-37	249	50	20.0
	1922-25	197	21	10
	1926-29	257	68	26
Plot 5	1930-33	415	90	22
	1934-37	375	134	36
	1922-37	311	78	25.1
	1922-25	349	57	16
	1926-29	347	68	19
Plot 6	1930-33	499	122	24
	1934-37	548	289	53
	1922-37	436	134	30.7
	1922-25	221	19	9
	1926-29	230	35	15
Plot 7	1930-33	325	54	16
	1934-37	476	184	39
	1922-37	313	73	23.3

Total Yield of all trees on all plots 1922-1937 = 300,703 pounds

Total Drop of all trees on all plots 1922-1937 = 74,422 pounds

Per cent of total crop that dropped prematurely = 24.75%

Note: Some trees which were injured during the period have not been included in the above computations. Sixty-one trees have been used.

Approximately one-fourth of the total crop produced over this sixteen-year period falls in the pre-harvest drop classification. Three of the plots exhibited a higher percentage drop than the average. These are Plot 6 which has bden liberally fertilized with nitrogen and potassium since 1927; Plot 1 which has had a complete fertilizer since 1932; and Plot 5 which has been fertilized with nitrogen only since 1927. Plot 7, a complete fertilizer plot, has shown the next highest percentage drop. Of the plots showing comparatively low drop, 2 and 4 are nitrogen only plots and 3 has never received any fertilizer. From these data it seems that as the better fertilizer practices were followed, increases in pre-harvest dropping of McIntosh resulted. At the same time, there were definite crop increases. Contrary to a previous finding by Shaw and Southwick (64) there is exhibited in this case an association between total tree yield and the percentage of fruit that dropped prematurely. The whole sixteen-year period is considered on the basis of plot yield in Table 3.

Table 3

Per Cent Drops and Tree Yields by Plots, Block E

Plot	Per Cent Drop	Average Annual Tree Yield in Pounds
6	30.7	436
1	26.5	377
5	25.1	311
7	23.3	313
2	22.6	279
3	22.2	233
4	20.0	249

The two descrepancies are of minor significance. Plots 5 and 7 with practically equivalent yields show considerable difference in amount of pre-harvest dropping. Nevertheless, the two plots are adjacent in the series. Plot 3, as expected, has yielded the least of any plot but the amount of dropping as measured in percentage of total yield has averaged higher than that of Plot 4. The yield of the latter, however, has likewise been low. In short, there is no important exception that seriously interferes with the yield-drop correlation.

In the consideration of a single plot, however, the correlation may be upset. For instance, in Plot 5 the per cent drop decreased from the second to the third period whereas the mean yield increased markedly. The same is true of Plots 2 and 4. Furthermore, the reverse is true when comparing the third and fourth periods of Plot 5. (See Table 2)

In order to ascertain the statistical significance of the association between yield and drop in Block E, several standard correlation tables were constructed and the correlation coefficients determined according to the Unity Step Method as outlined by Love (41). The period from 1922 to 1937 was taken and each individual tree yield (above 50 lbs.) with the associated drop was plotted. The results by plots are compiled in Table 4.

Table 4

Correlation Between Yield and Drop in Block E

Plot	Cofrelation Coefficient	Individuals in sample
1	+.487±.056	85
2	+.160±.071	85
3	+.389±.059	95
4	+.079±.073	85
5	+.097±.075	79
6	+.525±.076	90
7	+.205±.069	88

The Coefficients of correlation in the cases of Plots 6, 1, and 3 are highly significant no matter what test for significance is used. (These tests will be explained further in another part of this thesis.) The significance of the correlation in Plot 7 is doubtful. In plots 2, 4, and 5 there is no correlation between yield and drop. These three plots have received a nitrogen only program. Of the other plots, 3 has had no fertilization, 6 has received potassium in addition to nitrogen, and 1 and 7 have received phosphorus and potassium as well as nitrogen.

Plots 1, 6, and 7 have revealed a steady increase in dropping severity from period to period with a greater than average increase showing in the last four years. In the other plots the dropping percentages remained fairly constant revealing only minor fluctuations until the last period when again a sharp rise occurred. Three possible factors may have had something to do with bringing about this trend: increasing tree age, heavier fertilizer applications, and more drop-favorable weather conditions.

Block G

Block G is two-thirds of an acre in size. There are now eighteen twenty-seven year old McIntosh trees 40 by 40 feet apart on this land. Since 1922 one-half the plot has been under a cultivation-cover crop system and the other half under a heavy mulch system. No fertilizer has been applied to the mulched plot and none to the cultivated plot until 1931. Since then about 10 pounds of nitrate of soda have been given to each tree in this latter plot. The following data substantiate and bring up to date the material reported in 1936 (64).

Table 5

Total Yield and Total Dropped Fruit (pounds)

and Per Cent Drop, Block G

Plot	Dates (inclusive)	Average Annual Tree Yield	Average Tree Drop	Approx. Per Cent Drop
	1922-1925	298	22	7
	1926-1929	354	58	16
Culti-	1930-1933	666	111	17
vated	1934-1937	910	245	27
	1922-1937	557	109	20
	1922-1925	491	76	15
	1926-1929	709	200	28
Mulched	1930-1933	968	286	30
	1934-1937	1212	486	40
	1922-1937	845	262	31

Table 5 shows that dropping has been more severe on the mulched than on the cultivated plot and has increased with the age of the trees as already shown in Block E. The constantly increasing severity of drop during the sixteen-year period from 1922 to 1937 is striking and again a greater than average increase is seen from the third to the fourth periods. Possible causes of this increase have been mentioned It would seem from the data presented that increased dropping was associated with larger yields as seen in some of the plots in Block E. However, by the use of correlation tables it was found that this relationship is more apparent than real in this case. The coefficients of correlation were $+.184 \pm .071$ and $+.188 \pm .068$ respectively for the cultivated and mulched plots. These two values though positive are not significant indicating very little relation between the size of the crop and the percentage of dropped fruit. This supports the previous finding (64).

