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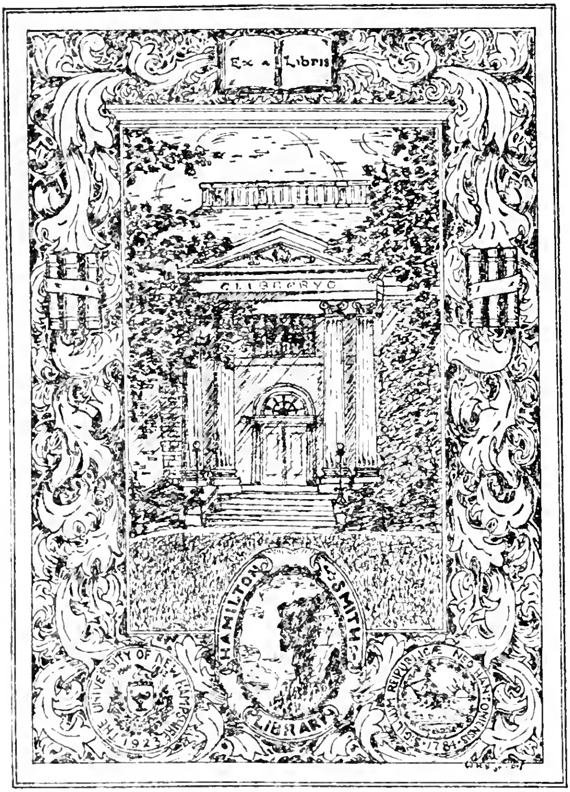

Station Bulletin 274

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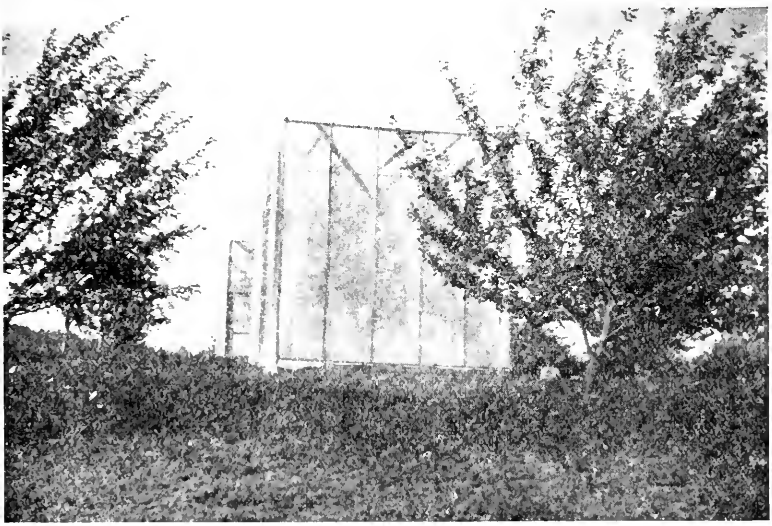
POLLINATION AND FRUIT SETTING IN THE APPLE

By L. P. LATIMER



Cheesecloth cages used to keep insects from trees during pollination experiments

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Pollination and Fruit Setting in the Apple

By L. P. LATIMER

Pollination has come to be a general problem in our New England orchards in recent years due to the fact that fewer varieties of apples are now planted in a given orchard than was the case a quarter of a century or more ago.

I. Development of Orcharding and the Pollination Problem

The earliest settlers in America brought apple seeds from Europe and planted them here. As time went on more seedlings were developed and occasionally plants of a named variety were imported from Europe. Later the special merits of certain seedlings were appreciated and grafts made from them to perpetuate the type. Thus different settlers and their descendants in the new world developed fruit gardens containing several to many trees of quite different types.

In those days wild bees, including bumble bees, were also plentiful and well able to carry all the pollen needed for pollination of self-sterile varieties which, then as today, would not set fruit when pollenized with their own pollen.

The result was that in those early times the large mixture of varieties and plentifulness of wild bees in proportion to the size of planting led to no difficulties of set as are experienced today. Hence no problem of pollination became apparent.

Up to the middle of the 18th century, commercial orchards as we now know them had not been definitely established in America. Grafted trees were planted before this time, but plantings of "common" or "cider" apples still predominated.

The rapid growth of New York City, and its importance as a seaport, resulted in a large market and outlet for American apples. Boston was a similar center. During the last quarter of the 18th century, considerable trans-Atlantic shipments of apples were made.

The Newton Pippins (green and yellow) had by this time come to be known as America's highest-quality apple. Its popularity on the continent followed the receipt of a box by Benjamin Franklin in London in 1758. The increasing tendency since then has been to plant only those varieties which seemed most profitable in large centers of population and in foreign trade. This resulted in the development of the truly commercial orchard where only grafted and budded varieties of proven merit were planted.

At first the list of such varieties was rather large, because of the various tastes and demands of consumers who were still used to the products of the older fruit gardens. As the years passed, fewer and fewer varieties were planted. Local demands and the profit from the different varieties in the market governed the planter's choice. Varieties tender to cold or unproductive of large and regular crops, were culled from the orchard. Those especially subject to disease and insect attacks and those not universally popular because of color, flavor, or keeping qualities, came to be placed in the catalog of obsolete varieties.

New varieties were eagerly sought in order to obtain apples better in some respect than those already established. These changes finally led to conditions occasionally found in the last of the 19th century and often during the present century, where apple plantings that bloomed heavily failed to produce fruit.

One of the earliest examples of this condition appeared in the pear industry. Many plantings of Bartlett pears in large blocks were made in the 70's and 80's. When they reached bearing age they produced little or no fruit. The trouble was traced to the fact that under most conditions the Bartlett is partially or wholly self-sterile. The remedy was to plant some other variety with the Bartlett to provide pollen for its flowers, thus insuring a crop of fruit.

This discovery was made and published by M. B. Waite (1) in 1892-3 and the knowledge has since been invaluable to fruit growers. Even now self-unfruitful varieties are occasionally planted in solid blocks. In New England the McIntosh falls in this class. History will without doubt repeat itself in this respect whenever new varieties are introduced that are more profitable than existing ones.

When the error of planting a self-unfruitful variety in a solid block is discovered perhaps 10 or 15 years later, the remedy is to graft pollenizers into certain trees in the orchard and to include pollenizers in future plantings. The mistake is costly because five or six years pass before the pollenizers grafted into the orchard bloom sufficiently to be effective in cross pollination. This would make the tree needing pollination at least twenty years old before a full crop could be produced.

Not so well known is the fact that good pollenizers themselves may not be readily pollenized by the main crop variety which has shown need of pollination. Although Delicious will pollenize McIntosh, for example, this is no indication that McIntosh will in turn pollenize Delicious. Furthermore, inter-sterility may exist between two varieties.

Several varieties of apples in New England produce paying crops, even when planted in large blocks without pollenizers. They may therefore be considered self-fruitful sorts. Baldwin is outstanding in this class.

The fact that a variety may be self-fruitful does not signify that it is also a good pollenizer. The self-fruitful Baldwin is practically useless as a pollenizer for any other important commercial variety grown in New Hampshire.

Darwin emphasized in 1859 that "Nature . . . abhors perpetual self-fertilization." He indicated in his work that cross-fertilization is of value in the plant kingdom. Half a century earlier investigators were aware that bees carried pollen from one flower to another but were unaware of the exact nature of the benefit.

(1) M. B. Waite. The pollination of pear flowers. U.S.D.A. Bur. Veg. and Plant Path. Bul. 5 (1893)

The need of cross-pollination is thus a relatively new discovery following in the footsteps of commercialization of the apple industry. Since the time Waite attempted to discover what effects the self and cross-transfer of pollen would have on the resulting fruit, it has been determined that the amount of fruit setting on the various varieties can be increased through cross-pollination by many other sorts and that, in most cases, this is a very necessary consideration.

To determine the list of suitable pollenizers for the various cultivated sorts, certain experiment stations have conducted pollination tests. The requirements of some of the older sorts have been pretty well worked out, but there will always be the necessity for determining the requirements of new varieties as they are developed, and likewise the effectivenss of new varieties as pollenizers for the older ones.

The experiment station may save growers much time by recommending quality orchard varieties that will pollenize one another satisfactorily. With a list of such varieties and some idea of the degree of coincidence in their blooming dates, the grower should be able to pick desirable combinations. It is to be assumed that he will exercise some judgment in choosing varieties with relation to market demands, climatic and regional adaption and other points related to profitableness.

II. Flower Bud Formation and Development

Inasmuch as the set of fruit is intimately connected with the blossom (the apple fruit being formed from the basal portion of the flower), it is very essential to keep the tree in such a state of vigor that it will produce a plentiful supply of strong flower buds.

The first essential is that the tree be grown properly. A strong framework, proper fertilization of the soil and good management of water-supply are necessary. When the tree has reached the age to produce flower buds, attention must be paid to this process. Without these, or with the formation of only weak ones, no fruit will result.

The flower-cluster buds on the apple tree are produced principally on short growths or shoots called spurs. With some varieties flower-bud clusters are also formed at the tips of new shoots or in the axils of the leaves of new growth. In any event this is a summer development preceding blossoming.

