SOME FACTORS ASSOCIATED WITH THE FRUITFULNESS OF THE DELICIOUS APPLE

By
William Holland Griggs

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INTRODUCTION

The Delicious apple, introduced under this name in 1895, has been widely planted in Maryland, as well as in other fruit sections of the United States, and is becoming increasingly important as additional orchards of this variety come into commercial bearing each year. With greater growers' experience with the Delicious apple, certain of its limitations are becoming more evident.

The pertinent problem is unproductiveness. In spite of strong sales demand and excellent prices this variety has proven to be disappointingly unprofitable for many growers, due mainly to its lack of productivity. However, under some conditions, not well understood, Delicious has been satisfactory in production.

Obviously any study pertaining to production of the apple must concern itself with a host of interrelated factors as the late Professor H. D. Hooker so aptly described in 1922 (63):

> The response in terms of growth and yields is the culmination of many different activities - absorption, elaboration, utilization and storage - of correlative effects of other constituents of distinct processes of growth, fruit bud differentiation, fruit setting and development, each of which is conditioned by different factors or sets of factors.

Therefore, the present investigation is not a quest for a panacean practice, but rather an effort to determine certain factors responsible for low yields. The study included experiments on nitrogen fertilization, shading, ringing, defoliation, controlled environment and pollination. Such studies, together with chemical analyses of leaves, were designed to furnish information on the mineral nutrition, carbohydrate synthesis, and pollination requirements of this variety.

REVIEW OF LITERATURE

In this review of literature only certain horticultural experimental evidence will be pointed out to cover some pertinent ideas on nitrogen nutrition, chemical analyses of leaves in relation to mineral nutrition, interrelation of nitrogen, phosphorus, and potassium in tree nutrition, carbohydrate synthesis as influenced by ringing, defoliation, defloration and lastly to present a few references on pollination and xenia.

Nitrogen Nutrition

Of the several mineral elements which have given response when applied under field conditions or have been associated with certain deficiency symptoms, nitrogen has been most outstanding and, therefore, has received a great deal of attention. Especially since the emphasis on the carbohydrate-nitrogen concept as given by Kraus and Kraybill, 1918 (72), horticulturists have been extremely conscious of all phases of nitrogen fertilization.

Remy, 1913 (107) has shown that if nitrogen content of leaves in the fall gets below a certain level, flower bud formation is inhibited. Hooker, 1920 (62) concluded that starch-nitrogen relationship is more indicative of conditions favoring flower bud differentiation than total carbohydrate-nitrogen relationship.

Hooker, 1922 (63) Chandler, 1925 (22) Schrader and Auchter, 1926 (113) Cooper and Wiggans, 1929 (25) Armstrong, Stuckey and Cochran, 1936 (3) Murneek, 1936 (87) and Gardner, Bradford and Hooker, 1939 (37) and many others have shown with both peach and apple trees that nitrogen fertilizer applications have resulted in increased vegetative activity, greater leaf area, and an increase in the amount of bearing surface. Dorsey and Knowlton, 1926 (30) obtained marked increases in growth, bloom, set of fruit, and yield from the use of nitrate of soda. Probesting and Kinman, 1934 (105) found that:

> Nitrogen influenced the amount of shoot growth, abundance of foliage, color of leaves, time of leaf fall, and time of maturity of the fruit.

Sullivan and Cullinan, 1932 (121) Sullivan and Baker, 1937 (120) and Baker, 1936 (9) concluded from extensive studies of the response of apple trees to nitrogen fertilizer that terminal and trunk growth were correlated with the nitrogen content of the trees.

Overley and Overholser, 1940 (101) (after ten years of fertilizing Rome Beauty apple trees with various forms of nitrogen carriers) stated that no significant differences were obtained in the growth and fruiting responses except possibly in the case of calcium nitrate. Of the forms employed they recommend the use of the one which is the most inexpensive per unit of nitrogen. According to Schrader and Auchter, 1926 (113) trees deficient in nitrogen responded with increased foliage color, terminal growth, spur growth and trunk circumference from applications of either nitrate of soda or ammonium sulphate.

Harley, Masure and Magness, 1933 (50) stated that although sufficient soil moisture and nitrogen are important in maintaining good growth conditions, in their experiments they had no direct effect on the time or extent of fruit bud formation. The main factor concerned in flower bud initiation seemed to be the ratio of the amount of foliage to fruit.

Waltman, 1940 (129) grew apple trees in sand and nutrient solutions varying in amounts of nitrogen and phosphorus. When the amount of nitrogen used was twice that in the basic solution, the trees increased in weight but not in proportion to the amount of nitrogen added.

Ballou, 1916 (11) and others have reported an increased set from nitrate of soda applications made about the middle of April. Haber, 1923 (47) found that the effect of nitrates on increasing set of fruit on Delicious was not the result of stimulating pollen tube growth. Huth and Baker, 1930 (112) compared correlations of bloom and yield among nitrogen-fertilized and unfertilized apple trees. Slightly higher correlations between bloom and yield were found among the nitrogen-fertilized trees.

Southwick, 1939 (118) has presented data which show a correlation between the number of seeds and the date of drop of apples from individual McIntosh apple trees. A high number of seeds was associated with delayed drop. Hoffman, 1940 (60) and Southwick, 1940 (119) have shown that treatments, cultural practices and conditions which increase the availability of nitrates during the latter half of the growing season increased the pre-harvest drop of McIntosh. Heinicke, 1940 (55) reported heavy pre-harvest dropping of apples from heavy applications of barnyard manure. Since the manure had markedly increased the organic content and the amount of available potassium of the soil, he wrote:

> Evidently the influence of abnormally high amounts of nitrogen cannot be offset by balancing this element with high amounts of available potash.

Mineral Content of Plant Parts

Attempts to determine the mineral nutrition status of the trees have usually involved analyses of plant parts such as apple spurs, but more recently attention has been focused on leaf analyses. In both cases the matter of sampling technique assumes great importance. The interpretation of leaf analyses must necessarily consider the growth responses of the trees as an index of tree behavior or deficiency symptoms. Hence, conclusions of investigators may vary in accordance with sampling technique and methods of measuring growth responses.

The earlier chemical analyses of apple spurs showed wide variation resulting from the type of spur, age, length, portions of the spur and from the season during which the samples were taken. Hooker, 1920 (62) found wide differences in the chemical composition of apple spurs as a result of seasonal changes. Harley, 1926 (48) has studied the normal variation in chemical composition of bearing and non-bearing apple spurs. He found that the reliability of spur analysis may depend upon the uniformity of spurs selected for samples. His conclusions indicated that the new spur growth is a more satisfactory differential index of the nutritional conditions in bearing and non-bearing spurs than older wood. Further refinement of the sampling technique was practiced in 1942 (49) by separating the buds from basal portions of the new spur growth. Tufts, 1926 (125) showed marked differences in the chemical composition of bark and wood and cautioned workers against taking samples varying widely in their proportions of bark to wood.

Lilleland and Brown, 1941 (78) found from a study regarding tree variability of eighteen-year-old peach trees of uniform size and growing on uniform soil that:

> Duplicate samples of 100 basal leaves from the same tree generally do not differ by more than 0.2 per cent K. However, tree variations greatly exceed this . . . .

From agreement between the averaged data (variations in the leaf potassium content of individual peach trees mentioned above) and their probable errors they suggest that ten trees may be an adequate sampling for a foliar survey. They further stated:

> Thus a tree which distinctly exhibits a superior K status in one season may, during the following year, be at a constantly lower K level. The averages of ten trees, however, remain about the same from year to year. Such transient K levels indicate the importance of factors other than the soil in determining the leaf K content of individual trees and stress the need of sampling an adequate number of trees.

The per cent of potassium in the leaf was affected, as evidenced in late July and later, by the amount of fruit on the tree.

Lilleland and Brown, 1939 (77) working with prune trees said it was best to limit the time of leaf sampling to a period from early June to early August, since later sampling fails to distinguish the marked differences in the potassium contents, and stated:

> Young non-bearing trees in general reflect in their leaf analyses, the available K content of the soil and exhibit symptoms in accordance with such data. Bearing trees, however, do not furnish such confirmatory data. The effect of the crop on reducing the K content of the leaf is an important one as can readily be demonstrated by defruiting trees in early summer and comparing their leaf analyses with adjacent trees not so treated.

Waugh and Cullinan, 1941 (131) found that the potassium value from peach tree leaves taken at three different periods showed a slight trend downward as the season advanced. This was previously observed by Lilleland and Brown, 1939 (77). After three years of potassium application there was no indication from the leaf analyses that there had been an increase of potassium reserves in the tree.

Burrell and Cain, 1941 (19) studied the effect of potassium treatments on condition and chemical composition of McIntosh apple foliage. They found that the per cent of ash does not differ greatly from tree to tree and such differences as exist were not correlated with treatment. They also stated that the trends were identical whether the potassium is based on ash or dry matter.

Most of the investigators in this country have failed to show definite beneficial responses from the application of potassium to fruit trees under orchard conditions, Chandler, 1934 and 1936 (20 and 21) and Potter and Percival, 1938 (104). It is known, however, that potassium is used by fruit trees in relatively large amounts in certain areas where potassium deficiency occurs. Wallace, 1928 (128) Hoblyn and Bane, 1934 (58) in England, and Shaw, 1934 (114) and Burrell and Cain, 1941 (19) in the United States have shown responses from the use of potassium fertilizer.

Owing to the recent discoveries in several areas attention has been focused upon leaf analyses as a measure of the level of potassium nutrition. In other areas where no deficiency exists Batjer and Magness, 1939 (15) found that the potassium content of the leaves of young York Imperial apple trees grown in sand cultures with varying amounts of potassium to be closely correlated with both the growth of the trees and the amount of potassium supplied to the nutrient solution. Vigorous growth occurred in trees having above 1.0 per cent potassium in the leaves, although the maximum growth did not occur until the potassium content of the leaves was above 1.7 per cent. Leaves of trees showing definite deficiency symptoms contained less than 0.7 per cent potassium. From a survey of the potassium content of leaf samples from orchards in the various widely separated fruit sections of the United States they concluded that:

> Orchard trees of York Imperial and Jonathan having under 1.0 per cent potassium in the leaves, and Delicious and Rome Beauty having under 1.5 per cent, would seem most worthy of study from the standpoint of response to potash applications.

Wander, 1938 (130) found from spectrographic analyses of apple leaves that a tree grown in sand culture showed 0.44 per cent potassium by dry weight when grown without potassium in the solution, and 2.69 per cent when it was included.

Batjer and Degman, 1940 (14) working with one-year York Imperial whips in various nutrient solutions found that in the nitrogen series the nitrogen content of both leaf and bark tissue was directly related to the concentration of this element in the nutrient solution. In the potassium series the potassium content also generally increased with increasing concentrations of this element in the nutrient solution and in turn was directly associated with growth response. They stated:

> The fact that definite symptoms of potassium deficiency were not observed until the potash content of the nutrient solution was reduced to less than 10 p.p.m. indicates that response to potash applications may be expected under some conditions where no visible symptoms of deficiency can be observed.

The phosphorus content of the nutrient solution required for optimum growth was approximately only one-fifteenth of the concentration required for nitrogen and potassium.

Boynton, Reuther, and Cain, 1941 (18) from leaf analyses of several prune and apple orchards found that in any one orchard the leaf percentage of potassium was proportional to the amount of fertilizer applied to the soil.

Dunkle, Merkle, and Anthony, 1939 (33) from studies of potash availability in Pennsylvania stated:

> Leaf analyses did not correlate with the replaceable soil potassium but in some cases gave indications of the effects of potash application which could not be detected by exchange analyses.
>
> . . . .
>
> This might be expected since the percentage of any element present in tissue is expressed upon the total growth which in itself depends upon all growth factors, nutritional and otherwise.

Cullinan, Scott and Waugh, 1939 (27) grew young peach trees in nutrient solutions. They found no significant differences in growth when phosphorus was maintained in the nutrient solution above four parts per million. The potassium content of the leaves of peach trees receiving various amounts of potassium showed almost a direct relationship to the concentration of this element in the nutrient solution under the nutrient conditions maintained in the experiment.

Waugh, Cullinan, and Scott, 1940 (132) working with young peach trees in sand culture stated that although the percentage of each element found in the leaves was principally dependent upon the amount supplied, the effects of other elements and interactions were in some cases significant.

Interrelation of Nitrogen, Phosphorus and Potassium

With the accumulation of evidence from leaf analyses there has evolved a greater appreciation of the effects of one element upon the intake of other elements. In other words, there is an interrelationship of elements such as nitrogen, phosphorus, and potassium in the nutrition of fruit trees.

Gildehaus, 1931 (39) reported that his experiments failed to produce any direct evidence of a definite relation between nitrogen and potassium although the results indicated a relationship which is important to the normal growth of apple trees. Colby, 1933 (24) showed that a potassium deficiency resulted in reduced nitrate absorption. Thomas, 1933 (124) grew Stayman Winesap apple trees in cylinders under applications of N, P, and K. The entire trees were removed and analyzed after a growth period of six years. The omission of any one element from the complete fertilizer (N, P, and K) was followed by a decreased absorption of the remaining elements.

Chandler, 1936 (21) stated:

> The relation of potassium to nitrogen seems to be largely a common cause association; that is, nitrogen and potassium both being essential to the life of the cell, more nitrogen and potassium occur where more living cells exist.

He also stated that heavy applications of potassium increased the nitrogen content of the trees, but the fact could not be adequately explained.