It is plainly evident that the mulched trees have exhibited more severe dropping than those under cultivation. The two factors which are outstandingly different in the two plots are available nitrates and moisture in the soil. Both are higher under the heavy mulch. On first thought it would seem that these would prevent rather than foster premature fruit abscission. A possible explanation of what has happened, however, may be found in the fact that these two factors are more favorable not only in the fall but also in the spring (64). Abundant nitrogen and water are necessary, as shown in the review of literature, for a successful fruit set and for subsequent fruit development. Excessive competition for water and nutrients results in the abscission of developing fruits in one of the first four "waves" of drop. It seems logical to assume that since the flowers and young fruits on the mulched trees are better supplied with nutrients (particularly nitrogen) and water less severe competition is set up. Hence a larger set results and a greater proportion of the young fruits remains on the tree. Among these fruits are many which would have fallen under more usual conditions. As harvest approaches and the natural competition between fruits again assumes greater proportions, those apples which under ordinary circumstances might have dropped in the early part of the season now are forced to pre-harvest abscission. The records further substantiate this interpretation. From 1923 through 1935 blossom records as per cent of possible bloom and set records as per cent of possible spur set were taken. As long as one apple in a cluster remained at the time of recording, the spur was considered to have set. In only one year of the thirteen was the average set on the mulched trees lower than that on the trees under cultivation. Furthermore, the mulched trees also blossomed more heavily than the others as a general rule. The following data illustrate.

Average Per Cent Spur Set and Per Cent Blossoming in Block G

Plot	Set	Blossoming
Cultivated (1923-1935)	74.7	57.9
Mulched (1923-1935)	82.3	63.8

With the mulched trees, more blossoms per tree followed by a higher percentage set naturally resulted in a very large number of apples per tree as compared with the average tree under cultivation. Proceeding further, since the set fruit included only those which escaped the critical period of early abscission, as described elsewhere, this greater number of apples would be expected to hang on until another critical period. This is what evidently happened. Just prior to the harvesting period and during the early part of it, those apples not so well prepared or equipped for the struggle for existence abscissed first. Thus, the large pre-harvest drop was composed in part of those fruits which under ordinary circumstances, i.e., the cultivation system, would have dropped before the middle of June. This interpretation may not be wholly adequate but it is believed to be sufficiently sound to merit the above consideration.

Block D

This block of two and three-fourths acres was planted in 1928 to McIntosh and Wealthy on several clonal and seedling rootstocks. The clonal stocks, first assembled, classified, propagated, and distributed by the East Malling Experiment Station at Kent, England are numbered from 1 to 16 and vary markedly in dwarfing effect. Stocks 2, 3, 8, and 9 are very dwarfing; 1, 4, 5, and 6 are semi-dwarfing; and 10, 12, 13, 15, and 16 behave as standard seedling stocks. Fertilizer treatment over the entire block has been the same.

The total yield and drop and the percentage of dropped fruit are given in Table 6 for the cropping period of this block. The McIntosh trees on some of the stocks have not yielded because of incompatibility, or dwarfing effect. The stocks are arranged in the order of descending average percentage drop for the period 1934 through 1937.

Table 6

Block D Yields and Drops by Stocks

Stock	Class	No. Trees	Years	Average Annual Tree Yield	Per Cent Drop
16	Vigorous	13	1932-33	13	43
			1934-35	125	50
			1936-37	309	53
			1934-37	218	52
4	Semi-dwarf	2	1932-33	67	16
			1934-35	121	39
			1936-37	207	57
			1934-37	164	50
6	Dwarfing	3	1932-33	3	32
			1934-35	40	23
			1936-37	105	57
			1934-37	72	47
Own-rooted trees	Vigorous	14	1932-33	14	24
			1934-35	111	33
			1936-37	241	50
			1934-37	176	45
Seedling	Vigorous	14	1932-33	15	27
			1934-35	96	43
			1936-37	229	47
			1934-37	163	45

Stock	Class	No. Trees	Years	Average Annual Tree Yield	Per Cent Drop
15	Vigorous	14	1932-33	1	5
			1934-35	27	33
			1936-37	139	34
			1934-37	83	34
13	Vigorous	13	1932-33	6	17
			1934-35	64	22
			1936-37	152	38
			1934-37	108	33
10	Vigorous	13	1932-33	8	12
			1934-35	86	14
			1936-37	242	40
			1934-37	164	33
5	Dwarfing	3	1932-33	15	14
			1934-35	59	13
			1936-37	127	41
			1934-37	93	32
1	Semi-dwarf	13	1932-33	35	19
			1934-35	78	31
			1936-37	212	28
			1934-37	145	29
12	Vigorous	14	1932-33	6	25
			1934-35	74	19
			1936-37	212	24
			1934-37	143	23

The per cent fruit drop for the four-year period 1934-37 varied from 52% of the total crop of McIntosh trees on the vigorous stock 16 down to 23% of the crop of trees on the vigorous stock 12. It is interesting to note that the class of the stock had little influence on dropping severity.

Dropping seems to have increased with tree age. Even though these are young trees, it seems that the dropping problem has been as severe as with the older trees in the two blocks discussed previously. As in those two blocks, in the most recent period the per cent of fruit dropping in this block increased markedly.

Shaw (63) reported in 1935 that no relation between yield and drop was found in this block. A statistical analysis of more extensive data substantiated that finding for the 1934-35 crop but not for the 1936-37 crop. The correlation coefficients found in each of these cases follow.

1.- Crops of 1934-35 $+.111 \pm .066$ (not significant)

2.- Crops of 1936-37 $+.329 \pm .048$ (significant)

Evidently, in the last two years there has been some association between the yield of a particular tree and the amount of its dropped fruit. This was not true in the two preceding years.

Perhaps the outstanding finding from this Block D data is the great variation in dropping severity from stock to stock. Since each of these rootstocks is unlike any other stock (all specimens of a single stock are of course identical) individual stock-scion influences would be expected. In other words, these different rootstocks are comparable to as many seedling rootstocks in that in both groups are found genetically different individuals. The wide variation in the dropping severity of the McIntosh apples growing on these Malling stocks may yield a partial explanation of the individual behavior of seedling-rooted trees in commercial orchards.

Block B

This was a large block of apple trees consisting of several varieties growing on several variety rootstocks. The data of this block are not treated extensively because they simply fortify the Block D findings. In short, the McIntosh trees on the different rootstocks showed variable percentages of dropped apples. Wealthy, Yellow Transparent, Ben Davis, and McIntosh stocks seem to have favored drop while Red Astrachan, Oldenburg, English Paradise, Sweet Bough, and Wagoner seem to have lessened drop. Fifteen-year data give average dropping percentages varying from twenty to thirty-five per cent. In this block, dropping severity did not seem to increase with increasing tree age. However, yields were very low considering the age of the trees as shown by the average figures in Table 7.