Microscopic examination of buds on spurs of the Baldwin and McIntosh has shown that in New Hampshire the first stages of flower-bud differentiation can be detected from the middle to the last of July.* At this time with the aid of the microscope, buds that are going to form only leafy shoots or spurs may be readily told from those that have the possibility of ultimately forming fruits. It must be remembered that for the buds to mature into good blossoms and fruit, favorable conditions must be maintained for their continued development.

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* E. J. Rasmussen. The period of blossom-bud differentiation in the Baldwin and McIntosh apples. Amer. Soc. Hort. Sci. Report 26:255-260 (1929).

Fig. 1. Bud of Baldwin, July 29, 1928 (after Rasmussen).
Typical of leaf and shoot buds.

Fig. 2. An early stage in the development of a flower bud cluster.
Baldwin, August 20, 1928 (after Rasmussen).

Fig. 1 shows just how a leaf or shoot bud looks when cross-sectioned and observed under the microscope. The hard outer scales enclose embryonic hairs, leaves and leaf primordia. The growing tip located in the center has a smooth, rounded surface. All leaf and flower buds in the first stage of development show this appearance.

After the first of July in New Hampshire, some of the buds on trees of bearing age may show a change in the character of this central growing point. Instead of remaining nicely rounded, the outline of the growing tip becomes marked by angular projections. These elongate, so that after a period of some three weeks, the buds have changed in appearance to that noted in Fig. 2. Here the rudiments of the various flowers of the cluster have been formed. Fig. 3 explains the parts and their regular succession. The first prominences to appear are those of the outermost part or calyx; those of the pistil and ovules are last.

Under favorable conditions the flower buds continue to develop slowly

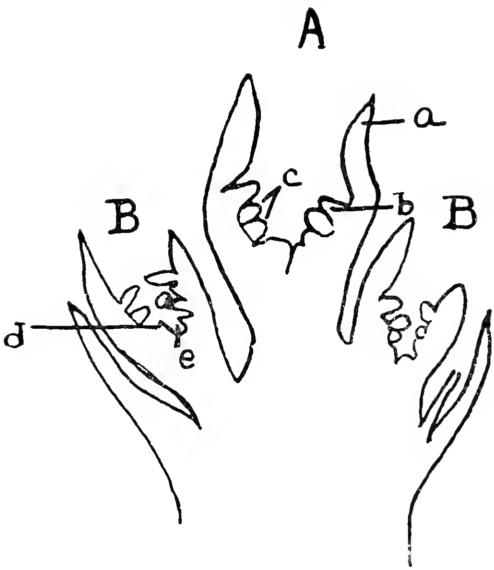

Fig. 3. Illustrating the development of the flower bud cluster. Baldwin, March 9, 1933 (25x). A. Terminal bud of the cluster. B. Lateral buds of the cluster. a. Primordia of calyx or sepals. b. Primordia of petals. c. Primordia of stamens. d. Primordia of pistil. e. Cavity which eventually becomes the ovary with its contents—ovules, etc.

through fall and winter. During April the primordia rapidly complete their development into calyx, petals, stamens and ovary. Then in May warm weather brings rapid growth and swelling of the flower buds. They subsequently burst into bloom, with mature pollen and ovules.

Much can happen to prevent many or all of these embryonic flower buds from reaching the mature stage. Factors that strongly inhibit fruit or flower-bud formation are: 1. A heavy set of fruit such as may occur especially in biennial bearers like Baldwin, Wagener, and Wealthy. 2. Heavy shading, as from foliage of an extra-vigorous tree. 3. Cool weather or dark days about the time fruit-bud formation usually takes place. 4. Improper balance between food and nutrients, which may be caused by lack of leaf surface due to insect attacks or lack of minerals in the soil, especially nitrogen. Once flower buds have been initiated, conditions for carbohydrate, moisture, and mineral supplies must be kept as near the optimum as possible to insure continued development of the buds.

The tree must also be brought safely into the rest period by prevention of growth late in the season. Late growth may result from injudicious applications of nitrogen or excess moisture in the soil. In the cultivated orchard a cover crop planted about July 1 will alleviate the latter condition.

In the winter there is danger with the more tender varieties that 25° to 30° F., below zero will freeze some or all of the flower buds. Once killed by freezing, no other flower buds will form in time to open in the spring. The leaf buds are more hardy and do not freeze at these temperatures. Provided the hazards of winter have been avoided, there is still danger from spring frost where a temperature of 25° or 26° F. may totally ruin the fruit crop through freezing of the unfolding buds or open blossoms. Under such conditions the pistils are usually injured. The pollen may also be injured and often the ovules.

To insure the proper nutrient and moisture conditions, an application of nitrogen is generally made in the sod or sod-mulch orchard a short time before the trees come into bloom in May and a mulch applied a little before July 1 to conserve moisture. This early nitrogen application is beneficial to the setting of fruit, to fruit-bud formation, and to the further development of the fruit. Light frost after the buds have appeared may not interfere at times with the set or pollen formation but may cause injury to the outer layer or epidermis of the flower parts. The result will be a russeted fruit or one with russet rings, cracks, or malformations.

III. Mechanics of Apple Fertilization

Pollination:

Pollination means the transfer of pollen from the stamens to the pistils of the flowers. With apples this is mostly effected by insects, principally the various kinds of bees. The pollination of apples cannot be assured through the agency of the wind.

Pollination is only one step toward insuring a set of fruit. Fertilization of the egg cells in the ovules is necessary with most apples to cause fruit to set. This fertilization process results in the formation of seed. Further growth of the tissue of the fruit is directly correlated with seed development. The pollen of only certain varieties can under certain conditions effect satisfactory fertilization and set, hence the need to study the value of different varieties as pollenizers for the different apple sorts.

To show the relation of various factors to the fertilization of flowers and set of fruit, a short description of the structure of the flower and the process of egg fertilization is presented.

The Flower:

Fig. 4 shows the cross section of an apple flower. Figs. 5, 6 and 7 show and describe the essential parts in detail. The important parts of the flower with relation to pollination are the stamens and pistils. Each stamen con-

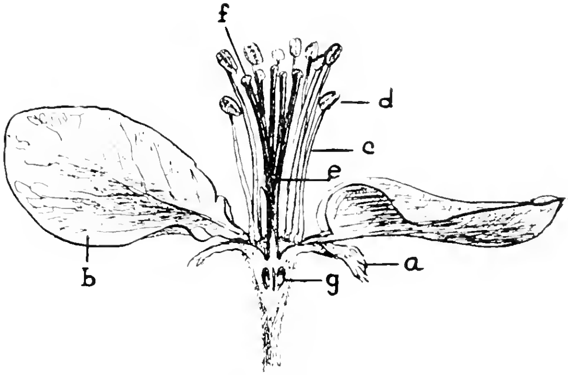

Fig. 4. Cross section of apple flower. a. Sepal or calyx. b. Petal. c. Filament of stamen. d. Anther of stamen, containing pollen. e. Pistil. f. Stigma of pistil. g. Ovary containing ovules. It is the ovary and the adjacent fleshy parts of the flower that ultimately become the fruit.

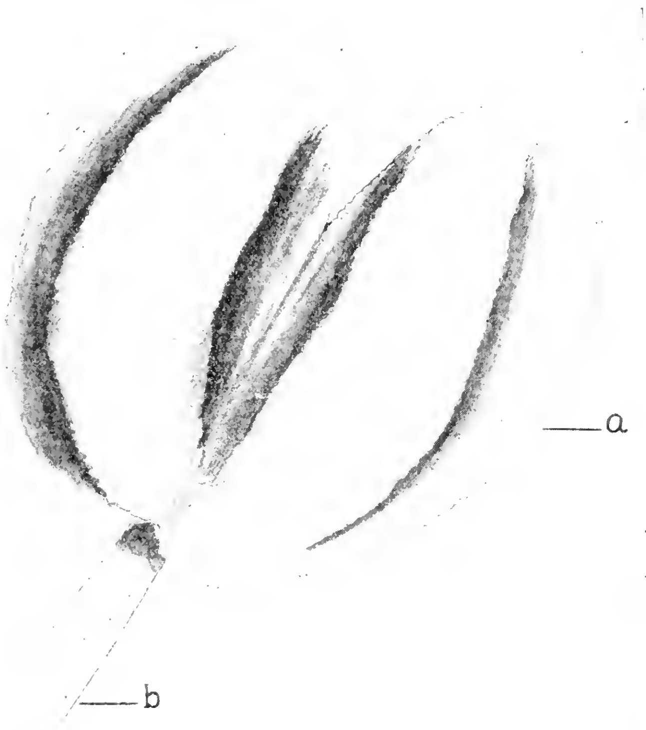

Fig. 5. Upper portion of stamen (McIntosh). a. Anther (40x). b. Filament.

sists of an anther, a small yellowish sac attached to the end of a slender white filament or stalk. The anthers contain thousands of minute rounded cells known as pollen grains which contain sperms, the male elements of the flower.

The cultivated varieties of apples ordinarily have 20 stamens, although occasionally small petal-like organs may be found to have replaced some of the stamens, and sometimes the filaments of the stamens may appear petal-like.