Cullinan, Scott, and Waugh, 1939 (27) reported studies of varying amounts of N, P, and K on the growth of young peach trees in nutrient solutions. The potassium content of the leaves of all trees in the nitrogen series was uniformly high and appeared independent of the nitrogen content. It also showed no correlation with tree growth. The phosphorus content of the leaves in this same series, on the other hand, showed an inverse relationship with the nitrogen content of the nutrient solution, being highest in the leaves of those plants which received the lowest nitrogen.

Batjer and Degman, 1940 (14) working with one-year-old York Imperial trees in pot culture reported:

> Neither the absorption of nitrogen in the potassium series nor the absorption of potassium in the nitrogen series was appreciably affected by varying the concentration of the other element.

However, Batjer, Baynes, and Regeimbal, 1940 (13) later reported that the potassium and phosphorus content of foliage of young York Imperial apple trees in sand culture increased with decreasing nitrogen. No explanation was given for the conflicting results with similar material and technique. The phosphorus content of the foliage was not affected by the different potassium and nitrogen treatments at a low phosphorus level. At a high phosphorus level, on the other hand, there was a tendency for the phosphorus content of the foliage to increase with decreasing potassium.

Baker, 1941 (10) studied the effect of different methods of soil management upon the potassium content of apple and peach leaves. He gave further evidence of the effect of nitrogen application in reducing the potassium content of the leaves, stating that this difference was quite consistent, especially on the earlier sampling dates, each season.

Waugh, Cullinan, and Scott, 1940 (132) studied the response of young peach trees in sand culture and found that the reduction in growth due to inadequate phosphorus became greater as the nitrogen content of the nutrient was increased:

> At the low levels of either nitrogen or phosphorus no foliar potassium deficiency symptoms were seen, but they were observed in the low potassium trees at the intermediate and adequate levels of nitrogen and adequate level of phosphorus.

Waltman, 1940 (129) stated:

> When the nitrogen or phosphorus supply was doubled, additional quantities of these elements accumulated in the tissues but not in proportion to the amounts added in the nutrient solution.

Light Intensity

With horticultural plants marked vegetative and reproductive, responses to different light intensities have been demonstrated. References regarding this subject are presented in a chronological order.

Kinney, 1896 (69) found that there were less fruit buds formed on ten apple branches shaded or partially shaded than there were on ten similar branches in the sunlight. Taylor and Clarke, 1904 (123) concluded from various shading experiments with strawberries that thin cheesecloth increased the yield, whereas heavier cheesecloth shading decreased yield. Paddock, 1905 (102) reported greater and earlier fruitfulness of trees in the increased sunshine of high altitudes. Blackman and Matthaei, 1905 (17) have shown that with low light intensities the rate of photosynthesis of different plants is almost directly proportional to the light intensity if other factors are not limiting. In 1908 Clark (23) reported that flowers and flower bud formation require a relatively high illumination. Roberts, 1919 (108) concluded that pruning in the cherry may be effective in increasing fruit bud formation largely by removing the effect of dense shading.

Gourley, 1921 (40) and Gourley and Nightingale, 1921 (42) shaded various horticultural plants. They stated that shading increased leaf area, decreased thickness of leaves, intensified green color of leaves, caused leaves to lose their convex character and become flat, and was responsible for fruit trees failing to develop flower buds as freely as unshaded trees. Kraybill, 1923 (73) analyzed the trees used by Gourley and concluded that shading was probably effective by either reducing carbon assimilation or increasing nitrogen intake or by both actions. Vinson, 1924 (127) observed and analyzed various plants which had developed in the shade. He stated that the growth of the plants in shade was characterized by greater length of internode, more slender stem, and leaves of larger area but with smaller cross section. He found that in general the ratio of nitrogen to carbohydrate was higher in the shaded plants than in those in the sun.

Auchter, Schrader, Lagasse, and Aldrich, 1927 (7) and Auchter and Schrader, 1926 (6) after shading a whole Stayman Winesap apple tree and halves of several Stayman Winesap and

Grimes Golden apple trees listed (along with other responses of the shaded trees) a reduction in the percentage of fruit set and inhibition of blossom bud formation.

Roberts, 1927 (111) exposed young apple trees to the following treatments: sun, shade, girdling, photoperiod, and nitrogen nutrition. He found that none of these treatments had a specific effect, but that shading could be neutralized by girdling, and vice versa. This led him to conclude that:

> Growth character, including blossom bud formation, is primarily dependent upon internal composition and secondarily upon external environment.

Shirley, 1929 (115) stated, after an extensive literature review:

> In general, shading experiments show that the light intensity cannot be reduced much below 50 per cent of full sunlight in temperate regions without causing a decrease in the growth of many plants.

From his own experiments with eleven species under four sets of light conditions he concluded, among other things, that leaf area and plant height attained maxima at light intensities of about 20 per cent of full summer sunlight, the time of maximum flowering and fruiting was considerably delayed by low light intensities. Fruiting did not occur at all in the plants studied under intensities below 8 per cent of full summer sunlight.

The experiments of Haddock and Charles, 1929 (103) indicated that the critical period during which shade could inhibit blossom formation was either just prior, during, or immediately following full bloom. In their experiments, shading apple tree branches one week after full bloom was too late to influence flower bud formation.

From studies of the effects of shading upon fruit setting in the sour cherry, Gray, 1934 (43) concluded that the reduced light intensity of cloudy weather was not responsible for poor set when adequate pollination had been effected. Langoard, 1936 (74) reported on six years' results from both shading and illuminating sour cherry trees, that the effect of shading varied considerably with the season and the material used for shading. Muslin and cheesecloth were less effective in reducing the per cent of fruit setting than burlap.

Ringing

Ringing, (cincturing, girdling or any practice which completely severs the bark or the phloem of either a stem or branch) is a simple operation that effects a drastic change in the nutritional conditions both above and below the incision. Ringing, therefore, is a convenient practice for innumerable physiological studies and occasionally has been recommended as a practice to promote fruitfulness of fruit trees. Wiggans, 1918 (135) presented an extensive review of the early literature regarding this practice. The beneficial influence of ringing on fruitfulness was observed by the earliest investigators.

Drinkard, 1915 (32) obtained increased development of fruit buds by ringing at the time the foliage was fully developed. Alderman and Auchter, 1916 (2) stated that ringing usually results in dwarfing the top of an apple tree. They mentioned, however, the possibility that the dwarfing may have been caused by the heavy flowering and fruiting produced.

Wiggans, 1918 (135) studied the effects of girdling upon the concentration of plant sap. He found that girdling resulted in an accumulation of substances above the girdle, causing greater blossom production. Kraybill, 1923 (73) also obtained increased flower bud formation from ringing. Ringed branches as compared to non-ringed were lower in moisture, slightly higher in free reducing sugars and sucrose, and much higher in starch.

Swarbrick, 1928 (122) reported from ringing studies with two-year-old apple shoots that the date of ringing markedly altered the responses produced. Healing of the ringing wounds was an important factor determining the amount of starch accumulated above and below the point of ringing.

Fagan, 1926 (35) obtained an increased yield on filler trees by ringing. Gourley and Howlett, 1927 (41) stated that either scoring or ringing resulted in increased flower bud formation and that a normal set of fruit was developed. MacDaniels and Heinicke, 1929 (84) obtained wide differences in fruit set in favor of ringing several varieties of apple trees. Howlett, 1931 (67) declared that at that time there was no known method of preventing excessive abscission of fruits during the first flowering years when it occurred in such varieties as Arkansas, Parogon, Delicious and Stayman. In 1937 Greene (44) reported from extensive ringing studies with vigorous eight-year-old Grimes apple trees, that early ringing approximately doubled the percentage of spurs that set fruit. The ringing was executed on different days just prior to blossom opening (April 28-29) and on May 1. The spurs on the ringed branches were found to be higher in sugar and starch content than were similar spurs on non-ringed branches.

Murneek, 1938, 1939, and 1940 (88, 89, 90 and 91) has shown that ringing increases set, size, sugar content and effects earlier maturity and color. Griggs and Schrader, 1941 (45) also reported a significant increase in set from ringing Delicious apple trees. Howlett, 1941 (68) presented data which refuted Murneek's findings. He stated that in general, ringing produced neither outstanding nor dependable results.

As to when is the best time to practice ringing, Heinicke, 1924 (54) reported an increased set of fruits on several apple varieties as a result of ringing branches just before the blossoms opened. Greene, 1937 (44) presented data which showed that fruit setting can be influenced over a considerable period of time during and following the blossoming period. He ringed or scored Grimes Golden apple branches between April 28 and May 18 in 1931. Although he obtained the greatest increases in the percentages of spurs setting fruit (approximately double) from ringing April 28 and 29, just prior to the opening of the blossoms, scoring as late as May 18 markedly increased the numbers of fruits that set. Murneek, 1940 (90) has recommended ringing at the time of full bloom to increase fruit set for several apple varieties including Delicious.

Pollination

No attempt will be made to review all of the references on pollination of the apple. Those references dealing with the Delicious apple and the technique of pollination are presented.

The Delicious apple is commercially self-unfruitful, thereby requiring provision for cross-pollination, Whitehouse and Auchter, 1927 (134), Luce and Morris, 1928 (79), Marshall, Johnston, et. al., 1929 (82), Howlett, 1930 (66), Murneek, Yocum and McCubbin, 1930 (94), and Griggs and Schrader, 1942 (46).

Many experiments have shown relatively low percentages of set for Delicious with a considerable number of pollenizers, Dorsey, 1922 (29), Haber, 1923 (47), Whitehouse and Auchter, 1927 (134), Howlett, 1929 and 1930 (65 and 66), Murneek, Yocum and McCubbin, 1930 (94), Overholser and Overly, 1932 (100), Knowlton, 1932 (71), and Murneek, 1932 (86). Ranker, 1926 (106) stated that Delicious, even with adequate pollination, normally thins its flowers to not more than one fruit per spur.

Murneek, 1932 (86) has presented an extensive review of the literature regarding the evolution of the methods of controlled pollination since the classical studies of Waite, 1894.

Heinicke, 1917 (53) has presented reasons for showing the number of spurs blossoming in regard to the relationship of the amount of bloom and the percentage set.

MacDaniels, 1929 (83) emphasized the importance of recording the number of growing points as well as the number of blossom clusters on the branches used for pollination. He stated that this gave an indication as to whether the branch was weak and spurry or vigorous. He further stated:

> A good commercial set on a limb 10 centimeters in circumference is 20 to 25 fruits with large sized apples like McIntosh, Rhode Island Greening, and Northern Spy, and 25 to 30 with such varieties as Baldwin and Jonathan.

The term "xenia" is used according to the discussion by Crane and Lawrence, 1938 (26) who applied it to the effects of pollen upon the maternal tissue which they stated has been unnecessarily termed metaxenia.

Numerous attempts have been made to trace the immediate effect of the male gamete upon the apple.

Nebel and Kertesz, 1934 (97) gave a comprehensive review of xenia and metaxenia. Nixon, 1928 (98 and 99), working with the date palm (Phoenix dactylifera var. Deglet Noor) reported from an extensive investigation that the time of ripening, as well as the size of both fruit and seed, may be directly affected by the pollen used. Lewis and Vincent, 1909 (75) reported from cross-pollination studies with various apple varieties, instances of the immediate effects of pollen on the color of the fruit. They found that with an increase in the weight of the crossed apple there was a proportional increase in the weight of the seeds.

Heinicke, 1917 (53) stated:

> The size of the fruit varies with the number of seeds, provided the apples in question are borne under similar conditions on spurs of equal vigor.

Heinicke, 1917 (53), MacDaniels, 1929 (84), Wentworth, Furr, and Mecartney, 1928 (133) and Murneek, 1932 (86) have shown that the number of seeds in the mature fruit gives an indication of the relative effectiveness of the pollenizer.

Alderman, 1918 (1) found two to six times as many seeds in crossed fruits as in the self-pollinated ones. There was also a good correlation between the number of seeds and the size and weight of the apple.

Einset, 1930 (34) has stated that in the Gravenstein apple the fruit weight is directly correlated to the combined number of both empty and filled seeds. Nebel, 1930 (95) found dissimilarities in height, width, color, weight and seed length in the apple, and later, 1936 (96) presented data from which he concluded that rotting of apples was differentially affected by separate pollen parents.

Murneek and Schowengerdt, 1936 (93) presented data showing that the number of seeds in cross-pollinated apples was considerably larger than those obtained from self-pollination. They obtained records from shaded and not shaded fruit which showed good correlation both between weight of fruit and number of seeds and weight of fruit and weight of spur leaves. They concluded that from the point of view of fruit size, flowers poorly situated as to organic food supply would seem to require more efficient pollination than those more favorably situated.

Tydeman, 1938 (126) made a study of the progressive development of fruits of apples and pears, pollinated by different varieties, from the time of pollination until maturity. The study included the fruits of six varieties of apples with eighteen pollinations and of five varieties of pears with fourteen pollinations. He wrote:

> Comparatively large differences in the size of the fruits of each variety, fertilized by different pollens, were found within the first few weeks after pollination. These differences grew smaller as time went on and, by the time the fruits were ripe, had become almost negligible. It was possible to show that this reduction in size difference was associated with fruit drop. In all the crosses studied it was found to be the smaller fruits which fell, irrespective of the variety with which they had been pollinated. The differences in final weight between fruits of any one variety differently pollinated, were found to be larger, sometimes of the order of 10 per cent. Rather large differences were also found in the average seed content of the fruits, but it did not always follow that the larger fruits had the greater number of seeds.