Table 7

Yield and Drop, Block B

Inclusive dates	Average Annual Tree Yield (pounds)	Per Cent of Drop
1923-1926	26	32
1927-1931	54	34
1933-1936	73	32
1923-1936 (excluding 1928 and 1932)	51	33

Weather Factors

It is evident that weather conditions, particularly wind movements, determine to some degree the extent of pre-harvest dropping of McIntosh. A strong, gusty wind lasting only for a period of minutes may cause more apples to fall from the spurs than a steady breeze lasting for a much longer period. Since fruit drop is primarily dependent on the formation of an absciss layer as described elsewhere, wind is purely a secondary influence.

Other factors considered include temperature, humidity, sunlight, and rainfall. Observations elsewhere, as shown in the introduction and literature review seem to indicate that some weather factors may tend to increase pre-harvest drop.

It should be emphasized that these indications are based more on observations and opinions, often at variance, than on research findings and facts which to date amount to nil. The factors listed have at least come to my attention as having the tendency to increase fruit dropping.

1. High temperatures at critical periods.
2. A high fall temperature mean.
3. Unseasonably warm nights just before harvest.
4. A high temperature mean for the entire growing season.
5. Drought conditions during the latter part of the season due to low precipitation or to unretentive shallow soils.
6. Rainy weather just preceding and at harvest.
7. A lack of sunshine in the month of September.
8. Conditions favoring an early, lush vegetative growth.
10. Poor location with regard to elevation, exposure, etc.

The weather records of the station at Massachusetts State College were studied in connection with premature dropping. The growing season was divided into seven-day periods and the mean values for the several weather factors for each period and for the entire season were correlated with drop. Significant results were negligible. In all the years analyzed exception was more notable than agreement. In the first place, it was found that, with the dropping severity varying considerably between trees and blocks in individual years, the selection of definite heavy and light drop years on the basis of the drop records available was very difficult. Secondly, no one factor was found to produce uniform results.

Pre-harvest dropping occurred without definite reference to rainfall, cloudiness, or other related factors. There was some indication that temperature, especially a short while before harvest, was a controlling factor in the matter of fruit drop in some years. A high temperature at this critical period undoubtedly may tend to increase drop at times. According to Blake (6), the effect of the temperature factor is variable depending to a considerable extent on the tree growth status. At high temperatures in the fall, McIntosh is likely to respire carbohydrates rapidly. This condition may initiate the abscission process.

Individual Tree Data

This study over a two-year period concerned the natural dropping (abscission) of the apples of several McIntosh trees. The daily drops were gathered and various data were taken as explained above. Tables 8, 9, and 10 give a picture of the dropping phenomenon as exhibited by certain trees in 1936 and 1937.

Table 8

Dropping Record 1936

	B-6 Block P		B-7 Block P		J-10 Block E	
Date	Number	Per cent	Number	Per cent	Number	Per cent
Sept.						
4					3	0.9
5					7	2.0
6	6	0.6			1	0.3
7	22	2.3			3	0.9
8	21	2.2	4	1.4	1	0.3
10	75	7.8	17	6.0	9	2.6
11	115	11.9	14	4.9	9	2.6
12	58	6.0				
13	74	7.7	18	6.4	28	8.0
15	95	9.8	25	8.9	53	15.1
16	71	7.4	16	5.7	13	3.7
17	35	3.6	20	7.1	33	9.4
18	30	3.1	15	5.3	8	2.3
19	33	3.4	18	6.4	28	8.0
20	25	2.6	4	1.4	8	2.3
21	29	3.0	15	5.3	18	5.1
22	16	1.7	17	6.0	11	3.1
23	25	2.6	17	6.0	13	3.7
24	19	2.0	6	2.1	14	4.0
25	25	2.6	9	3.2	11	3.1
26	4	0.4	2	0.7	1	0.3
27	10	1.0	15	5.3	11	3.1
28	17	1.8	5	1.8	19	5.4
29	15	1.4	4	1.4	1	0.3
30	11	1.1	3	1.1	3	0.9
Oct. 1	12	1.2	3	1.1	7	2.0
3	11	1.1	6	2.1	4	0.9
5	20	2.1	7	2.5	6	1.7
6	16	1.7	6	2.1	5	1.4
7	9	0.9			7	2.0
8	22	2.3	9	3.2	3	0.9
9	15	1.6	4	1.4	4	1.1
13	32	3.3	3	1.1	10	2.8
	966	100.3	282	100.0	352	100.0

Table 9

Dropping Record 1936

Date	H-20 Block E		J-18 Block E		J-12 Block E	
	Number	Per cent	Number	Per cent	Number	Per cent
Sept.						
5	5	1.8	3	0.7	1	0.3
6	2	0.7	2	0.5		
7			1	0.2		
8	1	0.4	2	0.5		
10	4	1.5	4	0.9	3	0.8
11	7	2.6	7	1.6	1	0.3
13	19	7.0	31	7.1	2	0.5
15	12	4.4	14	3.2	8	2.1
16			1	0.2	1	0.3
17	16	5.9	22	5.1	8	2.1
18	9	3.3	5	1.2	10	2.6
19	13	4.8	22	5.1	32	8.4
20	8	2.9	8	1.8	6	1.6
21	14	5.2	27	6.2	19	5.0
22	7	2.6	7	1.6	16	4.2
23	14	5.2	32	7.4	38	10.0
24	8	2.9	30	6.9	34	8.9
25	7	2.6	21	4.8	25	6.5
26	3	1.1	7	1.6	11	2.9
27	7	2.6	12	2.8	14	3.7
28	8	2.9	35	8.1	19	5.0
29	5	1.8	8	1.8	18	4.7
30	6	2.2	5	1.2	12	3.1
Oct. 1	12	4.4	20	4.6	19	5.0
2	4	1.5	3	0.7	6	1.6
3	5	1.8	12	2.8	11	2.9
5	5	1.8	21	4.8	19	5.0
6	12	4.4	30	6.9	10	2.6
7	13	4.8	11	2.5	4	1.1
8	14	5.2	13	3.0	10	2.6
9	10	3.7	8	1.8	6	1.6
13	18	6.6	10	2.3	12	3.1
19	4	1.5			7	1.8
	272	100.0	434	100.0	382	100.0