Each pistil in the apple consists of five slender green stalks which are coalesced in the lower part to form a single cylinder of tissue, usually more or less covered with fine hairs. The five individual parts of the pistil are called styles. Each style is capped with a stigma. The stigma has a papillated surface (see Fig. 7.). It is on this surface that the pollen grains are left by the insects and this is the place where the germination of the pollen grains takes place.

The female portion of the flower consists of three parts: ovary, style and stigma. The ovary is the basal portion of this apparatus. It lies im-

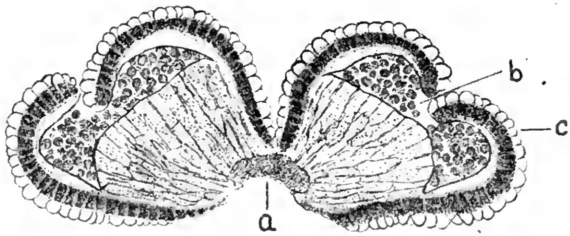

Fig. 6. Cross section of mature anther of McIntosh (35x). a. Filament attachment. b. Cavity containing pollen grains. c. Integuments which open out as the anthers dry, exposing the pollen.

bedded in the tissues beneath the calyz and contains the ovules, occasionally 20 in number but in most varieties 10. Each ovule contains a female element or egg cell, so that with perfect fertilization it is possible in some varieties to develop 20 seeds in the apple. Fertilization and complete development of all the ovules into seeds seldom occurs in any apple, five to 10 seeds being the usual number.

Fertilization of the Egg Cells:

To fertilize the 20 ovules of a McIntosh apple ovary, at least 20 different pollen grains are needed. As it happens only a few of the thousands of pollen grains produced ultimately reach an ovule to effect fertilization.

Individual pollen grains when mature are crowded closely together in the anther. When the flower bud opens and the anther is exposed to the sun and dry air, it splits open leaving the pollen exposed.

This pollen looks to the unaided eye like a fine, powdery-yellow dust. Each grain is too small to be seen as an individual by the unaided eye. The pollen grain (Fig. 8A) when saturated with water is slightly triangular in

Fig. 7

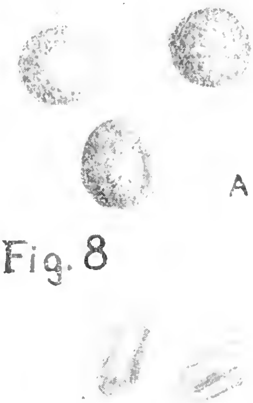

Fig. 8

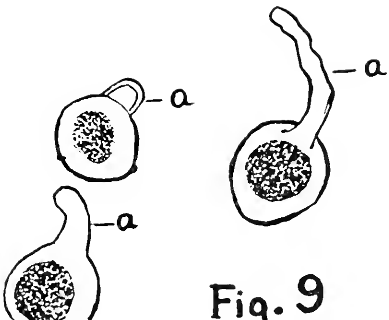

Fig. 9

Fig. 7. End of pistil of McIntosh (45x). a. Papilla-like terminal cells of stigma. b. Pollen grain caught in terminal cells.

Fig. 8. A. Pollen grains after absorbing water (270x). B. Pollen grains before absorbing water (270x).

Fig. 9. Pollen grains after three hours in germinating medium of 15 per cent sucrose (270x). a. Pollen tubes shortly after germination of the pollen.

shape but with a well-rounded surface which is somewhat roughened, enabling it to adhere to the bodies of bees and other insects that visit the flowers.

Perhaps 75,000 pollen grains are produced by each vigorous, healthy apple flower and all these could easily be carried on the body of a single bee. Should each pollen grain from a single flower ultimately fertilize an ovule, then the pollen from this one flower would be capable of causing the setting of from 7,500 to 15,000 fruits, or the crop of 10 trees. What actually happens is that not more than one pollen grain in 10,000 ever reaches and fertilizes an ovule; so it takes the blossoms on one whole tree of a pollenizer to insure the production of a good crop on ten other trees.

Under natural conditions in the orchard many factors prevent the efficient utilization of pollen. Weather and the presence or lack of insects are most important in this respect. The honey and bumble bees are the principal insects involved in the transfer of apple pollen.

The mature pollen grain is a specialized cell containing a great amount of stored food. A large nucleus occupies a portion of it, or in the case of apple pollen, two nuclei, one of which is known as the "tube" nucleus because it directs the course of the pollen tube growth down the style into the ovary. The other is known as the generative nucleus because it contains the male elements that function later in the fertilization process.

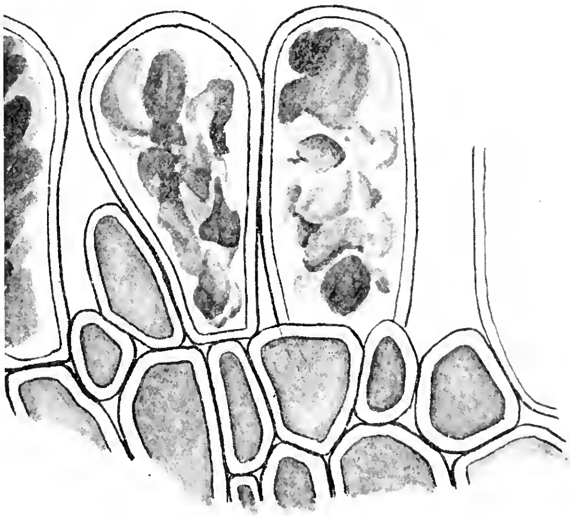

Fig. 10. Terminal and underlying cells of stigma (600x).

The nuclei and the stored food are enclosed by two layers of material. The outer one is composed chiefly of cutin, a substance very resistant to moisture and to the penetration of chemical substances.

The bee visiting the opened flower in search of either nectar or pollen brushes against the opened anthers and becomes covered with pollen grains which stick to the hairs covering the body of the insect. Some of these grains may be deposited on the surface of the stigma of other flowers or possibly the same flower.

On reaching the stigma the normal pollen grain germinates by sending out a so-called "tube" (Fig. 9.). This penetrates the tissue of the stigma and grows downward through the central portion of the style in the direction of the ovary. This progress is accompanied by the movement of the tube nucleus down through the stylar tissue, with the generative nucleus traveling behind or beside it. During this period the latter divides into two sperm nuclei.

As the nuclei move farther and farther down the style, the older part of the tube becomes plugged with callose, which separates the growing part forever from the original pollen grain.

The pollen tube finally reaches the ovary, enters an ovule and discharges the male nuclei or sperms. One of these fuses with the egg nucleus and an embryo is formed. The ovule then develops into a structure known as the seed. Without fertilization the seed would not develop. If reports of their occurrence can be considered authentic, cases of seed development without fertilization of the ovules rarely occur in the apple.

It is the development of viable seed that is so important to the set and further development of the fruit. A tree soon sheds flowers in which a sufficient number of ovules are not fertilized. Other flowers in which ovules become aborted are also generally dropped. Flowers may set fruit heavily, apparently with plenty of seeds, yet the June drop may be heavy because of the competition for food and water. To insure the sticking of fruit that has been fertilized, it is important, therefore, that the tree be properly supplied with moisture and nitrogen.

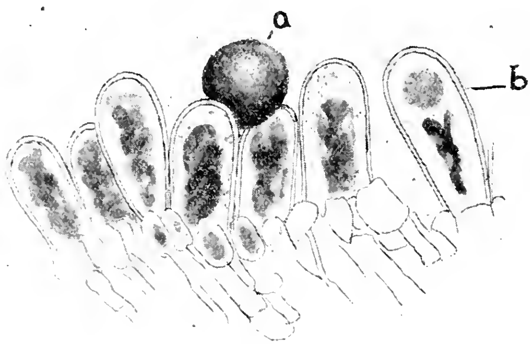

Fig. 11. a. Pollen grain after alighting on stigmatic surface b.

IV. Pollination of the Apple Under New Hampshire Conditions

The Need for Pollenizers:

Self-unfruitfulness. A large majority of apple varieties and nearly all of the important commercial sorts are unable to develop seed or set a crop of fruit when pollenized with their own pollen. These are considered self-unfruitful, because of the general inability of the pollen to effect self-fertilization.

In orchard observations the self-unfruitfulness of certain varieties has often been strongly suspected, but carefully controlled hand-pollination experiments have been necessary to prove the fact. The supposition has also been advanced that certain varieties were especially good pollenizers for these self-unfruitful sorts. This has often been indicated in orchards, one section of which has a given variety in the vicinity of certain other varieties. Heavier sets of fruit have consistently been obtained in such areas as compared with other parts remote from these pollenizer trees. This can be checked through hand-pollination experiments.

Even though liberally supplied with bees, plantings of large blocks of a single variety of apple such as Delicious, for instance, have often failed to set fruit. This has frequently led to the supposition that under existing environmental conditions the lack of set was due to self-unfruitfulness. This would later be confirmed when good sets of fruit were obtained after the introduction of other varieties to act as pollenizers. Emphasis should be placed on the fact that one must be sure lack of bees is not the cause of poor pollination before concluding that the trouble is lack of good pollenizers.