Lewis and Vincent, 1909 (75) obtained satisfactory sets as a result of emasculation and hand pollination when the pollen was applied at the time of emasculation. Alderman, 1918 (1) obtained an increased fruit set for two seasons as a result of emasculation plus cross-pollenization over not emasculated plus cross-pollinated blossoms. Contrariwise, Knowlton, 1930 (70) found emasculation to be detrimental due to its drying effect. Howlett, 1930 (66) also mentioned the undesirability of emasculation. Auchter, 1922 (4) stated that the delay between the time of emasculation and cross-pollination may greatly influence pollination results. Immediate pollination gave higher sets.

MATERIALS AND METHODS

Nitrogen Studies

In April 1940 thirty-four Delicious apple trees were chosen as material to be used in a study of nitrogen nutrition in relation to the phosphorus and potassium levels as well as the vegetative and reproductive behavior of the trees. The trees were fourteen years old, growing on Sassafras sandy loam soil, and moderately vigorous, although they had received no nitrogen fertilizer application during 1939. The trees had been planted in two double rows consisting of eight pairs of trees and one single tree in each double row, as shown in Figure 1. Adequate pollenizers were located in adjacent rows.

As indicated in Figure 1, each pair of trees (single tree in the case of I and XIII) was subjected to one of the following randomized treatments:

1. Five pounds of nitrate of soda per tree applied monthly throughout the growing season.
2. Two and one-half pounds of nitrate of soda, plus five pounds of dried blood containing 8 per cent nitrogen applied monthly throughout the growing season.
3. Check, no fertilizer application.

I	II	III	IV	V	VI	VII	VIII	IX
x	x	x	x	x	x	x	x	x
	x	x	x	x	x	x	x	x
X	XI	XII	XIII	XIV	XV	XVI	XVII	XVIII
x	x	x		x	x	x	x	x
x	x	x	x	x	x	x	x	x

N

W-------------E

S

Figure 1. Field plan for fertilizer treatments on Delicious apple in College Park orchard.

<u>Legend</u>

By the randomized selection the trees were placed in the following categories:

1. The treatment for trees II, VI, IX, X, XIV and XVII was five pounds of nitrate per tree applied monthly April, May, June, July and August, respectively.

2. The treatment for trees I, IV, VII, XII, XV and XVI was two and one-half pounds of sodium nitrate, plus five pounds of dried blood containing 8 per cent nitrogen, applied monthly April, May, June, July and August, respectively.

3. Check trees were III, V, VIII, XI, XIII and XVIII.

The fertilizer applications for 1940 and 1941 were made on the fifteenth day of April, May, June, July and August, respectively. No fertilizer was added in 1942.

An estimate of the per cent of bloom, which would represent the total number of growing points blossoming, was made for each tree during the period of full bloom for each of the three years.

A representative branch was selected on each tree during the blossoming period of 1940. This served as an index for the number of blossom clusters produced, the number of vegetative points present, and the per cent of blossom clusters which set. Two additional check branches per tree were tagged in the spring of 1942 and similar records taken.

Except in cases where none was available, leaves from twenty bearing spurs were collected from each tree at monthly intervals, and leaves from each tree constituted a sample for analysis. Fresh weights of these samples were taken, after which they were dried at 70-75° C. for three days. Upon removal from the oven dry weights were taken.

The amount of total nitrogen in the leaf samples was determined by the Kjeldahl-Gunning-Arnold method with the addition of selenium and other catalysts as adopted by Murneek and Heinze, 1937 (92). The potassium content of the leaves was determined by means of an aqueous solution of trisodium cobaltinitrite in the presence of nitric acid as reported by Wilcox, 1937 (136). The method of Fiske and Subbarrow, 1925 (36) was used for phosphorus determinations.

Before the samples were subjected to the various analyses they were run through a Wiley laboratory mill with a 40-mesh sieve, redried for five hours at 75-80° C., and cooled and stored in a desiccator.

At harvest time the mature fruits were allowed to drop. At frequent intervals counts were made of the number of fruits under each tree, as a measure of the relative periods of dropping.

The only extremely dry period throughout the duration of the experiment was during the month of June 1940; however, to overcome the effects of this dry period the trees were well irrigated by means of the stationary spray lines from June 27 to July 2.

Light Intensity Studies

Muslin on individual branches. During the blossoming period of 1940 fifty large branches were selected at random from nine Delicious apple trees as material for the shading studies. From 60 to 90 per cent of the growing points on these trees were bearing blossom clusters. Full bloom period was May 8 and 9. These trees were growing on Sassafras sandy loam, making satisfactory annual growth and were maintained under good cultural practices.

The treatments were:

1. May 10, a branch enclosed in muslin on each of five trees.
2. May 10, flower clusters removed and branch enclosed on each of five trees.
3. May 10, flower clusters removed and branch not enclosed on each of five trees.
4. May 18, a branch enclosed on each of five trees.
5. May 18, flower clusters and fruit removed and branch enclosed on each of five trees.
6. May 25, a branch enclosed on each of five trees.
7. May 25, flower clusters and fruit removed and branch enclosed on each of five trees.
8. June 3, a branch enclosed on each of five trees.
9. June 3, flower clusters and fruit removed and branch enclosed on each of five trees.
10. Check.

Heavy muslin bags 5x10 feet were used for enclosing the branches. Weston illuminometer readings from various points within the bags averaged 1009 foot candles whereas readings in the open sun averaged 7360 foot candles. Therefore, the bags admitted only about 13.7 per cent of the full sunlight.

At the time the branches were enclosed, counts were made of the number of flower clusters and fruits removed and of the purely vegetative and non-fruiting points. Aphid control was accomplished by the application of Rotenone Dust at weekly intervals. All of the bags were removed on August 2. On September 20 the apples were picked from those branches where fruits were permitted to develop.

Cheesecloth on individual branches. Prior to blossom opening in 1940 (May 4) fifty-four branches were selected at random from the same nine trees used for muslin shading. At the time of selection these branches were enclosed in Number 90 cheesecloth bags 3x5 feet and subjected to the following treatments:

1.	May 15,	removal	of	bags	from	six	branches.
2.	May 25,	"	"	"	"	"	"
3.	June 4,	"	"	"	"	"	"
4.	June 14,	"	"	"	"	"	"
5.	June 24,	"	"	"	"	"	"
6.	July 4,	"	"	"	"	"	"
7.	July 14,	"	"	"	"	"	"
8.	July 24,	"	"	"	"	"	"
9.	August 3,	"	"	"	"	"	"
10.	Check, six branches.						

The Number 90 cheesecloth bags had been used the previous season for pollination work and were therefore weathered to some extent. Weston illuminometer readings from within these used cheesecloth bags averaged 3532 foot candles while those in the open sun averaged 8027 foot candles. Therefore, they admitted 44 per cent of the full sunlight. For the sake of comparison, readings were also made of the light intensity within new cheesecloth bags of the same dimensions and grade as the old and compared with readings made in the open sun. The readings within the new cheesecloth bags averaged 5285 foot candles, whereas those in the full sunlight averaged 9249 foot candles. The new bags, therefore, admitted 57 per cent of the open sunlight.

Aphids were controlled as for other bagging treatments.

Shading of one-half of tree. During May 1940 a twelve-year-old Delicious apple tree was chosen which lent itself to being divided into a southern half and a northern half. A three-sided canvas shed which was open to the north was constructed over and around the northern half of the tree. The shed was completed about the first of June. Thus, the northern half of the entire tree received only indirect light from the north in addition to that which filtered through the heavy duck. The southern half of the tree was used as a check. Four branches on the shaded side (northern) and four on the exposed (southern) side of the tree were tagged and counts of the number of fruiting, as well as non-fruiting points were made. Light intensity readings with a Weston illuminometer from various positions within the canvas shed averaged 171 foot candles, whereas readings outside in the open sun averaged 9300 foot candles. The average light intensity within the shed was therefore only 1.8 per cent of that outside. The shed was removed November 8, 1940. During the period of full bloom of 1941 counts were made of the clusters produced on all growing points of the eight tagged branches.

Ringing of Branches

Forty twenty-year-old Delicious trees near Sandy Spring, Maryland, growing on Chester clay loam soil under bluegrass sod, were selected for these ringing studies. Prior to 1938, the trees received nitrate of soda annually at the rate of five pounds per tree and a moderate amount of pruning. In 1938 the grower, feeling that the trees were excessively vigorous, discontinued fertilizer and pruning treatments, with the intention of increasing production. In spite of the fact that these trees had blossomed profusely and had made vigorous growth, they have been consistently low yielding; however, no data were available relative to the percentage set for the years prior to the beginning of these studies.

The present study was concerned not only with the effect of ringing upon the fruit set of these particular trees, but also with time of ringing as a factor in increasing set.

In 1940, four large branches, about three inches in diameter at the base, were selected for ringing on each tree. One of the four branches was ringed May 3 at the pink stage, another May 16, immediately following petal fall, and still another on June 2. The fourth branch served as a check for the three ringed branches. Ringing was accomplished by means of a pruning saw of the curved type and the wounds were sealed with grafting wax. Counts of set of fruit were based on approximately one hundred blossom clusters tagged on the outer part of each branch.

It was found during the blossoming period of 1941 that only those branches which were ringed in 1940 had produced blossoms. This was true in the case of all forty of the trees. Typical examples of these blossoming branches are shown in Figures 2 and 3.

Three large leaders had been ringed on each tree. Therefore, the ringed branches provided not only from two to three bushels of apples per tree, but more important by far, they provided a source of cross-pollination for Stark, Black Twig and Stayman apple trees which made up the remainder of the orchard.

In 1941, one of the previously ringed blossoming leaders on each of thirty trees was selected and subdivided for the following treatments:

1. Ringed at petal fall.
2. Ringed at petal fall and defoliated by cutting off the proximal half of the leaf.
3. Branch bagged for hand pollination.
4. Check.

The likelihood of inadequate pollenizers for these trees led to further investigation. In order to obtain information regarding this question one branch on every third tree was bagged before the blossoms opened. When the blossoms were receptive Jonathan pollen was applied by hand

Figures 2 and 3. Blossoming of an individual branch of the Delicious apple in 1941 resulting from the effect of ringing in June 1940.

with a camel's hair brush. On May 13 counts were made of the set of fruits on all of the treated and check branches.

On the nine Delicious apple trees which were utilized in the shading studies in 1940, fifty-one branches were selected for additional ringing and defoliation studies. This work was executed on April 27 and 28, 1941, at the time of petal fall, in the following manner:

1. Ringed.
2. Ringed and defoliated.
3. Check.

Environmental Control Chamber

In an attempt to modify the climatic conditions under which the Delicious apple is grown in Maryland, an environmental control chamber was constructed to be used under orchard conditions. It consisted of two main sections which were bolted together. (See Figures 4 and 5). The compartment which functioned as a service unit to hold one tree branch was 2'x2'6"x3' and the chamber was composed of a wooden frame 2'x2'6"x3'6" covered with cellulose acetate.

The wooden service unit contained three compartments. The outermost portion was insulated and served as a chest which would hold 200 pounds of ice. Next to the ice chest there was space for an electric fan which forced the cooled air through a perforated board into the control chamber. Between the perforated end of the control chamber and the

Figures 4 and 5. Control chamber in operation showing a branch of a Delicious apple tree enclosed in the transparent section of the chamber.

fan, space was provided for a screen insert which was filled with calcium chloride. It was intended that this calcium chloride insert would remove a high percentage of the moisture from the cold air before it was forced into the cellulose acetate chamber. As an aid in manipulating the equipment a hygro-thermograph and thermometer were placed in the chamber.

On May 19, 1941, a branch holding thirty-two fruits on the east side of a thirty-five-year-old Delicious apple tree was enclosed within the chamber. Length and width measurements of the leaves within the box and of leaves from check branches were taken June 16, 1941.

Weston illuminometer readings taken at 9:30 A.M. July 21, 1941 from fifty points near fruit locations averaged 3470 foot candles, while readings in the open sun averaged 9867 foot candles. The chamber, then, admitted approximately 35.2 per cent of the full sunlight.

Fifty similar readings taken at about the same time from fruit locations on check branches averaged 6021 foot candles, whereas those in the full sunlight averaged 9900 foot candles. The fruit on the check branches was receiving 60.8 per cent of the full morning sunlight.

Light intensity measurements were also taken around 5:00 P.M. on July 21, 1941. Fifty readings from fruit locations within the chamber, at this time, averaged 694 foot candles. Readings outside averaged 4600 foot candles. Therefore, only 15.1 per cent of the outside light was available within the chamber at this time of day.

Readings from check branches at approximately the same time averaged 1248 foot candles at various fruit locations, while outside readings averaged 3333 foot candles. At about 5:00 P.M. on a clear day, therefore, the check branches were receiving 37.4 per cent of the open sunlight.

The fruit was harvested and the chamber was removed from the branch on September 20, 1941.

Pollination Studies

In the spring of 1940 a study was made to determine the relative effectiveness of Golden Delicious, Williams, Winter Banana, Jonathan, Lowry, Yellow Transparent, Rome Beauty, Gallia Beauty, and York Imperial pollens, as well as open pollination, in obtaining a set of fruit on Delicious. On May 4, forty-nine branches on eight twelve-year-old Delicious trees were selected and each branch was enclosed with a cheesecloth bag, 3'x3'. Ten of the forty-nine branches were selected from tree I so that each pollen source could be represented on this tree, while the remaining branches were distributed four to six per tree. A branch for open pollination occurred on each of the eight trees and no pollen source was used on more than one branch on a given tree, although it was impossible to place any one pollen source on all trees. Unopened blossoms of the different pollenizer varieties were collected from May 4 to 7, and the anthers were shelled out and allowed to dry in Petri dishes. Pollen from the various varieties was applied with camel's hair brushes to the test blossoms during full bloom (May 8 and 9). Counts of the number of blossom clusters setting one or more fruits each were made on June 2 after the "June drop".