Table 10

Dropping Record 1937

Date	G-18 Block D Number	Per cent	F-25 Block D Number	Per cent	J-10 Block E Number	Per cent
Sept.						
1	141	7.3	116	8.1		
2	22	1.1	71	4.9		
3	78	4.0	53	3.7	81	2.8
7	199	10.3	114	7.9	32	1.1
9	124	6.4	51	3.5		
10					30	1.0
13	388	20.0	133	9.2	95	3.3
14	149	7.7	64	4.5	50	1.7
15	75	3.9	16	1.1	24	0.8
16	140	7.2	84	5.8	24	0.8
17	226	11.2	103	7.2	78	2.7
18	134	6.9	61	4.2	42	1.4
20	170	8.8	105	7.3	174	6.0
21	44	2.3	49	3.4	123	4.2
22					92	3.2
23	10	0.5	96	6.7	154	5.3
24					255	8.8
25	37	1.9	194	13.5	461	15.8
26					520	17.9
27			92	6.4	158	5.4
28					116	4.0
29			36	2.5	191	6.5
30					73	2.5
Oct. 1					49	1.7
4					89	3.1
	1937	100.0	1438	100.0	2911	100.0

The tables bring out several important points. In the first place, individual tree variations are emphasized. In 1936, as early as September 16, fifty per cent of the crop on tree B-6 in Block P had dropped. On the other hand, J-12 in Block E had not dropped as much as half its crop until September 25. In 1937, this date ranged from September 13 to September 25. Table 11 summarizes this information.

Table 11

Dates When Fifty Per Cent of Tree Crop

Had Abscissed For Several Trees

Year of Record	Tree	Block	Date (September)	Number in Sample
1936	B-6	P	16	966
	B-7	P	19	282
	J-10	E	19	552
	H-20	E	24	272
	J-18	E	24	434
	J-12	E	25	382
1937	G-18	D	13	1937
	F-25	D	16	1438
	J-10	E	25	2911
				8974

In 1936, the total crop on one tree was labeled and studied, and in 1937, total crops of three trees were examined. In the other cases in 1936, only part of the crop in each case was used. It should be stated that even though the grand total of 8974 fruits were drops and were studied in connection with the abscission phenomenon, in ordinary commercial procedure probably considerably less than one-half would have been allowed to fall off. In these experiments, natural dropping was allowed to go to completion to facilitate the study.

The irregularity of dropping procedure emphasizes the probability of a complexity of causes. Undoubtedly, daily weather conditions influence daily dropping of apples. There is evidence that severe winds increased the amount of drop over that which would have fallen if the particular period was calm. None the less, wind is only of indirect or secondary significance. Generally speaking, an apple does not fall unless the abscission layer is pretty well formed in the specialized abscission zone separating the pedicel from the spur. A wind would have the effect of somewhat shortening the period in which an apple could remain attached after the initiation of abscission processes. Furthermore, wind effect is seen in the collision of an abscissed fruit with one or more others causing a completely unnatural drop. The significance of this factor and its variable influence on the daily drop records on which this study is based is emphasized. Under the conditions of these experiments, this factor was uncontrollable and its influence unpredictable and unmeasurable. Since the analysis of data does not take this variable factor into account there is a possibility that some associations may be more or less masked.

The dropping data when correlated daily with maximum temperature shows some association. For instance, in 1937, dropping was most severe following the 24th and 25th days of September when high maximum temperatures were prevalent. This effect was notable with J-10 in Block E which up to that time had lost relatively little fruit in any one-day period. It is also significant that during that period of especially high drop, the wind movement as reported by the College Observatory was small. In 1936, also, indications that dropping followed periods of high temperature are not lacking, but the closeness of the associations are not as apparent as in the case described above.

Statistical Analyses

The statistical procedure followed in this thesis has been based largely on simple correlations as measuring association between two variables. Significance of values has been based on the size of the probable error or it has been taken directly from specially prepared tables. The correlation work was basically concerned with seed content as related to drop. It has been shown (see literature review) that seeds are vitally important in the early growth period of the apple fruit. Very little evidence as to the significance of seeds in delaying or hastening pre-harvest dropping is available. This study was made to find out what part the seeds do play, if any, in the growth and behavior of the apple fruit from the June Drop to the time of natural Fall Drop - but especially during that time just preceding and continuing through the harvest period.

Seed Number Study

In 1936, the apples on several sections of tree J-10 in Block E, comprising approximately one-fifth of the crop, were labeled for the dropping study. Individual branches were chosen to represent the different parts of the tree and every apple on each of these branches was labeled. The number of fruits thus made available for study was 347. Each of these apples was sectioned and the seeds, mature and undeveloped, were counted. A correlation table was made from the grouped material and the relationship of the fruit seed number to the time of drop was determined. For convenience of calculation and for uniformity, either ten or eleven "periods" each composed of two or three days, were used (see Appendix). With the 1936 dropped apples of J-10 a positive correlation coefficient (r) of $.318 \pm .035$ was obtained. On the assumption that the data fits a normal curve, the correlation between seed number and time of fruit abscission is highly significant. According to a table of significant values of the correlation coefficient (41), a value as low as .148 would be significant with the above sample. It is also assumed that if the coefficient value is at least six times as large as its probable error, it is significant.

Oftentimes in correlation studies it is found that a curved line fits observed data better than a straight line. In such cases, that is when the regression is non-linear, the correlation ratio should be used as the measure of association rather than the correlation coefficient. Hence, when there is cause to doubt whether a certain correlation is linear or curvilinear some test for linearity is usually made. In the present problem it was desired to ascertain if the correlations were strictly linear. The correlation ratio was computed as .371 for the same data that gave a correlation coefficient of .318. In Blakeman's test (7), where the difference between the squared values of the correlation ratio and the correlation coefficient is less than three times its probable error, the relation is considered linear. In this case, n^2-r^2 = .0365 and $P.E._d$ = .0134 indicating true linear regression. Hence the association represents a straight line curve and should be measured by the coefficient of correlation. It should be stated that even if the regression is not strictly linear, the coefficient still gives a fair measure of association. In all the correlation work here reported, the coefficient value is used.

In Table 12 the correlation coefficients for the several trees studied reveal the extent of association of the two variables, seed content and time of drop.