From general observations and from carefully controlled experiments, it has been possible to classify most of the commercial varieties of apples into a number of classes ranging from the self-fruitful—those setting fruit with own pollen—to the kinds which are entirely self-unfruitful. A good many varieties will set a small amount of fruit through self-pollination, but this will not be enough to produce a paying crop.

Given varieties in different sections of the country differ as to the degree of self-unfruitfulness. Generally the soil and climatic conditions are widely different in places where such wide differences in self-fruitfulness and unfruitfulness exist. A good example is the McIntosh which is partially self-unfruitful in the humid eastern half of North America, yet is reported as being self-fruitful in Montana and Washington, the arid northwestern section of the United States. Baldwin, on the other hand, is considered self-fruitful in northern New England, but has been reported as being self-unfruitful in some other sections.

Among the varieties that are self-unfruitful to a great enough degree to reduce the set below any desirable commercial quantity in New Hampshire, may be listed McIntosh, Delicious, Gravenstein, Rhode Island Greening, Northern Spy, Wagener, Fameuse, Golden Delicious, Winesap, Stayman Winesap and Winter Banana. Certainly many other varieties also fall into this class, but it is not within the scope of this bulletin to include them. Some are new and have not as yet been thoroughly tested at this or nearby stations. Others are now obsolete or of little or no commercial importance.

Cross-unfruitfulness. Cross and inter-unfruitfulness may also occur among certain varieties. This fact is of importance to the apple grower because plantings are often made of varieties which may pollinate in one direction but not in the other. Gravenstein will not satisfactorily pollinate McIntosh, for example, but McIntosh is an excellent pollenizer for Gravenstein. Again, Northern Spy and Rhode Island Greening in some sections seem among themselves to be unfruitful, neither being able to set a crop of fruit when one pollenizes the other.

Inter-fruitfulness. Fortunately a few varieties are inter-fruitful; that is, cross-pollination is successful in both directions. This minimizes the number of varieties to be planted in a given orchard and may be an advantage under many conditions. Cortland and McIntosh are good examples. They will satisfactorily pollenize one another. Gravenstein and Delicious, Gravenstein and Wagener, and McIntosh and Oldenburg are similar inter-fruitful combinations.

Self-fruitfulness. Self-fruitfulness occurs where fruit setting is satisfactory from the application of a given variety of pollen to a flower of the same variety. The presence of bees helps to increase the set in such varieties by increasing the transfer of pollen. Many large blocks in New Hampshire consist entirely of Baldwin and always set heavy crops. Hand-pollination tests confirm these observations. The set on self-fruitful sorts may generally be further increased through cross-pollination, but in some cases this may not be desirable. Too heavy a set may be detrimental.

If the fruit of pollenizers does not have a high market value, self-fruitful sorts are economical.

Effect of Location:

The effect of locality on pollination and fruit setting has already been mentioned. Variations in the results of certain varieties as pollenizers for others, or in the self-fruitfulness of certain varieties, can be noted only when wide areas are considered. McIntosh is self-unfruitful to a high degree throughout New England, for example, but self-fruitful to a much greater degree in Washington (1) and Montana (2). Baldwin which seems self-fruitful in New Hampshire to the satisfaction of commercial growers has been found by Howlett (3) to be doubtfully so in Ohio.

Differences in the self-fruitfulness of these varieties, on the other hand, does not vary appreciably within a distance of several hundred miles, as indicated by a comparison of New Hampshire experiences with experiments in Massachusetts (4) and New York (5). The same is indicated in the case of McIntosh self-fruitfulness when comparing the results of Montana (2) and Washington (1). Nevertheless, McIntosh and other varieties nearly always set heavier crops in some sections of New England than in others.

McIntosh orchards located on hillsides and hilltops in some areas of New Hampshire are noted for their heavy set of fruit, which is generally better than in valley orchards. Even when pollenizers are reduced to a minimum at the higher elevations, the set of fruit is sometimes superior to that at lower elevations where better provision has been made for pollination.

Observations of McIntosh planted in blocks have sometimes led the grower to believe that in these orchards the McIntosh was self-fruitful. Generally in such cases, however, a few odd varieties may be discovered in adjacent fields which would easily be a source of pollen. Frequently a grower will overlook this fact, the usual feeling being that only common cultivated sorts can pollinate cultivated varieties. This assumption is wrong in most cases, for it is more often the fact that such odd varieties or seedlings make exceptionally good pollenizers.

A location at a small elevation may often be more favorable for fruit setting, because of the greater freedom from frost at blossom and fruit-

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(1) O. M. Morris. Studies in apple pollination. Wash. Agr. Exp. Sta. Bull. 163. (1921)

(2) F. M. Harrington and W. E. Pollinger. Pollination of the McIntosh apple. Mont. Agr. Exp. Sta. Bull. 256. (1932)

(3) F. S. Howlett. Apple pollination studies in Ohio. Ohio Agr. Exp. Sta. Bull. 404. (1927)

(4) F. C. Sears. The pollination problem in Massachusetts apple orchards. Rpt. Mass. Fruit Growers Assn. (1928)

(5) L. H. MacDaniels and A. J. Heinicke. Pollination and other factors affecting the set of fruit with special reference to the apple. Cornell Agr. Exp. Sta. Bull. 497 (1929)

Fig. 12. Cross section of ovary (20x). Note locule or cavity in which the ovule is located. a. Base of pistil.

setting time. The flower parts become progressively more susceptible to low-temperature injury as they approach the stage when the ovule becomes fertilized. The advantage of an elevation is well known with regard to lessening damage from spring frosts.

Location as affected by climate causes variations in the time that various varieties come into bloom. Varieties that coincide in time of bloom in one place may bloom on different dates elsewhere. This same variation may also occur in the same location in different seasons.

Tests for Self-unfruitful Orchards:

It is easy to test whether or not a lack of fruitfulness which has persisted year after year in an orchard is due to lack of pollenizers. If some blossoms of the variety are hand pollinated with pollen of a known good pollenizer and a high percentage of set occurs while the usual unfruitfulness of the remainder of the blossoms persists, then it may be concluded that either bees or pollenizers are lacking. If bees had also been provided in the orchard without increasing the set, then the conclusion would be justifiable that pollenizers were absent.

Another method to test whether the cause of unfruitfulness is lack of pollenizers, would be to introduce some branches of a good known pollenizer into the orchard at blossom time. If plenty of bees are also present and a set of fruit is obtained, this is proof of the lack of pollenizers.

For such reasons as these the recommendation is always made to interplant varieties in the apple orchard to insure a good set of fruit.

V. Pollination Experiments in New Hampshire, 1927-1932

Pollination of McIntosh:

In 1927 work was begun to determine the effectiveness of various commercial varieties as pollenizers for McIntosh. In addition to hand pollinations in screened cages, observations were made to compare the open set on McIntosh trees adjacent or near to various other varieties and on those somewhat isolated from other varieties.

In 1930, reciprocal pollinations were made with Delicious, Gravenstein, and Cortland.

In 1927 a moderately vigorous 20-year-old McIntosh tree was enclosed in a wire-screen cage just before the flower buds began to open. This tree was located in a sod orchard and had been fertilized with five pounds of sodium nitrate or ammonium sulfate annually since coming into bearing.

In 1929 a different McIntosh tree of corresponding size and vigor was similarly caged in the same sod orchard.

In 1930 in another orchard which is grown under cultivation with combined intercrops and cover crops, two McIntosh trees were enclosed just before the first blossom buds opened. The cages consisted of wooden frames covered with cheese cloth. These trees were 11 years old (from the time of planting), had borne two crops, and were of ordinary good vigor.

In 1931 two other trees were tested in the same cultivated orchard. These were also enclosed in cheese-cloth cages.

To increase the amount of data and to compare effects in differently located sections, a McIntosh tree was caged in cheese cloth in a southern New Hampshire orchard where normally trees of a given variety come into bloom from four to seven days earlier than at Durham. Two young Cortland trees were also caged and crosses made.

Because of the desire to try out some of the new McIntosh-like sorts, one of the leading questions of growers in New Hampshire is the efficiency of newer varieties as pollenizers. It was therefore concluded that some value to growers might be derived from using a few of the newly originated varieties as pollenizers for McIntosh. The work was therefore discontinued of testing as pollenizers varieties which had shown themselves to be consistently good pollenizers, or had proven less desirable from a standpoint of commercial value.

Pollen was obtained from the new varieties by removing the anthers from buds gathered as late as possible before the petals began to unfold and before danger of the stamens becoming contaminated by insect visits to the flowers. Since fresh pollen was gathered daily and none was held for use another day, the danger of loss of vitality in the pollen was reduced to a minimum.

Pollen was placed on the stigmas of opened flowers when the maximum number on a cluster were apparently in a receptive condition. In this way an average of four blossoms per cluster were pollinated. Unopened buds on a cluster, flowers that were apparently near the end of the receptive stage, and imperfect flowers were removed at this time of pollination.