With the results of 1940 indicating the need for greater replication, the work in 1941 was outlined to have eight branch replications for each of five pollen sources, as well as eight open-pollinated branches. Accordingly, on eight fifteen-year-old Delicious trees, six branches were selected per tree, which were used for a random placing of the five pollen varieties, York, Rome, Gallia Beauty, Jonathan, and Golden Delicious, leaving one branch per tree for open pollination. Since the season was earlier the test branches were bagged April 19 and 20 and the pollen from the various varieties applied April 22 and 23. Set counts were made May 15.

The work in 1942 was a duplication of that outlined for 1941 with the exception that there were ten branch replications for each of the six treatments, (including the five pollen sources and a branch for open pollination on each of ten trees). The bags were placed on the branches April 19 and the various pollens were applied April 22 and 23. Set counts were made May 15.

Size measurements of all the fruits which set as a result of the cross-pollination work, as well as those set on the check branches were taken June 24, 1942. The widest diameter of each fruit was measured in centimeters with a pair of calipers. On August 1, 1942 the fruit was harvested. At this time the widest diameter of each fruit was again measured, and the weight and number of seeds per fruit recorded. Such measurements were designed to determine more completely the relative efficiencies of the different pollenizers.

In connection with the pollination studies, it was of interest to compare the sets of fruit from emasculated plus hand pollinated blossoms with those bagged plus hand pollinated, open pollinated, and emasculated plus open pollinated. Therefore, on April 24, 1942 thirteen branches were selected at random on five sixteen-year-old Delicious apple trees. The blossoms which had opened were discarded and the unopened ones emasculated. Rome pollen was applied to the exposed stigmas of the emasculated flowers on seven of the branches, while the remaining six provided checks. Since the work was done during the period just preceding full bloom most of the apical blossoms were open, necessitating the use of the lateral blossoms of each cluster for the emasculation studies. Pollination was executed from immediately to three hours after emasculation.

Statistical Treatment of Data

Most of the following results are expressed as percentages, that is, per cent of clusters set, per cent of vegetative points forming flower clusters, etc.

Snedecor, 1940 (117) stated:

> " . . . if percentages result from less than 100 affected individuals, or if the event enumerated is infrequent, some transformation of the variable may be necessary before analysis of variance is carried through.

Since some of the original data fell into this category, the percentages were converted into angles, angle = arc sine $\sqrt{\text{percentage}}$, by employing Snedecor's table of angles corresponding to percentages, Snedecor, 1940 (117). Then, for the sake of comparison, both the percentages and the angles were subjected to analysis of variance.

The results of the analysis of variance of the percentages only, are presented here since no appreciable differences in the order of significance were found between the two criteria.

RESULTS

Effect of Nitrogen Fertilizers on Set of Fruit, Dropping of Fruit, and Chemical Content of Leaves

<u>Set of fruit and yield</u>. It may be seen in Table 1 that the trees receiving two and one-half pounds of nitrate of soda plus five pounds of dried blood had a significantly higher three-year average per cent of blossom clusters set (47.6 per cent) at the one per cent level than did the check trees (34.2 per cent). The trees receiving five pounds of nitrate of soda monthly set an average of 42.8 per cent of their blossoms, which was significantly higher than the check (34.2 per cent) at the five per cent level.

There were no significant differences in the average per cent set based on the total number of growing points (including both vegetative points and blossoming points) for the trees.

In 1940 (the first season that the trees were under treatment) the estimated mean per cent bloom produced by trees subjected to nitrate of soda plus dried blood was 57 per cent of their total growing points, for those treated with nitrate of soda, 64 per cent, and for the check trees, 54 per cent. The average numbers of apples produced per tree for these trees were 1393, 1618 and 1459, respectively.

In 1941 the estimated mean per cent bloom was 18 per cent for the nitrate of soda plus dried blood treated trees,

[redacted]

Table 1. Set of fruit and yield of fourteen-year-old Delicious apple trees as influenced by nitrogen fertilizer treatments. Averages for set of fruit for three seasons.

Fertilizer treatment	Total number of growing points on selected branches	Average per cent set based on all growing points	Average estimated per cent bloom for entire tree	Number of blossom clusters	Average per cent set after June drop	Average number of fruits produced per tree 1940	1941	1942
2-1/2 lbs. nitrate of soda plus 5 lbs. dried blood applied monthly	17,310 (11 trees)	19.6	45.5	8,284	47.6	1,393	730	1,493
5 lbs. nitrate of soda applied monthly	25,271 (12 trees)	19.5	49.9	9,792	42.8	1,618	737	1,933
Check (no fertilizer application)	15,941 (11 trees)	15.4	41.8	7,531	34.2	1,459	495	847
Difference required for significance								
5.0 per cent level					8.42			
1.0 per cent level					11.18			
F value for treatments		2.14			5.16**			
F value for replicates		2.40**			2.40**			

**Significant beyond the one per cent point.

[redacted]

18 per cent for the trees under nitrate of soda only, and 24 per cent for the check trees. The average yield per tree, in terms of number of fruits per tree, following the above order, were 730, 737, and 495.

In 1942 the trees which had received nitrate of soda plus dried blood produced (according to estimates) flowers on an average of 61 per cent of their growing points while the trees treated with nitrate of soda produced 68 per cent, and the check trees, 47 per cent. The average yields per tree for these trees were 1493 fruits for the trees treated with nitrate of soda plus dried blood, 1933 for those treated with nitrate of soda, and 847 for the check trees.

Considering the bloom and yield records for the three years it is evident that the lack of nitrogen was not effective until the season of 1941, as reflected by the lower bloom and parallel yield of 1942 on the check trees. It is recognized, however, that the bloom of 1940, formed in 1939, would not be affected by omission of nitrogen, and the relatively heavy yield of 1940 caused a considerable reduction of bloom on all plots for 1941.

Dropping of fruit. Table 2 shows the mean percentages of the number of fruits which had dropped by various dates during Septmmber and October. The same data expressed as the mean accumulated per cent drop plotted against time are presented in Figure 6. It should be noted again that the entire crop was allowed to drop and the dropping recorded at frequent intervals.

Table 2. Dropping of the Delicious apple as effected by nitrogen fertilization, 1940 and 1941.

Fertilizer treatment	Per cent drop of total crop in 1940						
	Sept. 4	Sept. 17	Sept. 26	Oct. 3	Oct. 10	Oct. 19	Oct. 27
Nitrate of soda plus dried blood	15.2	21.7	6.2	7.4	25.0	22.4	2.0
Nitrate of soda	17.8	22.9	5.3	7.5	24.9	20.0	1.4
Check	14.7	19.9	5.1	7.4	28.9	23.0	1.0

Fertilizer treatment	Per cent drop of total crop in 1941					
	Sept. 16	Sept. 23	Sept. 30	Oct. 7	Oct. 14	Oct. 21
Nitrate of soda plus dried blood	17.6	9.0	31.5	29.4	10.8	1.8
Nitrate of soda	14.0	7.0	29.5	31.3	14.7	3.4
Check	10.1	5.8	30.7	41.2	10.3	2.1

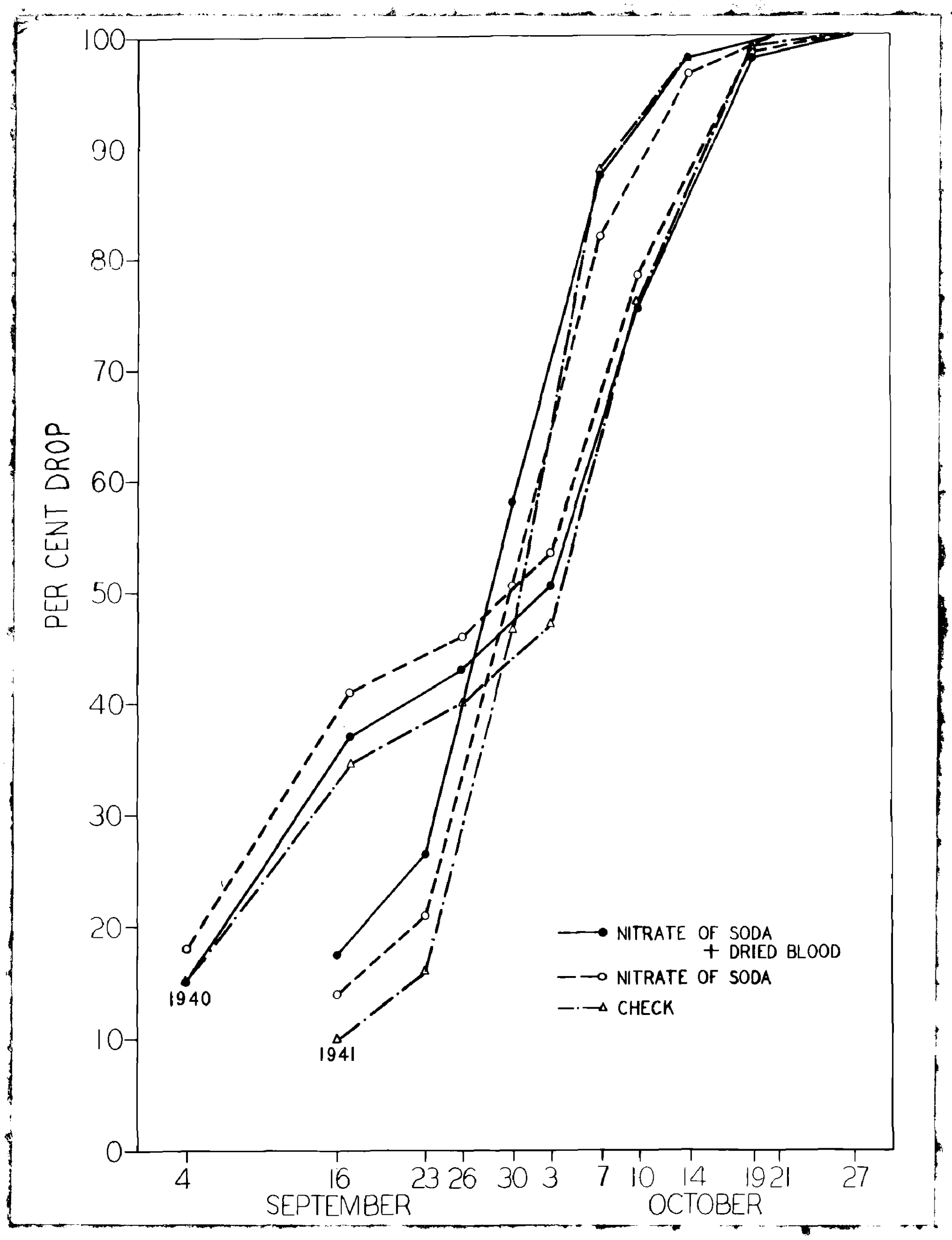

Figure 6. Dropping of Delicious fruits during harvest period in relation to nitrogen fertilizer treatments.

A comparison of the number of fruits on the ground as the season progressed revealed but small differences in dropping as a result of the treatments. There was slight lag in the per cent of the total crop on the ground from the check trees at the different dates as compared to the two heavy nitrogen fertilizer treatments for both 1940 and 1941. In 1940 this difference was most noticeable on September 17, September 26 and October 3, (see Figure 6). By October 10, 1940, however, there were practically no differences in the amount of fruit dropped as a result of treatment. In 1941 the check trees displayed the same slight lag in dropping. Differences in the per cent of fruit dropped from trees under the three treatments were no longer evident after October 7 of this season.

Summarizing, the results tend to show that although the check trees held their fruits slightly longer than the trees treated with nitrate of soda plus dried blood and nitrate of soda alone, the differences in the amount of fruit dropped at the various dates were small and diminished early in October.

Chemical analyses. The results of the chemical analyses of leaves from the nitrogen fertilized and check trees are presented in Table 3. On July 12, 1941 the mean per cent nitrogen contents of leaves from trees treated with either nitrate of soda plus dried blood (2.03 per cent) or nitrate of soda (1.92 per cent) were significantly higher at the one per cent level than similar leaves from

Table 3. Results of chemical analysis of spur leaves from Delicious apple trees. Percentages expressed on a dry weight basis.

Fertilizer treatment	Mean for eleven trees per treatment: Per cent nitrogen, July 12: 1941	Aug. 11: 1941	May 2: 1942	Per cent phosphorus, July 12: 1941	Aug. 11: 1941	May 2: 1942	Per cent potassium, July 12: 1941	Aug. 11: 1941	May 2: 1942	Milligrams in total leaves per spur, May 2, 1942: Nitrogen	Phosphorus	Potassium
Nitrate of soda plus dried blood	2.03	1.93	3.27	0.121	0.115	0.265	1.55	1.72	1.71	11.6	0.952	6.07
Nitrate of soda	1.92	1.86	3.20	0.126	0.118	0.275	1.20	1.46	1.55	11.7	1.007	5.64
Check	1.55	1.48	2.42	0.138	0.133	0.273	1.35	1.51	1.68	7.4	0.833	5.06
Difference required for significance												
5.0 per cent point	0.16	0.21	0.17	0.009	0.012			0.21		1.10	0.10	0.66
1.0 per cent point	0.22	0.28	0.24	0.012	0.016			0.29		1.50	0.14	0.90
F value for treatments	20.40**	11.36**	63.15**	8.00**	5.00*	0.75	3.17	3.92*	2.85	43.22**	6.50**	5.08*
F value for replicates	1.22	0.39	0.88	2.00	0.42	1.25	0.54	2.84	3.72**	0.92	1.41	1.10

*Significant beyond the five per cent point
**Significant beyond the one per cent point

the no fertilizer treatment (check) trees (1.55 per cent). The leaves taken August 11, 1941 showed no significant differences in nitrogen content from trees treated with either nitrate of soda plus dried blood or nitrate of soda alone. However, leaves from both of these treatments were significantly higher in nitrogen content than were those from the check trees.