Table 12

Correlation of Seed Number and Date of Drop

Year	Tree	Block	Correlation Coefficient	Number in Sample
1936	B-7	P	.542±.029	269
1936	B-6	P	.348±.019	933
1936	J-10	E (plot 3)	.318±.033	347
1936	J-12	E (plot 3)	.279±.032	369
1936	J-18	E (plot 5)	-.102±.032	424
1936	H-20	E (plot 5)	-.145±.041	262
1937	G-18	D (on stock 16)	.302±.018	1937
1937	J-10	E (plot 3)	.270±.012	2630
1937	F-25	D (on seedling root)	.264±.016	1433

Average = .231±.026

Seven of the correlation coefficient values are definitely significant. In the case of B-7, approximately thirty per cent of the variation in time of drop was due to seed effect. With F-25 on the other hand, even though the correlation was statistically significant less than seven per cent of the variation can be attributed directly to seed value. It is evident that the significance of seeds in delaying drop is not constant.

Two of the coefficient values are negative and insignificant. These were computed from the dropping records of trees J-18 and H-20 in Block E. Both of these trees are in Plot 5 which received a nitrogen only fertilizer program. The growth status of both trees has been poor for a number of years. On the basis of a definitely subnormal growth condition, the departure from expected performance in regard to dropping is doubtless largely explained. All of the other trees were fairly normal as far as growth status is concerned.

Tree J-10 in Block E was used both in 1936 and 1937. In 1936, the dropping period began on September 8 and continued through October 12. In 1937 the period was a little shorter covering the interval from September 10 to October 1. There were some apples still hanging on after this latter date but they are not included in the present analysis. The number of mature seeds per apple varied from one to eighteen in 1936 and from none to nineteen in 1937. It is interesting to note that the average number of seeds per apple was practically the same for the two consecutive years. In 1936, there were 6.18 and in 1937, 6.23 seeds per fruit on the average. It is further evident from Table 12 that the correlation coefficient computed from the 1937 data is less than that obtained from the dropping data of 1936. But it should be pointed out that the probable error of the 1937 coefficient value is considerably lower than that of the 1936 value. The two coefficients are thus seen to display approximately equivalent significance.

It is of value to show the closeness of this relationship. That is, it is important to know if the difference between these two correlation coefficients is significant. When the difference between two constants is obtained, the significance of the difference depends on the ratio to its probable error. In the case at hand, the difference (between the two coefficients) and its probable error were found to be .048$\pm$.035 respectively indicating that the difference is not statistically significant. For two successive years, then, there has been a constant relationship between date of drop and number of seeds per apple with this tree.

Locule Study

As might be expected, there was observed an indefinite relationship between the number of seeds and the number of empty locules in an apple. Table 13 illustrates.

Table 13

Empty Locule and Seed Number Relationship

Year	Tree	Block	Mean Number of Seeds Per Apple	Per Cent of Apples With One or More Empty Locules
1936	B-6	P	8.0	21
	J-12	E	7.9	19
	B-7	P	7.2	36
	J-18	E	7.1	26
	H-20	E	6.2	39
	J-10	E	6.2	39
1937	F-25	D	9.5	8
	G-18	D	9.3	11
	J-10	E	6.2	46

With a single tree, the locule-seed relationship is somewhat constant but it is likely to become more or less obscure when different trees on different plots are used or when data for more than one year is considered. Empty locules are quite likely to cause the fruit to be misshapen, especially when young. If two or more locules contain no live seeds, the apple probably will be lop-sided at maturity if it succeeds in hanging on at all. To reveal the importance of seed number and locule vacancy as related to time of pre-harvest drop, Table 14 gives the essential comparative data from one tree. Other individual trees reveal like trends.

Table 14

Average Seed Number Per Apple and Per Cent of Empty Locules

in Dropped Fruit by Periods

J-10, Block E, 1937

Period	Number of Drops	Average Number of Seeds	Per Cent of Empty Locules
1	124	5.0	70
2	73	5.1	72
3	102	4.8	66
4	215	5.0	64
5	213	5.6	53
6	406	5.7	55
7	977	6.5	41
8	273	7.3	33
9	263	7.7	28
10	49	8.1	27
Average		6.2	46

The apples borne by this tree have a very low average seed count. Latimer (36) has concluded that "with well cared for trees the average seed count fluctuates between 8 and 10 for McIntosh". It is probable that lack of proper cross-pollination has been a factor. In Blocks D and P which are not solid McIntosh plots, the average seed content is considerably higher as shown in Table 13. In Block D where the McIntosh are interplanted with Wealthy, the seed count is largest. The apples dropping in the last period from tree F-25 contained 11.1 seeds on the average with a total mean of 9.5. In this case variation in average seed number was not large from period to period. It is interesting to note that although a McIntosh apple normally contains a maximum of 20 ovules, one was found with 21 mature seeds.

Seed and Apple Size

It was observed that the apples which dropped during any one period, however short, ranged widely in size. It was thought advisable to find how much of this size variation was due to seed content. A correlation was run to determine if seed number was associated with apple size in those apples dropping in a twenty-four hour period. The eighth drop period of J-10 in Block E was chosen because of the large number of apples that fell. A coefficient of correlation of $.307 \pm .027$ was obtained. Thus, of the apples that dropped from this tree during this period, the larger specimens (as measured by cross-diameter) contained the greater number of plump seeds. Other data confirm this finding. This supports and extends similar findings found in the literature. Taking a specific case for analysis it would seem that although a definite number of seeds would exert a certain influence on the size of a particular apple, more would be needed if sufficient influence were to be exercised to delay the abscission tendency. Furthermore the weight of individual seeds was found to vary considerably. As the seeds were counted, they were divided into four lots, depending upon the cross-diameter of the apple, air dried thoroughly and weighed accurately in lots of one hundred seeds. The average weight of the seeds of the apples of a particular tree were found to vary little, as long as the apples were of a constant size, regardless when they abscissed. Variation occurred when the apples varied in size as shown in Table 15 which summarizes the data for the September 20 drop of three trees in 1937.

Table 15

Association Between Weight of Seed and Size of Apples

Size of apples (in millimeters)	Weight per seed in grams		
	G-18	F-25	J-10
50-55	.0340	.0321	.0374
56-60	.0342	.0346	.0390
61-65	.0348	.0392	.0400
66-70	.0364	.0399	.0431

All of the seed data reveal the same trend. Tree J-10 apples had the fewest seeds but also the largest. The apples of C-18 which dropped very badly contained a relatively large number of small seeds. Indirectly also, seeds influence size in that as long as an apple remains attached to the tree it will continue to increase in size as a general rule. Table 16 illustrates this principle.