Table I—*Percentage of blossoming spurs of McIntosh setting fruit after hand pollination*

Type of Cage	Wire Screen		Cheesecloth Covering							
Year	1927	1929	1930		1931			1932		
Soil Management	Sod	Sod	Cultivated		Cultivated		Sod	Cultivated		Sod
Tree Number	T335	T343	BF146	BF145	BF98	BF49	Tuttle 4	BF98	BF49	Tuttle 4
Pollenizer										
Baldwin	18.6	9.2	5.3					4.5		
Cortland		56.4	63.3		57.3	87.3		83.2		
Delicious	62.8	64.8	70.6		74.8	78.1		70.2		
Early Harvest			66.7							
Fameuse					66.7	77.8	37.9	92.7		
Gravenstein		17.2	10.3	0	3.1	13.0	2.9	50.0	39.3	60.0
Lobo					60.0	78.6	29.3			
McIntosh (hand pollinated)	1.9	2.9	11.8		4.8	0	0			
McIntosh (check)*	0	2.3	8.3	3.2	0.2	0.9	0	1.7		1.6
Medina					75.7	81.8	50.3			
Melba					53.1	78.0	29.3	66.0		67.4
Milton						83.6	27.3	70.2		70.8
Oldenburg	34.5	55.2								
Orleans							44.1			
Red Astrachan	29.4	62.6	54.7							
Red Gravenstein					9.0	3.8	2.4			53.1
Starking								75.0		
Wagener	83.6	23.8	69.5		65.3	69.6	30.0			
Wealthy	46.3	44.0	78.6							
Williams		77.8								
Winter Banana	35.7									
Open pollination on trees in the same orchard	51.4	41.8	34.7	34.7	59.6	59.6	22.0			58.5

* Blossoms were not hand pollinated but left to the effects of the weather.

In 1927, 1929 and 1930 all flowers in an individual cluster were pollinated with the same variety of pollen but various spurs on the same branch were often pollenized with different varieties.

Pollen was applied in 1931 and 1932 only to lateral flowers in the cluster, all terminals being removed. Another feature which differed from previous experiments, and which it was thought would give more uniform results, was the pollination of four flowers in every cluster used. This procedure was adopted on the basis of results presented in previous publications by the author (1, 2). The reasons for choosing these methods in preference to the spur-unit plan are also discussed in these papers.

Screen cages were kept over the trees throughout the season. But when cheese cloth was used, it was removed from the frames as soon as it was certain that the last flower to open was past the receptive stage. All conditions were therefore maintained as near to those of an open orchard as possible in 1930, 1931 and 1932.

Counts of set were made both before and after the June drop. The June drop was light during 1931, perhaps due to an unusually large amount of rainy weather during the early growing period.

A second or late drop, unusual in New Hampshire, occurred in August—about a month after the June drop. This feature is discussed in another paper (2).

At the time of bloom in 1927 weather conditions were cool and for the most part rainy. In 1928 pollination experiments were not carried on extensively because of almost continuous daily downpours of rain. In 1929 the first period of bloom was accompanied by mild days and cold nights, followed by an unusually cold, cloudy, misty period succeeded by pleasant weather. In 1930 the weather was unusually warm and dry throughout the blossom period and was by far the most favorable for bee flight.

Weather conditions were unsually favorable for fruit setting in 1931. Bright sunshine and high temperature prevailed with little rain during the period of full bloom. The least favorable feature was the rapidity with which the trees came into full bloom and the shortness of the period when stigmas were receptive.

Fine weather prevailed at pollination time in 1932.

Table I shows the results of five seasons' tests on McIntosh pollination in New Hampshire with relation to the per cent of blossoming spurs setting fruit after hand pollination.

The data show that for all practical purposes, McIntosh may be considered self-unfruitful. When McIntosh pollen is brushed onto the stigmas (hand pollination) a slightly higher set of fruit is to be expected with this variety than where the flowers are left undisturbed except by wind or rain (check).

Many previous workers suggest that when 30 per cent of the blossoming spurs develop fruit to maturity on full-bearing McIntosh trees, this is representative of a satisfactory crop from a commercial point of view. If these individuals are correct, then McIntosh is decidedly in need of pollenizers. In the five years of experiment, the highest set was 11.8 per cent. A set of

(1) L. P. Latimer. Pollination studies with the McIntosh apple in New Hampshire. Proc. Amer. Soc. Hort. Sci. (27) 1930.

(2) L. P. Latimer. Further observations on factors affecting fruit setting of the McIntosh apple in New Hampshire. Proc. Amer. Soc. Hort. Sci. (28) 1931.

TABLE 11—*Percentage of fruits harvested that were lop-sided (McIntosh)*

Type of Cage	Wire Screen	Cheesecloth Covering						
Year	1929	1930		1931		1932		
Soil Management	Sod	Cultivated		Cultivated		Cultivated		Sod
Tree Number	T343	BF146	BF145	BF98	BF49	BF98	BF49	Tuttle 4
Pollenizer								
Baldwin	55.6	75.0				62.5		
Cortland	21.4	10.3		4.7	3.8	22.1		
Delicious	6.7	8.4		9.6	8.7	8.1		
Early Harvest		23.9						
Fameuse				0	8.0	6.2		
Gravenstein	29.4	20.0		71.4	75.0	50.0	48.2	21.1
Lobo				10.2	4.6			
McIntosh (hand pollinated)	50.0	100.0	100.0	40.0				
McIntosh (check)	75.0	50.0				55.5		50.0
Medina				5.4	3.7			
Melba				14.3	2.6	11.0		9.5
Milton					14.6	9.9		10.8
Oldenburg	9.6							
Orleans								
Red Astrachan	22.6	0						
Red Gravenstein					66.7			6.7
Starking						11.8		
Wagener	25.0	5.4		8.3	3.8			
Wealthy	24.0	14.3						
Williams	27.8							
Winter Banana								
Drops				11.1	3.1	17.4	68.2	

fruit on two to three per cent of the blossoming spurs after self-pollination is usually the case with McIntosh.

That varieties differ among themselves in the ability to pollenize McIntosh is also indicated. Baldwin seems to be the least satisfactory, but this is to be expected for the results of numerous investigators show that Baldwin is an unsatisfactory pollenizer for many other varieties. Where Baldwin pollen was used on McIntosh the highest and lowest set is seen to be 18.6 and 4.5 per cent, respectively, of the spurs that blossomed. This is far below the standard for a commercial crop of McIntosh.

Gravenstein and Red Gravenstein are also quite unsatisfactory as pollenizers for McIntosh. In only one year out of five was the set of spurs above 30 per cent where these pollen varieties were used. Two to 10 per cent was the usual set of blossom spurs. Although slightly better on the average than Baldwin, Gravenstein is far from being dependable in producing a commercial crop of McIntosh.

Delicious seems to be the variety most constant in ability to cause a set of fruit on McIntosh. During the five years' experiments the percentage of blossom spurs setting fruit on McIntosh has been more constant when Delicious pollen was used than with any of the other good pollenizers. This is true whether the trees were grown in sod or under cultivation.

The percentage of blossom spurs setting fruit on McIntosh varied from 63 to 78 per cent when this pollenizer was used. This is a remarkably small variation. A few other varieties may have caused a larger set when used as pollenizers but this is not necessarily an advantage. It might necessitate heavy subsequent thinning and even then be somewhat detrimental to the normal annual-bearing habits of the McIntosh.

Melba likewise seems to be a reliable pollenizer. The low results obtained on the Tuttle farm in 1931 were due to a somewhat weak growing condition in the tree used in the experiment, as indicated by the results of all other pollenizers used with that tree.

Cortland, Milton and Wagener may also be considered very satisfactory pollenizers.

Although tested fewer years Fameuse, Lobo, Medina, Oldenburg, Red Astrachan, and Wealthy also seem promising as pollenizers for McIntosh. The actual set of fruit on McIntosh when these varieties are used as pollenizers has not differed greatly from the results obtained with Delicious pollen.

One problem connected with the development of good commercial apples is the shape or form of the fruit. This becomes important when one considers the difficulties in packing lopsided fruit and its lower market value. That lopsidedness of McIntosh fruits in New Hampshire is due largely to lack of satisfactory pollination is seen from a comparison of Tables I, II, and III. The varieties that are notably poor pollenizers for McIntosh, namely McIntosh, Baldwin and Gravenstein, cause a greater development of lopsided McIntosh fruits than when the more satisfactory pollenizers are used.

It is apparent that this is connected with poor pollenizing ability when one views Table III. One also sees that with these pollenizers McIntosh develops an unusually small number of seeds. These have been found to exhibit poorer germinating power than seeds from McIntosh pollenized by the better pollenizers.