On May 2, 1942, immediately following petal fall, the young leaves from all three treatments contained relatively high percentages of nitrogen. Leaves from nitrogen fertilized trees (either nitrate of soda or nitrate of soda plus dried blood) were significantly higher in per cent nitrogen (3.20 per cent and 3.27 per cent) than were corresponding leaves from check trees (2.42 per cent). The milligrams of nitrogen in total leaves per spur on May 2, 1942 are shown in the tenth column of Table 3. Again on this basis the leaves from the nitrogen fertilized trees contained significantly higher amounts of nitrogen (11.7 mg. and 11.6 mg.) at the one per cent level than did the leaves from the spurs from the check trees (7.4 mg.). On this basis the greater intake of nitrogen per growing point is clearly shown for nitrogen fertilized trees. Similarly, there was a greater intake of potassium and phosphorus which is not indicated by the percentage figures for the same date of sampling. Calculating the amount of intake compared with check trees, it can be shown from the figures for milligrams per spur that the nitrogen trees took up at least 50 per cent more nitrogen and approximately 25 per cent more potassium and 20 per cent more phosphorus than the check trees.

The per cent phosphorus found in the leaf samples taken July 12, 1941 was found to be significantly higher in the leaves from the check trees (0.14 per cent) as compared to the leaves from the nitrate of soda (0.13 per cent) at the five per cent level and the nitrate of soda plus dried blood treated trees (0.12 per cent) at the one per cent level. The leaves from the nitrate of soda trees also contained a significantly higher percentage of phosphorus than leaves from the trees under nitrate of soda and dried blood at the five per cent level. By August 11, 1941 the percentage of phosphorus had gone down a similar amount (0.01 per cent) in the leaves from each of the three treatments, but there were no changes in the order of significance from those of the preceding month.

As was true in the case of nitrogen, the leaf samples taken on May 2, 1942 were all comparatively high in per cent phosphorus. However, there were no significant differences in the phosphorus percentage in leaves from trees under the three treatments.

When considering the milligrams of phosphorus in total leaves per spur it may be seen that spurs from the trees treated with nitrate of soda contained significantly higher amounts (1.01 mg.) at the one per cent level than did the check leaves (0.83 mg.). Spurs from the trees treated with nitrate of soda plus dried blood contained significantly greater amounts of phosphorus (0.95 mg.) at the five per cent level than the spurs from the check trees (0.83 mg.).

The potassium content of the leaves from trees under nitrate of soda plus dried blood was consistently higher at the three sampling dates than from similar leaves of the other two treatments. Leaves from nitrate of soda trees had the lowest percentage of potassium. The leaves from the check trees were intermediate in potassium content.

No significant differences were obtained in the per cent of potassium between leaf samples taken July 12, 1941 from the trees subjected to the three treatments. By August 11, 1941, however, leaves from the trees under nitrate of soda plus dried blood had a significantly higher percentage of potassium (1.72 per cent) at the one per cent level than did similar leaves from trees of the nitrate of soda treatment (1.46 per cent). They were also significantly higher in per cent potassium than leaves from the check trees (1.51 per cent) at the five per cent level.

Contrary to the case of either nitrogen or phosphorus the per cent of potassium of young apple leaves gathered May 2, 1942 was not outstandingly higher than the percentages of potassium found in the July 12, 1941 and the August 11, 1941 samplings. There were no significant differences in the per cent of potassium resulting from the different treatments of the leaves gathered on that date.

Spurs from trees treated with nitrate of soda plus dried blood contained significantly greater amounts of potassium (6.07 mg.) than either spurs from the check trees (5.06 mg.) at the one per cent level or spurs from trees treated with nitrate of soda alone (5.64 mg.) at the five per cent level.

Tree Variability as a Factor in Chemical Analyses

In regard to sample size, Snedecor, 1940 (117) wrote:

> Investigators are often content with samples less than 0.1 per cent of the population, while a sample of 10 per cent is usually considered large. Such loose statements can be replaced by more definite ones only if there is available some knowledge of the mean and the standard deviation of the population to be sampled. Although this knowledge may not be precise it enables us to make fair approximations to sample size.
>
> . . . .
>
> As for population parameters, you may be confident that the sample mean and the standard deviation are their best available estimates if the population distribution is not greatly different from the normal.
>
> Before laying down an experiment the investigator must arrive at some estimate of the size of sample required to gain a desired precision. This requires a knowledge of the size of the difference to be expected in the means together with the magnitude of the variability in the experimental material.

Table 4 presents information for estimating the minimum number of Delicious apple trees which must be sampled to show a significant difference of ten per cent in the nitrogen, phosphorus, and potassium content of their leaves as a result of various fertilizer treatments.

The figures were obtained by employing the chart for estimating the size of sample required for significance in group comparisons as given by Snedecor, 1940, (117). By

Table 4. Showing the number of trees which must be sampled to show a significant difference of ten per cent in the nitrogen, phosphorus, and potassium content of Delicious apple leaves, using analyses of non-fertilized trees as a base. (The figures are based on thirty-three analyses of leaves, representing individual samples of thirty-three trees, taken July 12, 1941, August 11, 1941, and May 2, 1942, from two fertilizer treatments and check).

Date of sampling	Minimum number of trees which must be sampled to give a significant difference of ten per cent in the nitrogen, phosphorus, and potassium content (expressed as the per cent of the dry weight)					
	Nitrogen		Phosphorus		Potassium	
	at 5% level	at 1% level	at 5% level	at 1% level	at 5% level	at 1% level
July 12, 1941	11	19	5	8	46	36
August 11, 1941	20	35	8	14	19	33
May 2, 1942	6	10	5	9	9	15
	Same as above except expressed as mg. per spur					
May 2, 1942	20	34	12	21	18	31

applying any actual or desired difference between means ($\bar{d}$) and the pooled standard deviation (s), as obtained from analysis of variance of the original data resulting from chemical analyses, one obtains the figures which represent the required number of observations in each sample for significance at both the five and the one per cent levels.

Obviously, some of the mean percentages calculated from the results of the nitrogen, phosphorus and potassium analyses of apple leaves (Table 3) showed no significant differences as a result of treatment. From samples taken July 12, 1941 the nitrogen content of leaves from trees under nitrate of soda plus dried blood was 2.03 per cent and that of the leaves from the trees treated with nitrate of soda 1.92 per cent. The mean difference (0.11) between these two treatments is not significant. According to Table 5, twenty trees would have to be sampled for this mean difference (0.11) to be significant at the five per cent level and forty trees for it to be significant at the one per cent level. Table 5 was prepared for estimating the minimum number of trees which must be sampled for the mean differences actually obtained to be significant as a result of the three treatments (nitrate of soda plus dried blood, nitrate of soda, and check) and as revealed by chemical analyses. The chart as given by Snedecor, 1940 (117) for estimating the size of sample required for significance in group comparisons was again used to obtain

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Table 5. (cont.) Showing the minimum number of trees which must be sampled for the mean differences obtained to be significant. (Mean differences from eleven trees per treatment).

Date of sampling	Mean difference in per cent of potassium of leaves from treatments	Mean difference expressed as per cent of higher mean	Mean difference	Minimum number of trees which must be sampled for this mean difference to be significant at 5% level	at 1% level
July 12, 1941	Nitrate of soda plus dried blood vs nitrate of soda	23	.35	7	12
	" " " " " " " check	13	.20	23	38
	" " " " "	11	.15	38	70
Aug. 11, 1941	" " " " " " " nitrate of soda	15	.26	7	12
	" " " " " " " check	12	.21	11	19
	" " " " "	3	.05	100+	100+
May 2, 1942	" " " " " " " nitrate of soda	10	.17	9	16
	" " " " " " " check	.02	.03	100+	100+
	" " " " "	8	.14	12	21
	Mean difference in milligrams of nitrogen per spur of leaves from treatments				
May 2, 1942	Nitrate of soda plus dried blood vs nitrate of soda	9	0.10	100+	100+
	" " " " " " " check	36	4.20	2	3
	" " " " "	37	4.30	2	3
	Mean difference in milligrams of phosphorus per spur of leaves from treatments				
May 2, 1942	Nitrate of soda plus dried blood vs nitrate of soda	6	0.06	100+	100+
	" " " " " " " check	13	0.12	8	14
	" " " " "	18	0.18	4	7
	Mean difference in milligrams of potassium per spur of leaves from treatments				
May 2, 1942	Nitrate of soda plus dried blood vs nitrate of soda	7	0.43	19	33
	" " " " " " " check	17	1.01	5	8
	" " " " "	10	0.58	11	19

[redacted]

Table 5. Showing the minimum number of trees which must be sampled for the mean differences obtained to be significant. (Mean differences from eleven trees per treatment).

Date of sampling	Mean difference in per cent of nitrogen of leaves from treatments	Mean difference expressed as per cent of higher mean	Mean difference	Minimum number of trees which must be sampled for this mean difference to be significant: at 5% level	at 1% level
July 12, 1941	Nitrate of soda plus dried blood vs nitrate of soda	5	.11*	20	40
	" " " " " " " check	24	.48	2	4
	" " " " "	19	.37	3	5
Aug. 11, 1941	" " " " " " " nitrate of soda	4	.07	100+	100+
	" " " " " " " check	23	.45	3	6
	" " " " "	20	.38	4	7
May 2, 1942	" " " " " " " nitrate of soda	2	.07	100+	100+
	" " " " " " " check	26	.85	2	3
	" " " " "	24	.78	2	3
	*Mean per cent nitrogen (July 12, 1941) of leaves from nitrate of soda + dried blood 2.03**				
	Mean per cent nitrogen (July 12, 1941) of leaves from nitrate of soda 1.92**				
	Mean difference 0.11				
	**See Table 3.				
	Mean difference in per cent of phosphorus of leaves from treatments				
July 12, 1941	Nitrate of soda plus dried blood vs nitrate of soda	40	.005	32	55
	" " " " " " " check	12	.017	4	6
	" " " " "	9	.012	6	10
Aug. 11, 1941	" " " " " " " nitrate of soda	3	.003	100+	100+
	" " " " " " " check	14	.018	6	9
	" " " " "	11	.015	7	12
May 2, 1942	" " " " " " " nitrate of soda	4	.010	30	50
	" " " " " " " check	3	.008	50	90
	" " " " "	0.7	.002	100+	100+

the figures presented in Table 5. To render some of the differences significant it is shown that more than one hundred trees would have to be sampled, whereas in other cases shown in Table 5 as few as two or three trees would be sufficient.

Effects of Reduction in Light Intensity on Flower Bud Formation in Delicious

Shading of branches. Table 6 shows the results (in terms of the per cent of flower clusters produced) of shading, shading plus clusters removed, shading plus fruit removed, no shading but clusters removed, and check. In this table the results with heavy muslin bags on individual branches are presented. As given previously, the muslin bag admitted only 13.7 per cent of the outside light. The check branches and the branches with their clusters removed but not shaded produced significantly higher percentages of flower clusters than either the bagged branches or those which had their clusters or fruit removed and then were bagged. No significant differences as a result of enclosure, or enclosure and defloration or defruiting were obtained in the percentages of flower clusters produced when based either on the non-fruiting points or the total number of growing points. However, if one considers the effect of the one procedure, bagging the branches only, (at the four dates May 10, May 18, May 25 and June 3) then the effect of the length of time the branches were enclosed is evidenced.

Table 6. Effect of shading Delicious branches with heavy muslin at successive intervals during the early growing season, 1940. (Number of branches per treatment ranged from five to ten).

Treatment	Period of treatment	Total number of growing points 1940	Average per cent producing flower clusters 1941	Number of non-fruiting points 1940	Average per cent producing flower clusters 1941
Shaded	May 10 to August 2	1,790	9.4	1,666	10.0
Shaded	May 18 to August 2	1,735	14.9	1,660	15.4
Shaded	May 25 to August 2	1,211	29.6	975	42.4
Shaded	June 3 to August 2	1,899	33.0	1,724	35.6
Clusters removed and shaded	May 10 to August 2	1,931	22.7	1,931	22.7
Clusters removed and shaded	May 18 to August 2	928	15.5	928	15.5
Fruit removed and shaded	May 25 to August 2	1,232	25.1	1,037	31.1
Fruit removed and shaded	June 3 to August 2	1,222	38.1	1,077	45.3
Clusters removed (no shading)	May 10	896	63.2	896	63.2
Check (no shading)		1,373	76.7	1,172	100.0
Difference required for significance:					
at 5 per cent level			23.20		26.04
at 1 per cent level			31.08		34.90
F value for treatments			7.17**		8.96**
F value for replicates			6.19**		6.02**

** = Significant beyond the one per cent point

Thus, the branches bagged May 10 produced the lowest per cent of flower clusters (9.4 per cent), those bagged May 18 next to the lowest (14.9 per cent), those bagged May 25, 29.6 per cent, and those bagged June 3, 33.0 per cent. These bags, therefore, shaded the branches for eighty-four, seventy-six, sixty-nine and sixty days respectively. Likewise, the early bagging with flower cluster removal resulted in low blossom bud formation compared with later bagging with fruit removal. However, there was no effect that could be ascribed to blossom or fruit removal in modifying the effect of shading.