Table 16

Size Increase of McIntosh Apples on B-7 During September

Period of drop	Average diameters Cross	Length	Average volume in cc.*
1 (Sept. 6-8)	64.2	55.0	118.7
2	64.1	55.5	123.1
3	65.7	56.2	127.1
4	66.8	56.7	132.6
5	67.3	57.9	137.3
6	69.3	59.3	149.0
7	69.6	59.1	150.4
8	70.0	59.3	151.6
9	71.4	59.5	158.9
10 (Oct. 3-5)	72.2	60.6	165.4

* Note $V = 4/3\pi a^2 b$

In a one-month period extending through the usual harvest season, the apples in the above case increased in average volume from 118.7 cc. to 165.4 cc. or forty per cent. This is a tremendously significant size increase when crop value to the fruit grower is considered. And, as I have shown, seeds (number and size) may be both directly and indirectly responsible in varying degrees.

Individual Limb Data

On the basis of apparent dropping behavior, it seemed that severity of drop varied from limb to limb in any particular tree. To check on this assumption, tree G-18 in Block D was divided into seven parts, each consisting primarily of one main branch. Drop data were taken and are summed up in Table 17.

Table 17

Limb Drop Data of G-18

Limb Description	Number of Apples	Mean Period of Drop	Mean Seed Number
A - Low branch NE*	144	5.62	9.66
B - Low branch N	223	5.29	9.96
C - Lowest branch W	27	6.37	10.28
D - Central Leader			
Main portion	182	5.69	8.53
Side branch	171	5.82	9.12
E - Large branch upright	357	5.52	9.12
F - Large branch SW	200	5.17	8.53

* Note Letters indicate direction of growth.

The mean periods of drop for the several branches were not markedly variable. On the basis of the data, the limbs of this tree behaved similarly to the tree as a unit in regard to severity of pre-harvest abscission. The figures for the mean seed numbers reveal that the apples on the low spreading branches contained more seeds than the apples on the more vigorously growing upright leaders. This indicates that when considering a single tree the vigor of growth (which is supposedly reflected in spur vigor) may play a part in determining the seed value required to forestall abscission. The most vigorous parts of the tree were able to hold apples with fewer seeds than those parts that were definitely less vigorous. This finding is in agreement with similar results obtained by Heinicke for young fruits (28).

Stem Study

Stem length measurements were taken on all of the 1937 experimental drops at the time of seed count. For total length of stem a beveled celluloid millimeter rule was used so that the base of the cavity could be reached. The length of stem above the plane of the top of the apple (stem protuberance) was also noted. This measurement was made by placing a narrow piece of stiff celluloid over the cavity next to the stem so that the maximum elevations of the apple were bridged. This bridge established the plane of the top of the apple. The portion of the stem below this plane was used to measure cavity depth. The essential data with correlations are given in Table 18.

Table 18

Stem Lengths and Correlations with Dropping, 1937

Tree	Number of Apples	Average Stem Length m.m.	Coefficient of Correlation - Stem Length and Date of Drop	Average Stem Protuberance m.m.	Coefficient of Correlation - Stem Protuberance and Date of Drop
J-10	2647	13.5	+.001 ±.013	5.5	-.113 ±.013*
F-25	1377	16.2	+.004 ±.018	8.3	-.128 ±.018*
G-18	1937	14.8	+.136 ±.016*	7.6	-.045 ±.016

* Indicates significance

In the cases of J-10 and F-25 there was no correlation between total stem length and time of drop. This correlation was significant with G-18. In regard to the other correlation, that between stem protuberance and time of drop, the results were diametrically opposite. The long-stemmed apples tended to drop earlier than those with shorter stems relative to the plane of the top of the apple with J-10 and F-25. The shorter-stemmed fruits of G-18 dropped first. Two of the findings are in agreement with those of Heinicke with young fruits. He found that short-stemmed fruits held an advantage over long-stemmed ones in that the former were in a better position not only to obtain water and nutrients but also to hold these against leaf withdrawal in time of drought. The relatively lower severity of dropping exhibited by tree J-10 may be accounted for by the probability that a high percentage of fruits was developed from the central flowers on the spurs, which flowers usually are comparatively short-stemmed. In regard to the two other trees, quite probably higher percentages of lateral blossoms set fruit. This would be brought about by the better growth status of these trees which allowed a better set to take place.

Other Studies

Influence of Leaf Area

With tree B-7 in Block P an experiment was conducted to determine the extent of influence on dropping behavior of spur leaf area. Approximately 150 apple bearing spurs were stripped of leaves on September 1, 1936. An equal number was labeled but left unaltered. The two samples were equivalent in so far as it was possible to so select them. The apples from the unstripped spurs had a mean period of drop of 5.14 corresponding approximately to September 22. Those from the spurs stripped of leaves had a mean drop period of 3.91 which corresponded roughly to September 17. Stripping hastened drop. The leaves seem to have exercised the definite effect of retarding the formation of the abscission layer. In this connection, a correlation between

le

leaf area and date of drop was made from complete tree data and no significant association was determined. For example, the correlation coefficient .063 $\pm$.035 was computed for tree J-12 in Block E. It is possible that inaccuracies inherent in the method of leaf area determinations were partly responsible for the non-significant results. The leaf area for each spur was computed on the basis of the number of small, medium, or large leaves and the resulting figures were approximations only. However, it can be said that other factors than leaf area are of more significance in fostering the dropping of maturing apples on normal trees. But when leaves are stripped off, the immediate effect of unbalance seems to hasten dropping materially as shown.

Influence of Spur Diameter

It has been shown that spur diameter may be an influential factor in determining whether or not abscission will take place in the early development period of an apple. It would seem that a like influence might be exhibited during the pre-harvest and harvest periods. Spur diameters, measured at the cluster base, were found to vary from three to seven millimeters. With tree B-6 in Block P the data weakly supported the conclusion reached in regard to young fruits, namely that the large spur has the advantage in delaying fruit abscission. The positive correlation coefficient of .151 $\pm$.025 was obtained. With two other trees the correlations, though positive, were not statistically significant. Further data are needed to substantiate the contention that spur diameter in itself is vitally important in the determination of dropping severity.