TABLE III—*Average number plump seeds per fruit (McIntosh).*

Type of Cage	Wire Screen		Cheesecloth Covering						
Year	1927	1929	1930		1931		1932		
Soil Management	Sod	Sod	Cultivated		Cultivated		Cultivated		Sod
Tree Number	T335	T343	BF146	BF145	BF98	BF49	BF98	BF49	Tuttle 4
Pollenizer									
Baldwin	4.5	2.3	2.0				2.3		
Cortland		5.5	7.6		7.9	9.0	5.0		
Delicious	7.0	7.1	10.0		8.7	9.5	8.3		
Early Harvest			5.7						
Fameuse					7.3	8.1	7.2		
Gravenstein		2.4	4.2		2.6	2.9	3.0	2.0	4.7
Lobo					8.4	8.5			
McIntosh (hand pollinated)		3.3	1.0	3.0	3.6				
McIntosh (check)		4.3	3.4			1.0	3.8		2.3
Medina					8.4	9.4			
Melba					8.6	9.5	6.1		9.0
Milton						6.6	7.1		9.9
Oldenburg	5.0	5.1							
Red Astrachan	8.0	4.4	9.6			2.3			
Red Gravenstein									5.5
Starking							6.9		
Wagener	7.0	5.3	9.7		8.4	9.3			
Wealthy	7.0	6.2	7.3						
Williams		6.9							
Winter Banana	6.0								
Drops					8.4	9.0	7.1	1.7	

TABLE IV—*Average number of fruits on one hundred fruit-setting clusters (McIntosh).*

Type of Cage	Wire Screen		Cheesecloth Covering						
Year	1927	1929	1930	1931			1932		
Soil Management	Sod	Sod	Cultivated	Cultivated		Sod	Cultivated		Sod
Tree Number	T335	T343	BF146	BF98	BF49	Tuttle 4	BF98	BF49	Tuttle 4
Pollenizer									
Baldwin	100	115	100	179	176		100		
Cortland		114	126	174	136		136		
Delicious	147	128	113				140		
Early Harvest			124	183	200	109			
Fameuse				100	120	100	226		
Gravenstein		100	100	161	167	110	100	130	128
Lobo									
McIntosh (hand pollinated)	100	100	100	100	100				
McIntosh (check)		125	100	128	193	110	100		100
Medina				139	168	108			
Melba					149	100	138		140
Milton							171		165
Oldenburg	125	189				111			
Orleans									
Red Astrachan	147	119	131	100	100	100			
Red Gravenstein									112
Starking				178	183	119	127		
Wagener	131	132	133						
Wealthy	116	123	127						
Williams		121							
Winter Banana	135								

TABLE V—*Percentage of blossoming spurs setting fruit on Cortland, Delicious and Gravenstein after hand pollination*

Variety Pollenized	Cortland					Delicious	Gravenstein
Type of Cage	Cheesecloth Cover						Cheesecloth Bags
Year	1930	1931		1932		1930	1930
Soil Management	Sod	Cultivated		Cultivated		Cultivated	Sod
Tree Number		BF289	BF309	BF289	BF309	BF12	
Pollenizer							
Baldwin	8.3			35.7		0	0
Cortland (hand pollinated)		0		57.5			14.3
Cortland (check)	12.0	0	0	20.4	32.4		
Delicious	32.9		33.6	66.2		0.8	71.4
Early Harvest							37.0
Fameuse				60.4			
Golden Delicious			30.3				
Gravenstein	42.8	0	0	51.1		32.6	0 (check) 2.4 (hand)
Lobo		27.3	10.0				
McIntosh	54.5	37.3	22.0	74.6		18.9	36.5
Melba		22.5		56.9			
Medina		23.9					
Milton		35.7					
Oldenburg							22.2
Red Astrachan	65.0					16.7	34.1
Red Gravenstein		0		56.7			
Starking				78.3			
Wagener	72.0	37.1				26.8	31.3
Wealthy	27.3					30.0	
Yellow Transparent			0				
Winter Banana						10.7	

Another method of indicating the efficiency of certain varieties of pollen in causing fruit to set on McIntosh is evident from Table IV which records the average number of fruits per cluster. The data show that rarely more than one fruit develops on a McIntosh cluster pollinated by Baldwin, Gravenstein, McIntosh or Red Gravenstein. It has been shown previously (Table I) that these varieties are also incapable of causing a good set of fruit on the tree as a whole where McIntosh is cross pollinated.

Fameuse heads the list from the viewpoint of the number of fruits per cluster. Usually about two per cluster were obtained where McIntosh was pollinated by this variety (Table IV). It has already been noted that Fameuse is one of the leaders in causing a high percentage of fruit spurs of McIntosh to develop fruit as a result of cross-pollination. Wagener is a close rival in this respect.

Pollination of Cortland:

The methods used in Cortland pollination experiments were similar to those followed with McIntosh. Cheese-cloth cages only were used to exclude insects.

Cortland as indicated in Table V seems at times to be partially self-fruitful, especially when hand or bee pollinated. In both cases the set was heavier than when the flowers were left entirely to the effects of the wind and rain.

Baldwin was found to be a poorer pollenizer for Cortland than Cortland itself. A fair set of fruit was obtained when Delicious pollen was used but was not as satisfactory as that effected by several other varieties. The highest set of Cortland fruit was generally obtained when McIntosh or Wagener was used as pollenizer. Gravenstein produced a satisfactory set of fruit in two of the three years, and Red Gravenstein in 1932. The data show that in 1932, however, the set with Gravenstein and Red Gravenstein as pollenizers, was no improvement over that obtained with Cortland pollen itself. Lobo pollen does not seem to give a satisfactory set of fruit on Cortland. The most important finding is that Cortland and McIntosh are cross-fruitful varieties.

Pollination of Delicious and Gravenstein:

One year's results (1930) indicate that Delicious and Gravenstein are nearly self-unfruitful. In neither case was fruitfulness increased by the use of Baldwin pollen. Although the use of Gravenstein, Wealthy and Wagener resulted in a set of fruit on 32.6 per cent, 30 per cent and 26.8 per cent, respectively, of the blossoming spurs on Delicious, this might be considered unsatisfactory from a commercial viewpoint, as the tree used in the experiment, although vigorous, was decidedly alternate in its bearing habit. McIntosh and Winter Banana as well as Red Astrachan might also be considered in most seasons as unavailable for Delicious pollenizers because of the earliness of their blooming season as compared with Delicious. (See Table V.)

One year's results with Gravenstein indicate that Delicious would be a satisfactory pollenizer, except that its late blooming habit renders it uncertain. The periods of bloom of Delicious and Gravenstein do not overlap enough of the time to make availability of pollen dependable under field conditions. (See Table V.)

Next to Baldwin, Cortland and Oldenburg failed to show themselves as satisfactory pollenizers for Gravenstein. McIntosh, Red Astrachan, Wagener and Early Harvest did not produce a high set in 1930, yet owing to the heavy blooming habit of Gravenstein, 30 per cent would ordinarily be sufficient.

The foregoing results of pollination with McIntosh, Cortland, Delicious and Gravenstein emphasize the fact that these varieties are not only self-unfruitful but may fail to be pollenized satisfactorily by some other varieties. Self-unfruitful varieties used as pollenizers may not bear fruit unless these facts are taken into consideration.

Relation of Pollen Viability to Set of Fruit in Cross Pollination:

Poor set when certain varieties are used as pollenizers is probably due to a large extent to natural abnormality of the pollen of these varieties. These abnormalities may vary in different seasons.

Many investigators have found in artificial germination tests that Baldwin pollen germinates very poorly. Many of the pollen grains are imperfect in their development. Gravenstein also usually exhibits rather poor germinating power, but in this respect is less constant throughout a period of years than Baldwin. These facts partially explain why the low sets of fruit indicated in Table I are obtained when these varieties are used as pollenizers for McIntosh. It is also known that these varieties differ from McIntosh in the genetical make-up of the tissues.

Delicious is just the opposite. It produces well-formed pollen grains which germinate from 95 to 100 per cent on artificial media. It is one of the most satisfactory all-round pollenizers in existence.

Effect of Position of the Flower in the Cluster on Set of Fruit:

That all of the flowers in the cluster do not open at the same time is well known. The first to open is the central or terminal flower in the cluster. The latest to open are those at the base of the cluster.

Generally the first flowers to be pollinated in the cluster will remain on the tree through the June drop. Under most New Hampshire conditions, this will be the terminal flower. Yet if weather conditions are unsatisfactory for bee flight and consequently for pollination when the terminal flowers are receptive, the latter may fall off during or before the June drop. Those blossoming later, if they open under more favorable weather conditions, will then produce the fruit. With some varieties the first flowers to open may be injured by frost occasionally because of their advanced development, and again the later opening buds will be the ones to develop fruit.

Whether the crop came mainly from terminal or from lateral flowers of the cluster can easily be determined with McIntosh. Fruits developing from lateral flowers are flatter in shape and have usually much longer and more slender stems than those from terminal flowers of the spur. Fruits from terminal flowers are usually decidedly more attractive in appearance, and have better form and size due partly to the greater seed development. The position of these flowers in the cluster predetermines shape and other differences. Even in the dormant winter buds the superior size of the terminal flower and its larger stem diameter may be seen. They are in a better position to receive food, minerals and water from the tree.

To test the differences in anatomy of terminal and lateral flowers and the effect of these on the resultant fruit crop, a number of trees have been used experimentally. Terminal flowers were tagged and the two types of fruit developed were observed at harvest time. In a future publication a comparison of the rate of growth in terminal and lateral flowers of the cluster will be presented.