The period between August 2 (date when the bags were removed from the branches) and September 19 (when the fruit was harvested) was sufficiently long for ample color development and no appreciable differences were noted between the fruit which had been shaded and the check fruit.

The percentages of flowers formed on branches which were enclosed with cheesecloth bags just prior to the blooming period and removed at ten day intervals, starting May 15, are presented in Table 7. In this shading work the light intensity was reduced to 44 per cent of the normal open sunlight. Here, as in Table 6, all of the shaded branches produced significantly lower percentages of blossom clusters based on the total number of growing points than similar unshaded check branches. However, this shading procedure differed from the muslin shading, in that bags were all put on at one time and removed at successive

Table 7. Effect of shading Delicious branches with cheesecloth, 1940. (Full bloom period was May 8 and 9).

Period of treatment	Total number of growing points 1940	Average per cent producing flower clusters 1941	Number of non-blossoming points 1940	Average per cent producing flower clusters 1941	Number of non-fruiting points 1940	Average per cent producing flower clusters 1941
May 4 to May 15	856	37.7	182	84.9	692	45.0
May 4 to May 25	641	36.5	155	70.4	509	47.1
May 4 to June 4	869	20.7	128	59.5	701	23.1
May 4 to June 14	888	15.1	273	50.0	779	16.8
May 4 to June 24	752	22.7	93	75.4	647	26.1
May 4 to July 4	886	40.9	276	73.4	757	44.3
May 4 to May 14	698	35.9	141	74.1	605	41.5
May 4 to May 24	679	39.6	303	76.0	721	40.7
May 4 to August 3	356	18.6	60	42.8	279	23.0
Check (not shaded)	2,038	70.4	489	100.0	1,715	80.2
F value for treatments		2.47*		1.07		2.92**

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

intervals rather than putting bags on at successive intervals and all bags removed at the same time. No significant differences in the per cent of flower cluster formation resulted from the differences in the number of days during which the various branches were shaded. Possibly if muslin had been used some significant differences might have resulted as indicated by the trend of the results although not significant.

Shading of one-half of tree. No significant differences in blossom bud formation were obtained as a result of this type of shading. From a total of a thousand growing points on the shaded half of the tree, 32.7 per cent of these points formed blossom buds in 1940, as shown by blossom counts in 1941, compared with 28.6 per cent of blossom buds on 752 growing points on the check half of the tree. It should be noted that this type of shading did not involve entire covering of the half portion of the tree, but permitted exposure to the north light.

Effect of Ringing and Defoliation on Fruit Set of Delicious

The data presented in Table 8 show that the branches ringed May 3, at the pink stage, yielded significantly higher percentages set (10.9 per cent) at the five per cent level than did the check branches (7.7 per cent). Ringing May 16, immediately following petal fall, resulted in a significantly higher set (13.1 per cent) at the one per cent

Table 8. Effect of branch ringing before and after blossoming on the fruit set of twenty-year-old delicious apple trees, 1940. (Mean for forty trees).

Treatment	Mean set per 100 clusters
Ringing on May 3	10.9
Ringing on May 16	13.1
Ringing on June 2	8.1
Check (no ringing)	7.7

Difference required for significance:	
at 5.0 per cent level	2.98
at 1.0 per cent level	3.86
F value for trees	4.19**
F value for treatments	5.07**

** Significant beyond the one per cent point.

level than either the check branches (7.7 per cent) or ringing on June 2 (8.1 per cent).

The average set of 13.1 per cent for the best ringing treatments represents an increase in set of 5.3 per cent over the check treatments (7.7 per cent) or a percentage increase of 68.9 per cent over the check. Murneek, 1940 (90) reported that ringing of Delicious in full bloom gave a set of 5.3 per cent with 1.4 per cent in the check, a difference of 3.9 per cent or a percentage increase of 278 per cent, which may in part be explained by the unusually low per cent set on the check branches under Missouri conditions.

Table 9 shows the mean percentages of fruit set of branches ringed and defoliated in 1941, located on large leaders which had been ringed during the previous blooming period, 1940. There were no significant differences in set resulting from the following treatments: ringing at petal fall, open pollination, ringing plus the defoliation of one-half the leaf area plus open pollination and check. The mean per cent set from the hand-pollinated branches (26.3 per cent based on total number of growing points, and 38.4 per cent based on number of blossom clusters) was significantly higher than those resulting from the other treatments. The excellent results from hand pollination point to the pollination factor as limiting in this orchard as will be discussed later.

Table 9. Effect of ringing, ringing and defoliation, and hand pollination on the fruit set of branches situated on previously ringed (1940) blossoming leaders of twenty-one-year-old Delicious apple trees, 1941.

Treatment in 1941	Total number of growing points	Average per cent set based on total number of growing points	Number of blossom clusters	Average per cent set based on the number of blossom clusters	Number of trees
Ringed at petal fall (open pollinated)	6,898	6.5	3,972	11.1	31
Ringed at petal fall + 1/2 of all leaves cut away (open pollinated)	2,556	10.0	1,729	16.42	20
Pollinated by hand with Jonathan pollen	1,158	26.3	777	38.4	11
Check (open pollinated)	5,727	6.0	3,716	9.4	34
F value for treatments		18.32**		16.09**	

** Significant beyond the one per cent point.

In other ringing and defoliation experiments at College Park with younger Delicious trees, there were no significant differences in the mean sets shown in Table 10 as a result of either ringing (9.5 per cent and 16.1 per cent) or ringing plus defoliation (cutting away one-half of each leaf on the branch concerned -- 7.4 per cent and 14.1 per cent) and check. Again the low percentage set indicates the possibility of inadequate pollination.

Relative Effectiveness of Various Pollenizers on the Delicious Apple

Fruit set. In the pollination work of 1940 involving the branch unit method with nine varieties as pollenizers, rather variable results were obtained, partially due to lack of sufficient replications. The mean per cent sets of fruits based on the total number of growing points (including vegetative points as well as those bearing clusters) and set of fruit based on the number of blossom clusters pollinated are presented in Table 11. From the low F values it is evident that there was no significant difference in set resulting from the different pollen varieties when based on either total number of growing points or the number of blossom clusters pollinated.

With greater replication of branches in 1941 some positive results were obtained, which showed significant differences among five pollenizers used in that season. The mean per cent sets based on the total number of growing

Table 10. The effect of ringing and defoliation upon fruit set of the Delicious apple. (Mean sets for nine trees).

Treatment	Total number of growing points	Average per cent set	Number of blossom clusters	Average per cent set
Ringing + 1/2 of all leaves cut away	3,770	7.4	2,118	14.1
Ringed at petal fall	1,672	9.5	1,033	16.1
Check	2,158	7.8	1,227	13.5
F value for treatments		0.41		0.28

Table 11. Comparison of certain varieties as pollenizers for twelve-year-old Delicious apple trees (1940).

Pollen variety	For all trees					For Tree I only		
	Number of branch units	Total number of growing points	Mean set per 100 growing points	Number of blossom clusters pollinated	Mean set per 100 blossom clusters	Set per 100 growing points	Number of blossom clusters pollinated	Set per 100 blossom clusters
Jonathan	4	623	23.7	516	28.3	22	112	29
Golden Delicious	7	836	19.5	588	28.0	27	67	45
Winter Banana	5	714	20.3	554	26.6	11	61	18
Yellow Transparent	4	474	17.2	370	24.8	10	122	12
Lowry	5	548	19.9	385	23.0	39	93	42
Williams	4	571	16.8	462	19.5	21	80	25
Gallia Beauty	4	599	11.6	407	17.3	11	67	15
York Imperial	3	323	15.1	304	16.0	8	102	8
Rome Beauty	5	522	11.1	385	15.2	9	100	10
Open pollinated	8	1,637	17.9	1,257	23.3	20	96	24
F value for pollen treatments			0.70		0.87			

points, as well as of the number of blossom clusters pollinated, are presented in Table 12. On the basis of either total growing points or of blossom clusters the mean per cent sets with Rome, Jonathan, and Gallia Beauty were approximately grouped in one class. They were significantly higher than those obtained by Golden Delicious and York Imperial. It is interesting to note from the complete data (not presented) that Rome Beauty, Jonathan and Gallia Beauty gave sets which were consistently high on each of the eight trees while Golden Delicious and York on these same trees were much more variable.

Further results in 1942 with the same pollenizers used in 1941 are presented in Table 13. On the basis of the total number of growing points the mean set obtained by Rome (33.3 per cent) was significantly higher at the one per cent level than those obtained by Golden Delicious (18.5 per cent), York Imperial (17.7 per cent), Gallia Beauty (8.5 per cent) and open pollinated (18.0 per cent). The mean set obtained by Jonathan pollen was significantly higher at the one per cent level than that by Gallia Beauty, in fact, at the five per cent level it was significantly higher than all treatments except that attained by Rome pollen. The mean sets with both Golden Delicious and open pollinated were significantly higher at the five per cent level than that of Gallia Beauty.

The mean per cent sets based on the number of blossom clusters pollinated attained by both Rome (44.5 per cent)

Table 12. Comparison of certain varieties as pollenizers for fifteen-year-old Delicious apple trees, 1941. (Mean sets for eight branches on eight trees).

Pollen Variety	Total number of growing points	Mean set per 100 growing points	Number of blossom clusters pollinated	Mean set per 100 blossom clusters
Rome Beauty	778	34.4	333	78.0
Jonathan	890	32.2	465	64.2
Gallia Beauty	786	30.4	374	63.0
Golden Delicious	558	17.5	443	39.7
York Imperial	982	14.2	446	34.2
Open pollinated	2,134	20.3	802	49.4

Differences required for significance:		
5.0 per cent level	10.7	18.6
1.0 per cent level	14.3	25.0
F value for trees	1.36	1.65
F value for treatments	5.23	6.52**

** Significant beyond the one per cent point.

Table 13. Comparison of certain varieties as pollenizers for sixteen-year-old Delicious apple trees, 1942. (Mean sets for ten branches on ten trees).

Pollen variety	Total number of growing points	Mean set per 100 growing points	Number of blossom clusters pollinated	Mean set per 100 blossom clusters
Rome	1,005	33.29	745	44.49
Jonathan	1,033	28.38	715	42.12
Golden Delicious	1,268	18.54	874	28.48
York Imperial	1,091	17.69	829	24.94
Gallia Beauty	1,033	8.52	634	16.02
Open pollinated	11,255	18.05	6,331	29.15
Totals	16,685		10,128	

Difference required for significance:		
5.0 per cent level	8.56	12.09
1.0 per cent level	11.39	16.08
F value for trees	1.44	1.79
F value for treatments	6.76**	4.56**

** Significant beyond the one per cent point.

and Jonathan (42.1 per cent) were significantly higher at the one per cent level than those of York Imperial (24.9 per cent) and Gallia Beauty (16.0 per cent). At the five per cent level they were both significantly higher than all other treatments. Golden Delicious and open pollinated gave mean per cent sets (28.5 per cent and 29.1 per cent, respectively) which were significantly higher at the five per cent level than that of Gallia Beauty.

Number of seeds and fruit size. Number of seeds and weight and diameter of fruit for the pollination studies of 1942 are shown in Table 14. The mean weight of fruits and number of seeds per fruit were taken on August 1, 1942. Fruit diameter measurements were made June 24 and August 1.

There were no significant differences in fruit diameter and fruit weight as a result of the different pollenizers. However, significant differences were found between the number of seeds per fruit. Fruits resulting from Rome, Jonathan, Golden Delicious and Gallia Beauty pollen all contained significantly higher seed numbers (6.9, 6.5, 6.1 and 6.0, respectively) then fruits resulting from open pollination (4.8), at the one per cent level.

Fruits from Rome and Jonathan pollen also contained significantly higher seed numbers at the one per cent level than fruits resulting from York Imperial pollen (5.0). Gallia Beauty and Golden Delicious pollen obtained fruits with significantly higher seed numbers than York Imperial at the five per cent level.

Table 14. Effect of pollenizers on number of seeds and fruit size, 1942. (Means for nine trees).

Pollen variety	Number of fruits	Average fruit weight (gms)	Average number of seeds	Average fruit diameter (cm) June 24 1942	Average fruit diameter (cm) August 1 1942
Golden Delicious	183	77.8	6.1	4.3	5.7
Jonathan	203	80.7	6.5	4.3	5.8
York Imperial	162	71.5	5.0	4.1	5.5
Rome	221	81.0	6.9	4.3	5.7
Gallia Beauty	72	81.5	6.0	4.3	5.8
Open pollinated	308	76.6	4.8	4.1	5.7
Differences required for significance:					
5.0 per cent level			0.83		
1.0 per cent level			1.11		
F value for trees		2.43*	2.63*	3.70**	2.27*
F value for treatments		1.38	8.17**	2.16	1.73

* Significant beyond the five per cent point
** " " " one " " "

Fruits from Rome pollen were also higher in seed number than fruits from Gallia Beauty pollen.