Influence of Wood Age

The data indicated a possible relationship between the time of drop of an apple and the age of the wood supporting a particular spur. Correlation coefficients, generally of rather low significance, gave a slight positive correlation. In other words, spurs on old wood held apples more tenaciously than those supported by young wood or else the mechanical factors such as wind movement and extent of limb rigidity were differentially effective. On this latter basis, it would seem reasonable to expect progressively worse dropping from the tree center to the branch extremities.

Acid, Sugar, Pectin Determinations

Representative samples of apples which abscissed from one tree at three different times were analyzed according to the Official Methods of Analysis of the Association of Official Agricultural Chemists. The determinations are reported in the

Appendix. The data does not support the hypothesis that dropping is due to particular percentages of acid, sugar, or pectin in the flesh.

Mineral Analyses

Mineral analyses were made of apples which dropped from two trees in 1937 on these days: September 2, 13, and 23. Computed on a dry matter basis, the percentage of ash decreased from September 2 to September 23. Phosphorus, potassium, and magnesium showed decreases while calcium and sodium increased in percentage amounts. The data are given in the Appendix. No clear indication that total ash or its constituents determine dropping severity was found.

SUMMARY

This thesis is based on a study of the natural dropping of McIntosh just prior to and during the harvest period and the determination of those factors associated with bringing about fruit abscission. Several factors acting individually or perhaps collectively to foster pre-harvest dropping of the McIntosh apple have been found. Other factors are suspected of definite influences which, however, could not be isolated sufficiently for significant analysis. A brief summarization of findings follows.

(1) In the Station orchards, an average of twenty-five

per cent of the total crop for over fifteen years has dropped prematurely. Reports from orchardists and research specialists throughout the greater part of the McIntosh belt substantiate the magnitude of the dropping problem.

(2) Premature dropping seems to increase in intensity from Massachusetts to the southern limit of the McIntosh belt; it does not decrease so markedly as the northern limit is approached.

(3) Pre-harvest dropping varies from tree to tree, from plot to plot, and from orchard to orchard.

(4) The dropping severity of a single tree or an entire block is not constant from year to year.

(5) In recent years the dropping problem seems to have been more acute than formerly.

(6) Dropping was more severe with trees grown under a high state of fertility. Complete fertilizer plots suffered more dropping than nitrogen only plots. Nevertheless, high nitrogen availability as found under a heavy mulch system seemed to lead to excessive dropping of fruit. This can be explained in part by the setting and hanging on of fruits which under more natural conditions would fall in one of the early waves of drop.

(7) With a few exceptions the percentage of dropping was found to increase with increasing yield. This was true for plots as well as for individual trees.

(8) A significant influence of rootstock upon the dropping severity of the top was observed. The vigor of the individual stock seemed to have no special importance.

(9) The variable influence of weather factors was noted without much success in definitely assigning significance. Wind was found to exert largely a secondary influence. High maximum temperatures of even short duration in the harvest period hastened drop.

(10) Dropping varied directly with the number of empty locules.

(11) The average seed content per apple varied from 6.2 to 9.5 with different trees. Seed content of individual apples varied from none to 21.

(12) Seed number was positively correlated with date of drop of apples from individual trees. In one case, there was a constant relationship between seed number per apple and time of drop for a two-year period. Seed influence was variable from tree to tree.

(13) Seeds influenced apple size. The evidence supports the theory that seed influence may be exerted directly by

increasing drawing power for nutrients and water and indirectly by enabling an apple to hang on longer. Growth usually continued as long as the apple was attached to the spur.

(14) Size of individual seeds was found to vary according to apple size. The larger fruit specimens of any drop period contained the larger seeds.

(15) Variations in dropping severity among single limbs of one tree were found to be of minor significance.

(16) Long-stemmed apples often dropped before those with shorter stems contrary to general opinion. Competitive advantage as regards food and water was probably of prime importance. Results as reported are inconclusive, however.

(17) The evidence as to the influence of leaf area on dropping of fruits was contradictory. Artificially reducing leaf area late in the season caused increased dropping.

(18) The influence of spur diameter was a minor one.

(19) Spurs arising from old wood held apples better than spurs supported by younger wood.

(20) Correlations between dropping and either ash constituents or sugar, acid, and pectin percentages were not found.

CONCLUDING STATEMENT

Fruit abscission is the direct result of the formation of a specialized abscission layer in the abscission zone between the spur and the pedicel. Those factors immediately responsible for initiating this physiological phenomenon just before and during the harvest period have been elucidated to some extent. It is believed that the influences of each of several of these factors have been measured with some degree of accuracy. However, it is concluded that few of the phases of the problem studied in this thesis assume major individual significance. The evidence points to a complexity of interacting causes. It is conceded that factors other than those analyzed here may prove to be vitally significant in possible future studies. That a complete practical solution can be found is doubtful. However, any real addition to a fundamental understanding of the problem uncovers definite basic avenues of approach.

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APPENDIX

Table A

Sample Dropping Period Arrangement, 1936

B-7, Block P

Dates	Period	Number of Dropped Apples
September 9 - 10	1	37
September 11 - 13	2	16
September 14 - 16	3	63
September 17 - 19	4	29
September 20 - 22	5	32
September 23 - 25	6	29
September 26 - 28	7	28
Sept. 29 - Oct. 1	8	6
October 2 - 4	9	12
October 5 - 7	10	14
October 8 - 12	11	3

Table B

Dropping Periods, 1937

G-18, Block D			F-25, Block D			J-10, Block E		
Dates	Peri-od	No. of Dropped Apples	Dates	Peri-od	No. of Dropped Apples	Dates	Peri-od	No. of Dropped Apples
Sept.			Sept.			Sept.		
1	1	141	1	1	116	10-13	1	124
2-3	2	100	2-3	2	124	14-15	2	73
7	3	199	7	3	114	16-17	3	102
9	4	126	9	4	50	18-20	4	215
13	5	388	13	5	133	21-22	5	213
14-15	6	224	14-15	6	80	23-24	6	406
16-17	7	366	16-17	7	138	25-26	7	977
18-20	8	304	18-20	8	161	27-28	8	273
21-23	9	54	21-23	9	145	29-30	9	263
25	10	37	25	10	194	Oct.1	10	49
			27-29	11	128			
Drop Mean = Sept. 13			Drop Mean = Sept. 16			Drop Mean = Sept. 24		