Table VI shows data obtained in preliminary experiments to determine quantitatively difference between terminal and lateral fruits on the cluster. The trees concerned had all terminal flowers tagged while they were open. At harvest time the tags still remained on the stems of the terminal fruits which could easily be separated out and compared with the lateral ones on the same tree. In all cases the terminal flowers produced larger fruits. In addition to this important feature terminally developed fruits have better form as indicated by the greater percentage of lopsided fruits among the laterals. Aside from the better position of the terminal fruits to receive foods and water from the tree, two explanations of this better form and size are possible from a glance at the data. An increase of approximately 20 percent in weight is accompanied by an increase of two seeds per fruit in the terminals over the laterals. The shorter and thicker stems of the terminal fruits may also aid in causing a better development of the fruits.

In these trees terminal and lateral fruits were rarely matured on the same clusters, so that difference in size and shape could be considered as due purely to anatomical and physiological differences between the terminal and lateral flowers. That there is less difference in diameter than in length between fruits from terminal and lateral flowers can be determined from Table VI. It may be seen that the ratio between length of terminals and laterals is greater than between the diameters of the two.

VI. Pollination and Orchard Planting and Management

For satisfactory pollination, it is evident, first of all, that the apple must be pollinated by the apple, the pear by the pear, etc. This does not mean that fruits of different genera and in many cases of different species cannot possibly be crossed, but such crosses are rare and usually only result, when they are possible, after hand pollination.

Coincidence of Blooming Periods of Varieties:

It would be unreasonable to interplant an orchard of one variety with trees of another variety and expect cross pollination to occur if the two varieties did not have at least a few flowers open at the same time. This is evident because we know that the pollen is shed and is available to insects only after the flowers have fully opened.

Even though the flowers of an early blooming sort may in some years remain on the tree until the opening of some of the flowers of a later variety for which pollination is desired, in other years, especially when unusually warm weather prevails at blossom time, the flowers of the early variety may be shed before the later one opens its buds. The pistils are in a receptive condition as soon as or even just before the buds open. The bumblebee is the only insect able to push the petals of unopened buds apart, and it would only be such insects that could possibly pollinate unopened flowers.

TABLE VI—*Comparison of terminal and lateral flowers of the cluster (McIntosh)*

Year	1929		1929		1930		1930		1931		1931		1930	
Number of Tree	T310		B.F.97		T174		B.F.97		B.F.97		B.F.97 ~~(drops)~~		B.F.129 Immature fruit	
Soil Management	Sod		Cultivated		Sod		Cultivated		Cultivated		Cultivated		Cultivated	
Type of Fruit	Terminal	Lateral	Terminal	Lateral	Terminal	Lateral	Terminal	Lateral	Terminal	Lateral	Terminal	Lateral	Terminal	Lateral
Number of fruits examined	46	71	56	85	23	26	67	56	41	125	99	120	25	25
Average weight per fruit (grams)	137.0	115.0	134.0	107.0	135.2	118.7	169.5	142.9	142.0	123.1	154.1	130.6	36.2	30.6
Number of plump seed per fruit	7.0	4.1	7.1	5.5	8.6	7.3	9.4	7.2	10.2	8.3	11.0	9.7	—	—
Number of empty seed cavities per fruit	0.5	0.9	0.5	0.6	0.1	0.4	0.1	0.5	0.1	0.2	0.05	0.1	—	—
Per cent of fruits lop sided	0	0	0	0	13.0	23.1	6.0	19.6	2.4	10.4	7.1	9.6	—	—
Average diameter of fruit (millimeters)	—	—	69.0	67.1	71.9	70.1	78.6	75.1	73.8	59.2	75.5	71.4	44.7	42.3
Average length of fruit (millimeters)	—	—	60.0	54.0	57.6	53.2	63.0	57.4	70.1	55.7	59.7	55.7	39.3	36.2
Average diameter of stem (millimeters)	—	—	—	—	3.16	1.90	—	—	—	—	—	—	3.21	11.99
Average length of stem (millimeters)	—	—	—	—	12.50	18.80	—	—	—	—	—	—	12.20	15.86

Because of the scarcity of bumblebees, this unusual procedure is not dependable.

A late-blooming sort would not be apt to cause any more successful set on an early blooming sort because the pistils soon begin to disintegrate after full bloom. Even if the pistils have not begun to shrivel, unless flowers are promptly pollinated, the ovules may begin to disintegrate before the pollen tubes can reach them. As has already been mentioned, locality may alter to a certain extent the relation of blooming dates among certain varieties.

Varieties may be separated into five general classes with relation to date of bloom: very early, early, mid-season, late and very late. Some may have a short and others an extended period of bloom, depending on the positions of blossom clusters on the tree. Most varieties of apples produce the majority of their flowers only on spurs arising from wood more than one year old. A few varieties produce most of their flowers terminally on slender shoots. Some also produce fruit from lateral buds on last season's new shoots. Others yield flowers in clusters of all three types.

With trees producing all types the period of bloom covers the longest possible period. When only one type is produced, the period of bloom is exceedingly short.

With relation to position of clusters, McIntosh, Gravenstein, Red Astrachan, Melba, Milton, Fameuse, Delicious, Baldwin, Northern Spy, Red Gravenstein and Starking fall in the class of trees coming into full bloom nearly all at once, since their flowers are rarely produced on anything but spurs on older wood.

Cortland flowers appear both on spurs and terminally, while Wagener, Wealthy, and Winter Banana possess all three types of clusters with relation to position on the tree, with spurs predominating.

Where more than one type of cluster is present, the order of bloom is, spurs first and usually lateral clusters last. Partly because of this fact Cortland, Wagener and Wealthy are regularly available as pollenizers, except that Wagener and Wealthy tend to a large extent to bear only in alternate years.

As classified under the headings, very early to very late, the blooming period of apples in New Hampshire is as follows:

Very Early—Red Astrachan, Gravenstein, Red Gravenstein.
Early—Fameuse, Gravenstein, Red Astrachan, McIntosh, Melba, Milton, Oldenburg, Wagener, Early Harvest.
Mid-Season—Delicious, Oldenburg,, Cortland, Wagener, Wealthy, Medina, Lobo, Winter Banana, Orleans, Starking, Williams, Baldwin.
Late—Golden Delicious, Cortland, Macoun, Wealthy, Wagener, Northern Spy, Winter Banana.
Very Late—Northern Spy, Macoun, Northwestern Greening, Rome, Wealthy, Winter Banana.

Even in a given class some varieties are slightly earlier than others, and those in one class may overlap into another somewhat. Very young trees may bloom slightly later than mature trees of the same variety. Cortland, Gravenstein, Macoun, Northern Spy, Wagener, Wealthy and Winter Banana are placed under more than one class because of their more or less extended period of bloom.

From this classification of varieties it is possible to pick those apt to bloom coincidently with the ones needing pollination. Such combinations should be planted as far as possible, providing cross pollination has been proven effective in such cases. In some instances interplanting two or three pollenizers is desirable so that pollination will be satisfactory for all. It may also be wise to plant pollenizing varieties that usually slightly precede or follow the variety requiring cross pollination, to insure against seasonal variability in coincidence of blooming periods. Under some conditions it has been found that varieties like Northern Spy, which in some sections bloom so late as to be useless as a pollenizer for McIntosh, will in a few locations bloom early enough to be available as pollenizers. Under average conditions a four or five-day blooming period may be expected with varieties producing flowers as McIntosh do.

Bees in the Orchard:

There is no doubt that in the majority of orchards, especially where cultivation is practiced, the bringing in of honeybees at blossom time will increase the set of fruit on the trees. It has been proven by observation that bees are the only important insects for transferring sufficient apple pollen for commercial orchards. It is true that some flies and even other insects have a small share in this transfer, but they are never very significant when a commercial crop is concerned. Even honey bees as individuals fall far below bumblebees in their efficiency. But a sufficient number of bumblebees is seldom found in an orchard. Lack of knowledge of their habits and failures in attempts to propagate, protect and care for them as is done with honeybees, indicate that the honeybee alone can be managed properly by the fruit grower.

It is only the queen bumblebees that are flying about at apple-blossom time, and the difficulties that befall them during the winter while they hibernate in the grass or under brush or stone walls, cut down their numbers considerably. Were the bumblebees more plentiful nothing more could be desired, for they are able to fly about and work at times when the honeybee is incapable of flight. Wind, low temperature and light rains that preclude the work of honeybees are no obstacles to bumblebees. Honeybees are not very active until the air temperature rises above 65° or 70° F. Rain and winds also effectively lower their efficiency. At Durham, N. H., bumblebees have been seen flying about the apple blossoms when the temperature was 42° F., a gentle rain was falling and a light wind blowing. Bumblebees have also been observed to open buds to get inside the flowers.

The usual recommendation is one strong colony of honeybees to the acre. Perhaps distributing the hives throughout the orchard would give best results, but placing the colonies in a group in one part of the orchard is generally satisfactory in smaller orchards and means less trouble in caring for the bees.

Distribution of Pollenizers in the Orchard:

The best plan for providing pollenizers is to plant them at the same time the orchard is planted. The distance between pollenizers is important. Unless they are valuable commercially, it is often desirable to know the maximum distance apart that they can be planted and still give satisfactory results.