Of 747 individual blossoms which were emasculated and pollenized only four (0.0053 per cent) set fruits. None of the 682 blossoms which were emasculated for open pollinated checks set fruit. The humidity range on April 24, 1942, the day of emasculation, was 13-20 per cent, which may account for the poor set, possibly due to drying of the pistils.

Environmental Control Chamber

The chamber designed to regulate temperature and humidity around an individual tree branch under field conditions was brought into use on a branch of a Delicious tree during the spring and summer of 1941.

During the day the temperature within the chamber ranged from 5 to 15° F. lower than outside. At night it averaged from 15 to 25° F. lower. It was impossible, however, to lower the humidity with the methods employed. It varied but slightly from that outside the chamber in spite of the quantity of calcium chloride used.

The length/width ratios, from leaf measurements taken June 16, 1941 were 1.84 for leaves within the chamber and 1.88 for check leaves outside.

At this time there were twenty-six apples with an average of 26.8 leaves per apple within the chamber, while the apples on the check branches averaged 22.1 leaves per fruit.

The branch was enclosed on May 19, 1941, three weeks after which the fruits within the chamber were noticeably larger than those on the check branches. Soon after this some of the leaves within the chamber started turning yellow, followed by browning and dropping. By July 15, forty-six leaves had abscissed. Starting around August 10 there was another period of yellowing and dropping, and by August 19, eighty-six more leaves had fallen.

On August 23, it was noticed that the enclosed leaves were infected with red spider. They were sprayed at that time.

In spite of the foliage damage, the fruits within the chamber held their larger sizes than the check apples until around the last of August. From that time on the fruits on the check branches were as large or larger than the enclosed fruit.

At the time the fruit was harvested (September 20) the fruit which had developed within the chamber was more striped and had less red color than the fruits from the check branches.

No differences were noted in the keeping quality of the check and treated fruit after over seven months in cold storage.

DISCUSSION

In considering the several factors affecting the fruitfulness of the Delicious apple, these investigations can be broadly grouped in three categories, namely, mineral nutrition, carbohydrate synthesis, and pollination. It has been pointed out by Blake, 1934 (16) that the Delicious apple tree apparently requires favorable soil and growing conditions to maintain a high status of growth, necessary for the satisfactory flower bud formation with this variety, in contrast to less rigid requirements of other varieties. Harley, Masure and Magness, 1933 (50) on the other hand emphasized leaf area-fruit relations, rather than growth conditions. Likewise, this variety has been considered rather easily influenced by conditions affecting carbohydrate synthesis, as indicated by work in Maryland where Delicious blossoms failed to set fruit under manila paper bags, though cross-pollinated, whereas similar blossoms under transparent bags or under cheesecloth gave satisfactory sets with the same pollenizers. As the Delicious variety has been shown to be practically self-unfruitful, it has received considerable attention in pollination work to determine the more satisfactory pollenizers among our standard varieties, as a result of which cross-pollination with any one of several commercial varieties has been recommended. However, the relative merits of the several possible pollenizers have not been adequately evaluated.

Although differences in the fertility and physical characteristics of the soil make it difficult to make generalizations regarding orchard fertilization, there are few consistent or satisfactory data from field experiments showing any beneficial results from any mineral nutrient except nitrogen. The present concepts have been derived from the results of chemical analysis of orchard soils and either whole or portions of the trees, as well as from experimental evidence of tree response such as growth, set, and yield records of trees under different fertilizer treatments.

Recently many workers have studied young apple and peach trees in nutrient solution culture where the addition of various elements may be controlled to show interrelationships of mineral elements, particularly nitrogen, phosphorus and potassium, as measured by growth responses and intake of the elements. Under such controlled conditions it was hoped that information could be gathered which could be utilized in orchard practice. The next logical step is to study orchard trees under well-planned field experiments to correlate with the results of the controlled pot cultures.

The mineral nutrition phase of the present study was instigated to study the effect of varying amounts of nitrogen fertilizer application on the absorption and interrelation of nitrogen, phosphorus, and potassium as shown by chemical analysis of leaves.

The omission of nitrogen application during a three-year period resulted in a reduction in nitrogen content of the leaves accompanied by light green foliage and poorer growth and fruiting. By contrast the trees receiving nitrogen applications had dark green foliage, excellent growth and fruiting and a high level of nitrogen content of leaves.

In this work there was a rather consistent inverse relationship between the nitrogen and phosphorus content of apple leaves from bearing trees under field conditions. This corroborates the results of various studies of young apple and peach trees in nutrient solutions; Cullinan, Scott and Waugh, 1939 (27), Batjer, Baynes and Regeimbal, 1940 (13), and Waugh, Cullinan, and Scott, 1940 (132). Froebsting and Kinman, 1934 (105) also obtained similar results from leaf analysis of variously fertilized apricot, plum, and peach trees under orchard conditions.

The relation between potassium and either nitrogen or phosphorus or both appeared to be variable depending on treatment. The leaves from the trees treated with nitrate of soda which showed intermediate percentages of nitrogen contained the lowest potassium. On the other hand, in the leaves from the check trees a medium amount of potassium was consistently found at the three samplings with a low content of nitrogen and higher content of phosphorus.

On the basis of the number of milligrams per spur a high potassium content (6.07 mg.) was associated with high amounts of phosphorus (0.95 mg.) and high nitrogen (11.6 mg.) in the leaves from the trees treated with nitrate of soda plus dried blood. In the leaves from the check trees the lowest amount of potassium (5.06 mg.) was associated with the lowest phosphorus content (0.83 mg.) and also the lowest amount of nitrogen (7.4 mg.).

The results with trees showing deficiency in nitrogen are in accord with the results on the tomato reported by Bartholomew, Watts and Janssen, 1933 (12) who called attention to the necessity of presenting interrelationships on a milligram basis as well as a percentage basis. However, with these apple trees a reduction in nitrogen content was not accompanied by a proportional reduction in phosphorus and potassium.

It appears, therefore, that there was no consistent antagonistic relationship between potassium and nitrogen in apple tree foliage under field conditions. This failure to produce any evidence of a definite adverse relationship between nitrogen and potassium has been reported several times by investigators working with young apple and peach trees in nutrient solutions, Gildehaus, 1931 (39), Chandler, 1936 (21), Cullinan, Scott and Waugh, 1939 (27), Batjer and Degman, 1940 (14).

On the contrary with another series of young apple trees in sand culture Batjer, Baynes and Regeimbal, 1940 (13) reported that with decreasing nitrogen there was an increase in both the potassium and phosphorus content of foliage. Likewise, Baker, 1941 (10) in a study of the effect of different methods of soil management upon the potassium content of apple and peach leaves concluded that nitrogen applications consistently reduced the potassium content of the leaves, especially at the earlier sampling dates. The results of the potassium analyses of the leaves of trees treated with only nitrate of soda appear to substantiate Baker's finding since these trees contained lower percentages of potassium than either the nitrate of soda plus dried blood or the check trees. The check trees, however, contained the lowest number of milligrams of nitrogen per spur, as well as the lowest amount of potassium. Also in the light of Baker's findings it is difficult to explain the highest amounts of potassium associated with the greatest amounts of nitrogen in the nitrogen plus dried blood trees. It may be that the use of dried blood as a supplement for nitrate of soda rendered more potassium available in the soil due possibly to the action of organic acids formed from the decomposition of dried blood.

According to Batjer and Magness, 1939 (15) Delicious trees having under 1.5 per cent potassium in their leaves may be obtaining inadequate amounts of this element. Of the leaves taken July 12, 1941 only those from the trees treated with nitrate of soda plus dried blood contained more than 1.5 per cent potassium. By August 11, 1941, however, the leaves from the check trees as well as those from the trees treated with nitrate of soda plus dried blood contained more than 1.5 per cent. Leaves taken immediately following petal fall from trees under all three treatments were higher than the arbitrary percentage for potassium content below which responses to potassium applications were considered possible.

As to which is the best time to take leaf samples Lilleland and Brown, 1939 (77) working with prune trees in California recommended from early June to early August, in view of the fact that later sampling fails to distinguish marked differences in potassium contents. They found that the potassium value from leaves of peach trees displayed a slight downward trend during the season. Waugh and Cullinan, 1941 (131) also noted this downward trend. The percentages of potassium found at the two dates in 1941 seemed to show an upward trend in the potassium content of leaves between July 12 and August 11. Contrary to other work, as cited, samples taken in May, July and August were equally satisfactory in showing the differential effects of treatment, as evidenced by the potassium content of the leaves. The leaves from the trees treated with nitrate of soda plus dried blood contained the highest per cent potassium regardless of time of sampling, the leaves from the check trees contained the next highest, and the leaves from the trees fertilized with nitrate of soda the lowest.

One important phase of the sampling problem was the development of a means of estimating the minimum number of trees which must be sampled and analyzed to give significant differences in the nitrogen, phosphorus and potassium content as a result of fertilizer treatment. According to Snedecor, 1940 (117) before an estimate of the size of sample required to gain a desired precision can be made there must be available knowledge of the mean and the standard deviation of the population to be sampled. He presented a chart which may be used for estimating the size of sample required for significance if the mean differences and the pooled standard deviation are known. By subjecting the original data from analysis of leaves from the variously treated trees in the present study the standard deviation and the differences between means were obtained and the chart as given by Snedecor, 1940 (117) for estimating the size of sample could be employed.

Accordingly, with this method of treatment of the data it appears essential that in studies with the mineral content of Delicious leaves from five to twenty trees must be sampled to show significant differences of ten per cent at the five per cent level or eight to thirty-five trees for the same difference at the one per cent level, (disregarding the potassium analyses for July 12, 1941). It is only when differences reach the order of twenty-five per cent that analyses from samples including only two or three trees are significantly different. Therefore, the data give proof for the suggestion by Lilleland and Brown, 1941 (78) that ten trees may be an adequate sampling for a foliar survey. The fact that Lilleland and Brown were working with eighteen-year-old peach trees, and that the present work was concerned with Delicious apple trees during their fifteenth and sixteenth seasons, would lead to the conclusion that tree variations (at least in leaf potassium content) are quite similar for the two kinds of plants. On this same point, Proebsting and Kinman, 1934 (105) reported with leaf analyses of apricots, prunes and peaches:

> The phosphorus content for a given season within a single treatment in some cases varied as much as 25 per cent of the mean. The nitrogen content, however, was more regular, the maximum range of variation being about 15 per cent, and several treatments showing a range of less than 5 per cent. It is, therefore, possible, that in some cases minor, but real, differences were passed over as due to normal variability.

Although the importance of sampling technique as to numbers of trees therefore has been recognized, it is apparent as has been determined in this study, that interpretation of the data from leaf analyses is not correctly made until a knowledge of tree variability is known.

Hoffman, 1940 (60) and Southwick, 1940 (119) have reported increased fruit dropping of the McIntosh apple as a result of plentifully available nitrates late in the season. The work of Heinicke, 1940 (55) substantiates their findings. The present study, however, revealed no significant differences in fruit dropping between heavily nitrated and check trees.

The inhibiting effect of shading upon flower bud formation was plainly evidenced from the results presented. This result has been repeatedly obtained by previous workers, Gourley, 1921 (40), Auchter, et.al., 1927 (7), Roberts, 1927 (111) and others.

In the experiments of Paddock and Charles, 1929 (103) shading apple tree branches one week after full bloom was too late to influence flower bud formation. In the present work there were no significant differences in the number of flower clusters formed as a result of the time the branches were enclosed. It was obvious, however, that the inhibitory effect of shading diminished as a result of enclosing the branches at ten day later intervals. Thus branches bagged May 10 produced flowers on only 9.4 per cent of their growing points, those bagged May 18, 14.9 per cent, those bagged May 25, 29.6 per cent, and those bagged June 3, 33.0 per cent. These results clearly point to a period in May when shading exerts a maximum effect on flower bud formation. The branches which were shaded the least number of days (from June 3 to August 2) formed the highest percentages of flower clusters from their growing points. But even the highest of these (38.1 per cent) was significantly lower than the per cent of the total number of growing points on the check branches forming blossom clusters (76.7 per cent).

In the shading experiments of Paddock and Charles, 1929 (103) in which shading was accomplished with light weight muslin cloth, all branches which were shaded from May, 1927 (just as the period of full bloom was coming on) until two weeks or more after that date suffered almost complete inhibition of flower bud formation. Similar branches enclosed later (May 10, May 17 -- at weekly intervals) and allowed to remain shaded until July 19 produced as many blossoms as the remainder of the trees. From these results

Paddock and Charles concluded that the critical period during which shade could inhibit blossom formation was either just prior, during, or immediately following full bloom. The results of the present experiment using similar methods of shading with lighter material seem to corroborate the findings of Paddock and Charles in the light of the fact that all of the shaded branches produced significantly lower percentages of flower clusters than the check branches. There was no difference in effect whether shading was done for a short time during the period of bloom, or if shading was extended beyond this time. However, Paddock and Charles obtained practically no flowers from branches shaded during the so-called critical period while the present results show from 15.1 per cent to 40.9 per cent of the total growing points producing flower clusters even on the shaded branches (as compared to 70.4 per cent on the check branches). This may be partially explained by the difference in the materials used for enclosing the branches.

It is obvious that shading the north half of a Delicious apple tree from June 1, 1940 until November 8, 1940 did not have a significant effect upon flower bud formation. In fact, the shaded (northern half) of the tree produced flower clusters from a higher percentage of its total growing points (32.7 per cent) than the southern half of the tree (28.6 per cent). As indicated in the other work the critical period during which shading appreciably effects flower bud formation probably was before June 1 in 1940. The data, therefore, seem to further substantiate the conclusions of Paddock and Charles. Although the results of shading Delicious were similar to the results of other shading work of apples it might be shown by further investigation that Delicious is particularly sensitive to light conditions within a short period after blossoming.