Figure A

Sample Correlation Table Showing
A Highly Significant Correlation

Correlation Between Number of Seeds, x, and The Time of Drop in Periods, y, for McIntosh Apples on Tree B-7 in Block P, 1936 (September 9 - October 13).

y \ x	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	7	1		6	5	7	3	3	1	2	1	1						
2				3	6	1	4	1	1									
3	9	2	3	4	8	5	4	5	5	9	6	2						
4	1			1	6	3	1	1	5	3	4		2	2				
5	1		1	2	1	3	4	3		5	3	6	1	1		1		
6	1		1	1	1	2	1	4	1	2	3	3	4	4		1		
7					2	1	3	4	1	7	2	3	3	2				
8					1		1			1		1			1	1		
9							2	1		1	2		2	3		1		
10								1	2	2	2	1	1		2	2		1
11										2				1				

Number = 269

Mean of x = 7.20
Mean of y = 4.58

Standard Deviation x = 3.778
Standard Deviation y = 2.598

Coefficient of Correlation (r) = +.542 ±.029

Figure B

Sample Correlation Table Showing
A Very Low Correlation

Correlation Between Stem Length in mm., x, and The Time of Drop in Periods, y, for McIntosh Apples on Tree G-18 in Block D, 1937 (September 1 - September 25).

x

y	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	1		1	4		5	12	8	11	12	15	14	11	3	1	1				
2			4	1	3		4	8	10	19	19	16	5	1	4	1		1		
3	1	1	1	1	3	3	8	12	22	37	36	21	15	8	4		2	1	1	
4	1				3	1	2	8	9	21	17	9	11	6	6					
5			1			4	10	17	39	56	63	52	38	29	7	7		1	2	1
6			1	1	2	2	8	8	31	43	35	32	18	6	1	1	1		1	
7			1		3	4	12	21	30	65	49	64	27	12	8	8	3	2		1
8						3	5	8	23	51	46	38	33	11	2		1	1	1	
9							2	2	4	7	9	8	5	2				1		
10								1	3	5	7	6	1	2	1	1		1	1	

Number = 1586

Mean of x = 14.79 Standard Deviation x = 2.22
Mean of y = 5.41 Standard Deviation y = 2.38

Coefficient of Correlation (r) = +.136 ± .016

Figure C

Sample Correlation Table Showing
A Non-significant Negative Correlation

Correlation Between Stem Protuberance in mm., x, and the Time of Drop in Periods, y, for McIntosh Apples on Tree G-18 in Block D, 1937.

x

y	-	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	1			1	5	7	6	17	7	16	9	14	6	8	1				
2			1	1	3	4	3	12	18	21	7	12	6	4	4				
3	1		3	2	4	8	10	18	28	25	28	22	16	5	2	5		1	
4	1		2	2	6	3	12	19	21	9	5	5	5	3	1				
5		1	3	4	7	14	26	31	52	50	45	37	24	11	10	6	2	2	1
6		1		4	8	9	18	30	32	36	16	16	13	3	3	1		1	
7		1	1	13	6	16	32	41	45	60	39	27	7	11	10	1			
8			1	2	5	12	11	58	30	50	23	13	14	2	1	4	1		1
9					1	2	3	7	8	7	8		3						
10				1		1	2	5	4	7	2	2	1		1		1		2

Number = 1590

Mean of x = 7.61
Mean of y = 5.43

Standard Deviation x = 2.21
Standard Deviation y = 2.64

Coefficient of Correlation (r) = -.045 $\pm$.016

Table C

Mineral Analyses of Apples that Abscissed From Tree C-15 in Block D at Approximately Ten-day Intervals, 1937.*

Determinations	Sept. 2 Drops Composition		Sept. 13 Drops Composition		Sept. 23 Drops Composition	
	As Recd.	Computed to Dry Matter Basis	As Recd.	Computed to Dry Matter Basis	As Recd.	Computed to Dry Matter Basis
Moisture	89.49	None	89.71	None	89.17	None
Dry Matter	10.51	100.	10.29	100.	10.83	100.
Ash	.255	2.429	.229	2.220	.212	1.954
Phosphoric Acid(P_2O_5)	.014	.135	.010	.099	.007	.069
Potassium Oxide(K_2O)	.099	.941	.094	.911	.086	.795
Sodium Oxide(Na_2O)	.014	.137	.015	.149	.016	.149
Total Nitrogen	.040	.378	.041	.399	.057	.542
Calcium Oxide(CaO)	.014	.134	.014	.140	.017	.164
Magnesium Oxide(MgO)	.012	.112	.011	.107	.011	.104

* All samples taken from cold storage in November and immediately ashed.

Table D

Mineral Analyses of Apples that Abscissed from Tree F-25 in Block D at Approximately Ten-day Intervals, 1937*

Determinations	Sept. 2 Drops Composition		Sept. 13 Drops Composition		Sept. 23 Drops Composition	
	As Recd.	Computed to Dry Matter Basis	As Recd.	Computed to Dry Matter Basis	As Recd.	Computed to Dry Matter Basis
Moisture	88.547	None	87.798	None	88.262	None
Dry Matter	11.453	100.	12.202	100.	11.738	100.
Ash	.279	2.439	.283	2.324	.254	2.161
Phosphoric Acid(P_2O_5)	.026	.227	.026	.214	.025	.209
Potassium Oxide(K_2O)	.134	1.166	.129	1.060	.086	1.007
Sodium Oxide(Na_2O)	.009	.077	.012	.101	.013	.114
Total Nitrogen	.047	.411	.047	.386	.038	.325
Calcium Oxide(CaO)	.014	.125	.014	.111	.015	.129
Magnesium Oxide(MgO)	.012	.108	.011	.093	.013	.107

* All samples taken from cold storage in January and immediately ashed.

Table E

Sugar, Acid, and Pectin Determinations on Apples that Abscissed from Tree G-18 in Block D at Approximately Ten-day Intervals

Date of Drop	Ph	Total Acid As Malic	Sugar			Pectin As Alcohol Precipitate
			Reducing	Sucrose	Total	
Sept. 2	3.87	.48	7.24	.71	7.95	.47%
Sept. 13	3.59	.52	7.47	.81	8.28	.47%
Sept. 23	3.59	.54	7.54	.89	8.43	.46%

Approved by:

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Graduate Committee

Date May 10, 1938