The fact that in 1941 the branches which were ringed in 1940 blossomed profusely on all forty of the Delicious apple trees while the remaining branches were almost 100 per cent vegetative indicates some specific relationship of carbohydrate synthesis to blossom bud formation of the Delicious variety. This adds further weight to the view that Delicious is easily influenced by factors such as shading, ringing, defoliation, etc. that influence carbohydrate synthesis.

An explanation for the greater set of fruit by ringing after fertilization is not readily apparent. It may lie in the nutritional balance as outlined by Harvey, 1923 (51) in which earlier ringing caused depression of growth by cutting off the supply of carbohydrates coming from older parts of the tree at the earlier stage of growth.

Since the fruit sets obtained at Sandy Spring as a result of ringing, ringing plus defoliation, and check were all significantly lower than those obtained from hand pollinated branches, it appeared that the pollination facilities were inadequate in this orchard. From the percentage sets resulting from ringing and open pollination (6.5 per cent and 11.1 per cent) and ringing plus defoliation and open pollination (10.0 per cent and 16.4 per cent) one can certainly not conclude that defoliation had a detrimental effect on fruit set or that it neutralized any beneficial effect of ringing. However, the differential effects of these two treatments were no doubt minimized due to inadequate pollination. In similar work with trees in the College Park orchard no significant difference in set was obtained as a result of ringing or ringing plus defoliation. It is unfortunate that the pollination facilities for these trees were not checked by hand pollination. The relatively low sets obtained might have been explained upon this basis. Since 1941 was a light crop year for these nine trees it may be that their internal composition or nutritional status overshadowed the effect of external environment, as emphasized by Roberts, 1927 (111).

Although the present work on defoliation and defloration showed no influence on set of fruit there have been many reports that defoliation markedly reduced flower bud formation, Magness, 1917 (80), Harvey, 1921 (52), Roberts, 1923 (110) and Hooker, 1925 (64). Defloration, on the other hand, has been shown to have a stimulating effect on blossom bud formation by Drain, 1925 (31), Bailey, 1929 (8), Auchter and Roberts, 1935 (5) and others.

Comparing the pollination results of the three seasons the sets based on blossom cluster were relatively low in 1940, high in 1941 and intermediate in 1942. These differences can be largely explained on the inverse relation between amount of bloom and set, as by calculation the percentage of blossoms on all branches based on total growing points was 76 per cent in 1940, 47 per cent in 1941, and 61 per cent in 1942. The per cent set of fruit on the basis of total growing points, "commercial" set, was quite similar for all three years, particularly with open pollination: 1940, 17.9 per cent; 1941, 20.3 per cent; and 1942, 18.0 per cent. This similarity indicates an apparent advantage of this basis of comparison, avoiding in great part the inverse relation between bloom and set.

The calculation of the set of fruit on the basis of total number of growing points served to show the set from a commercial aspect irrespective of the bloom and also made it possible to calculate the approximate leaf area per fruit, considering the consistent habit of Delicious to set one fruit per blossom cluster, Ranker, 1926 (106). Assuming an average of five leaves per growing point, a set of 20 per cent based on total growing points would mean twenty-five leaves per fruit, which might indicate that a set of 20 per cent would represent a safe commercial set for Delicious necessitating only some light thinning to adjust for higher leaf area per fruit.

On this basis, and assuming 20 per cent as a safe commercial set for Delicious, it is apparent that in 1941 with pollenizers such as Rome Beauty (34 per cent), Jonathan (32 per cent) and Gallia Beauty (30 per cent), the set was well above the safe margin. With Golden Delicious (17 per cent) and York Imperial (14 per cent) the set was not satisfactory, even though the set from these two pollen varieties based on blossom clusters was well above 30 per cent. From the 1942 data on commercial set only Rome (33 per cent) and Jonathan (28 per cent) remained above the assumed safe margin of 20 per cent.

Considering the 1940 data on commercial set it is impossible to draw conclusions as to relative values of the pollenizers in this season, due to lack of significance; however, it is pertinent to note the small differences between open-pollinated commercial sets between the three seasons, showing lack of seasonal effects (lack of significance shown by statistical comparison of eight to ten replicates in each season involving a total of over 20,000 blossoms).

Without statistical analysis of the data on pollenizers in 1940 one would be tempted to point out an apparent advantage resulting from the use of Jonathan, Golden Delicious, Winter Banana, Yellow Transparent, and Lowry as pollenizers, compared to Williams, Gallia Beauty, York Imperial, and Rome Beauty. Results from Tree I only would have led one to favor Golden Delicious, Lowry, Williams, and Jonathan. The failure of the data to show differences in the efficacy of the different varieties as pollenizers for the Delicious apple was, no doubt, partially due to the large error resulting from the large variability in set on replicate branches.

Several instances have been reported (usually from rather limited data) of the direct effect of pollen on fruit color, size, date of ripening, weight, resistance to rotting, etc. of the apple, Lewis and Vincent, 1909 (75) and Nebel, 1930 (95).

Tydeman, 1938 (126) has more recently made an extensive investigation of the influence of different pollens on the growth and development of the fruit in apples and pears. He found comparatively large differences in the size of the fruits of each variety, fertilized by different pollens within the first few weeks after pollination. These differences diminished, however, until they were practically negligible at harvest time. He showed that this size difference was associated with fruit drop. Larger differences (sometimes of the order of 10 per cent) were found in final fruit weight between fruits of any one variety differently pollinated.

From the results on fruit weights, diameters, and seed number, only seed number was differentially effected as a result of employing different varieties of pollen in cross pollination. In other words there was no evidence of "metaxenia" or, to be more exact in terminology, xenia.

Heinicke, 1917 (53); MacDaniels, 1929 (83), Wentworth, Furr and Mecartney, 1928 (133) and Murneek, 1932 (86) have all presented data from which they conclude that the number of seeds in the mature apple fruit gives an indication of the relative effectiveness of the pollenizer. Murneek, 1932 (86) in discussing the matter wrote:

> The relative size of the apple fruit seems to be affected primarily by two major factors, the leaf area in the immediate vicinity of the fruit and the number of seeds present. Fruit size, therefore, is but partly correlated with seed number. But there seems to be a more or less direct correlation between seed number and pollination.

In another section of the same publication he further stated:

> The direct result of pollination is the production of seed, a more secondary (biologically speaking) effect of which is the formation of the fleshy part of the fruit. The seed counts, therefore, should give a further, more definite clue as to the relative value of certain pollen.

Tydeman, 1938 (126) found rather wide differences in the average seed content of differently pollinated apple and pear varieties but stated that it did not always follow that the larger fruits had the greater number of seeds.

Thus, the idea that fruit size is directly affected by the pollenizer used as evidenced by a correlation between seed number and fruit size seems to have been based more upon logic than upon definite experimental results.

The findings of Southwick, 1939 (118) add pertinence to the favorableness of a high seed number. He has shown that the number of seeds per fruit is correlated with the date of drop of McIntosh apples. The higher seed numbers delayed the drop.

In regard to the effect of pollen upon seed number, the present results showed no relation between fruit size (as measured in diameter or weight) and seed number. This is in disagreement with the findings of Heinicke, 1917 (53) who stated that the sizes of the fruit vary with the number of seeds when apples are borne under similar conditions. Einset, 1930 (34) found the fruit weight of the Gravenstein apple to be directly correlated to the combined number of both empty and filled seeds. Nebel, 1930 (95), Murneek and Schowengerdt, 1936 (93) and Alderman, 1918 (1) also found good correlations between seed number and fruit weight. Nixon, 1928 (98 and 99) found from comprehensive studies of the direct effect of pollen on the fruit of the date palm that the time of ripening as well as the size of both fruit and seed may be directly affected by the pollen used.

Previous workers have expressed dissatisfaction with the practice of emasculating apple flowers before cross-pollination: Knowlton, 1930 (70), Howlett, 1930 (66), Auchter, 1922 (4) and others.

A comparison of the fruit set (0.0053 per cent) obtained from emasculation plus hand pollination with that of the per cent set from bagging plus hand pollination would certainly indicate a detrimental effect of emasculation in cross-pollination studies with the Delicious apple.

It should be noted that the relative humidity ranged from 13 to 20 per cent during the time that the emasculation and subsequent pollination was executed. This humidity range is extremely low under Maryland conditions. Knowlton, 1930 (70) found emasculation to be detrimental due to its drying effect.

Another factor which was undoubtedly partially responsible for the low sets obtained from the emasculated flowers was the fact that late bloom was utilized for these studies.

The performance of the environmental control chamber suggests a means of further refining the methods of future work regarding pollination, mineral nutrition and carbohydrate synthesis of the Delicious apple by controlling such variables as light, temperature and humidity. Davis and Hoagland, 1928 (28) described an apparatus for growing plants in a controlled environment and listed the advantages, justified from presented data, of establishing an environment which can be duplicated at will.

Lilleland, 1936 (76) in studying the growth of the apricot fruit was able to maintain the environmental temperature of an apricot branch approximately 20° F. higher at night than outside by constructing a celoglass shelter equipped with electric hot plates for heating.

Smock, 1937 (116) in his studies of bitter pit in Gravenstein apples also employed celoglass chambers around branches to control temperature. He heated one of the chambers by means of a kerosene camp stove and cooled another with ice and natural circulation of the air.

The preliminary work with ice as a cooling agent indicated the advisability of having a refrigeration unit, now available, for more accurate control of temperature and humidity.

Such an apparatus would be much more economical and useful in replication than a single unit enclosing an entire tree as described and used by Heinicke and Childers, 1937 (56).

SUMMARY AND CONCLUSIONS

These investigations were undertaken to obtain knowledge relative to factors conducive to better production of the Delicious apple under Maryland conditions.

The experiments were conducted in the orchards of the University of Maryland, College Park, Maryland, and that of William Moore, Sandy Spring, Maryland, during the seasons of 1940, 1941 and 1942.

The research included nitrogen fertilization, chemical analysis of leaves, shading, ringing, defoliation, environmental control and pollination.

As a consequence of these endeavors, it is possible to arrive at the following conclusions:

1. During the third season the trees which received the nitrogen fertilizer treatment showed a high level of nitrogen content of leaves, dark green foliage, and excellent growth and fruiting in contrast to a reduced nitrogen content of the leaves, light green foliage and relatively poor growth and fruiting of check trees receiving no nitrogen application. There were no appreciable differences in the amount of fruit drop during the harvest period between trees receiving excessive amounts of nitrogen fertilizer and trees receiving no fertilizers.

2. There is evidence from the data that there is a rather consistent inverse relationship between the per-

centages of nitrogen and phosphorus of apple leaves from bearing trees; however, this relationship does not hold on the basis of milligrams in total leaves per spur.

3. The relation between potassium and either nitrogen or phosphorus or both appeared to be variable, depending on treatment.

4. The time of leaf sampling (July 12, 1941, August 11, 1941 and May 2, 1942) did not affect the relative differences in potassium content resulting from the various treatments. At all sampling dates the addition of nitrate of soda plus dried blood brought about the highest per cent of potassium in the leaves. Potassium content of the leaves from unfertilized trees was intermediate and that of the trees treated with nitrate of soda was lowest. There was a slight upward trend in the potassium content of leaves from all trees between July 12 and August 11.

5. Variability of leaf analyses among individual trees was found to be of great importance in interpretation of data from such analyses. From a statistical treatment of the data, an estimate was made of the number of apple trees under various treatments which must be sampled to give a significant difference of ten per cent in the nitrogen, phosphorus and potassium content of leaves.

6. Of the various pollenizers employed over a period of three years Rome Beauty and Jonathan proved to be most satisfactory for the Delicious apple. Expressing the set of fruit as obtained from different pollenizers on the

basis of total number of growing points served to show the set from a commercial aspect.

7. There was no evidence of xenia as a result of the different pollenizers. From the results on fruit weights, diameters, and seed number, only seed number was differentially affected.

8. Hand pollination following emasculation did not prove successful under the conditions of these experiments with humidity probably as the deciding factor.

9. Delicious apple branches ringed immediately following petal fall gave higher fruit sets than similar branches either not ringed or ringed during the June drop.

10. Branches shaded with heavy muslin at seven-day intervals from the blossoming period (May 8 and 9) to June 3, 1940 and all shading terminated August 2 developed significantly lower percentages of blossom clusters in 1941 than unshaded branches. Although there were no significant individual differences in the number of flower clusters formed as a result of the time the branches were enclosed, it was obvious that the inhibitory effect of shading diminished with each seven-day delay in time of shading. The effect of shading could not be neutralized by defloration or defruiting as branches either deflorated or defruited and shaded did not produce higher percentages of flower clusters than branches shaded alone.

11. Shading branches with cheesecloth May 4, (just prior to full bloom) for intervals of ten to ninety-one days significantly reduced flower bud formation. There were

no differences resulting from shading periods longer than ten days.

12. Shading of one-half of a Delicious apple tree from June 1, 1940 until November 8, 1940 did not inhibit flower bud formation.

13. The results of the environmental control chamber suggest a means of replication of branch treatment under orchard conditions by which light, temperature and humidity may be regulated.

14. To the best of the author's knowledge this is the first time that statistical analysis has been used to determine significance of pollination data and likewise blossom bud formation as influenced by shading. Also, tree variability, as affecting leaf analyses, has been measured for the first time.

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