Conditions of the weather in a given section is an important consideration in this respect. Where warm weather prevails at blossom time, the pollenizers need not be so close together as where the temperature is lower. Cool weather at blossoming time interferes with bee flight and under such conditions, which frequently prevail throughout the apple sections of New Hampshire, pollenizers should be used abundantly. One tree out of every nine as a pollenizer is the minimum amount to recommend safely. Under many conditions more pollenizers would be better insurance for a full crop.

Every tree in the orchard should properly be adjacent in some direction to a pollenizer. In orchards of McIntosh where pollenizers are present only in a few spots, it may be noticed that trees adjacent to the pollenizers produce good crops, and that the crop becomes to a striking degree progressively less on trees farther and farther away. To forestall such results, the following planting plans are suggested:

If the varieties planted are cross fruitful, such as McIntosh and Cortland, one row of Cortland to two rows of McIntosh would be unquestionable from the pollination standpoint, unless Cortland were so desirable that the rows of Cortland could alternate with the McIntosh rows.

Plan A

Row 1 All McIntosh
2 All Cortland
3 All McIntosh
4 All McIntosh
5 All Cortland
6 All McIntosh

In this plan (A) it is understood that the trees are all to be permanent. Planting all one variety in the same row would facilitate keeping the pickers from mixing varieties in harvesting, should the two varieties ripen at the same time.

Plan B

M	M	M	M	M	M	M	M	M
M	P	M	M	P	M	M	P	M
M	M	M	M	M	M	M	M	M
M	M	M	M	M	M	M	M	M
M	P	M	M	P	M	M	P	M
M	M	M	M	M	M	M	M	M

M=McIntosh or other desired variety.
P=Pollenizer.

In this Plan B for permanent trees, the pollenizers are placed so that every tree is in contact with one. This number avoids having at least one tree not adjacent to a pollenizer.

Where more than one pollenizer is needed to overcome difficulties already discussed in relation to coincidence of bloom, the following plan may be considered:

Plan C

Row
1 All McIntosh or other desirable variety
2 All earlier blooming pollenizer
3 All McIntosh or other desirable sort
4 All later blooming pollenizer
5 All McIntosh or other desirable variety
6 All earlier blooming pollenizer
7 All McIntosh or other desirable variety
Etc.

If a premium is placed on the desired commercial variety, the following plan may be considered in an orchard of permanent trees:

Plan D

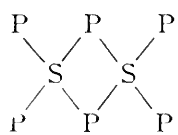
X	X	X	X	X	X	X
X	E	L	X	E	L	X
X	X	X	X	X	X	X
X	X	X	X	X	X	X
X	E	L	X	E	L	X
X	X	X	X	X	X	X

X=Common variety
E=Slightly earlier blooming sort
L=Slightly later blooming sort

In this case there will be two pollenizers to every seven trees of the main variety. Each tree will also be in contact in some direction with both an early and a late blooming pollenizer. Likewise each pollenizer will be in contact in the same way with each of the other varieties.

In case semi-permanent trees are planted in the orchard, some pollenizers should also be included in the permanent rows. Otherwise the orchard would be without pollenizers when the semi-permanents are removed.

One of the most satisfactory ways to plant semi-permanents is to follow the quincunx plan; that is, plant them where the diagonals between permanent trees cross. Thus:



P=Permanent trees
S=Semi-permanents

In this way the trees are crowded the least possible amount, and removal of semi-permanents is easy.

Using two pollenizers, the following plan is suggested:

Plan E

Row														
1	X		1		2		X		1		2		X	— Permanent row
2		X		X		X		X		X		X		— Semi-permanent
3	X		X		X		X		X		X		X	— Permanent
4		1		2		X		1		2		X		— Semi-permanent
5	X		X		X		X		X		X		X	Etc.
6		X		X		X		X		X		X		
7	X		1		2		X		1		2		X	
8		X		X		X		X		X		X		
9	X		X		X		X		X		X		X	
10		1		2		X		1		2		X		
11	X		X		X		X		X		X		X	
12		X		X		X		X		X		X		
13	X		1		2		X		1		2		X	
Etc.														

By this scheme if either the permanents or the semi-permanents are considered separately, the distribution of pollenizers in each is similar to that in Plan D. When the semi-permanent trees are finally removed, the distribution of pollenizers will then be identical with Plan D.

Naturally many other arrangements of pollenizers are possible, but the plans described are practical where the goal is high and uniform tree yield with a minimum amount of pollenizers. They also emphasize the value of the use of more than one pollenizer.

Where it is known that the chances for good pollination are exceptionally favorable, one pollenizer in a block of 16 trees may be sufficient, but ordinarily such distribution is risky.

With the orchard layout determined for interplanting pollenizers, the next problem is the choice of suitable pollenizers.

In Table VII are presented the results obtained in experiments concerning the success of various pollenizers for important varieties of apples. The data are the result of repeated trials at the New Hampshire and at other eastern experiment stations.

Data are omitted regarding tests which have not yet been thoroughly substantiated.

General experience with Baldwin and Wealthy indicates that under New Hampshire conditions these sorts nearly always set satisfactory crops with their own pollen. In other sections of the country this has not seemed to be true, hence these varieties and the Cortland are listed as doubtful. The

TABLE VII—*Results of self and cross pollination of common New Hampshire apple varieties*

Variety to be pollinated	Pollenizers													
	Baldwin	Cortland	Delicious*	Early McIntosh	Fameuse	Golden Delicious	Gravenstein**	McIntosh	Milton	Northern Spy	Oldenburg (Duchess)	Rhode Island Greening	Wagener	Wealthy
Baldwin	D	+	+		+	+	—	+		+	+	—	+	+
Cortland	—	D	+		+	+	+	D	+	+	+		+	+
Delicious*	—	+	—			D	D	—		D	+	—	+	+
Early McIntosh				—							+			+
Fameuse	—		+		—			+						—
Golden Delicious	—		—			—				+				
Gravenstein**	—	—	+	+			—	+		+	+	—	+	
McIntosh	—	+	+	+	+		—	—	+	+	+	—	+	+
Milton									—					+
Northern Spy	—	+	+			+		+		—	+	—	+	+
Oldenburg (Duchess)	—		+		+			+		+	—	—	+	+
Rhode Island Greening	—	+	D					D		—	+	—		D
Wagener	—		+				+	—				+	—	
Wealthy	—	+	+	+	+	+	—	+	+	+	+	—	+	D

Note: These data represent a summarization of data obtained in New Hampshire and elsewhere.

Legend:

+ = satisfactory pollination.

— = unsatisfactory pollination.

D = doubtful results. In this case a cross may be classed as doubtful because good results have been obtained in some cases and poor results in others, or else there are considerable variations.

How to use the table:

It is desired to find a good pollenizer for Wagener. Locate Wagener under the column headed "Variety to be pollenized." Note that Delicious, Gravenstein, and Rhode Island Greening are checked + or satisfactory under "pollenizers."

Or to learn what varieties will be pollinated by Rhode Island Greening: Find Rhode Island Greening under "pollenizers." Note that it will be satisfactory for Wagener alone.

*Starking, a bud sport of Delicious, has apparently the same pollenizing requirements of Delicious and is similar when used as a pollenizer.

** Red Gravenstein acts in the same way as Gravenstein as a pollenizer. It also has the same pollination requirements.

other varieties have never shown any definite evidence of self-fruitfulness in the eastern states and should never be planted in very large blocks or in the total absence of other varieties.

As a pollenizer Baldwin is a complete failure. This is indicated in Table VII which shows that with none of our leading New England varieties has Baldwin given satisfactory results as a pollenizer. Rhode Island Greening has behaved in a similar way except that it has been found to pollenize Wagener satisfactorily. The same may be said for Gravenstein. The poor pollenizing ability of these three varieties is probably due to the poor germinating ability of their pollen and to the large percentage of abnormal pollen grains which they develop as a result of their unusual genetical make-up.

The other varieties are generally efficient pollenizers, with these exceptions: Cortland has not yet proven a satisfactory pollenizer for Gravenstein. Delicious has failed to show evidence of satisfactorily pollenizing Golden Delicious or Rhode Island Greening. McIntosh has not satisfactorily pollenized Delicious, Rhode Island Greening or Wealthy. Northern Spy has not yet caused a satisfactory set of fruit on Delicious or Rhode Island Greening and Wealthy has failed as a pollenizer for Fameuse and Rhode Island Greening. Oldenburg and Wagener seem to be outstanding as good pollenizers for all varieties tested.

In addition to the crosses shown in Table VII Oldenburg has also been found to pollenize Melba and Lobo well. Melba is self-unfruitful.

With relation to the ability of certain varieties to be successfully pollenized by others, the following may be said: It has been difficult to find many satisfactory pollenizers for Delicious, Golden Delicious and Rhode Island Greening.

Of those shown in Table VII, Cortland, Oldenburg, Wagener and Wealthy are the only varieties that will pollenize Delicious satisfactorily beyond any doubt. Golden Delicious seems to be pollenized satisfactorily by Northern Spy but not by Baldwin or Delicious. Rhode Island Greening is pollenized well by Cortland and Oldenburg.

Finding suitable pollenizers for the remaining varieties has seemed less difficult.

In addition to failure to respond to pollination by Gravenstein and Rhode Island Greening and Baldwin, Delicious has failed to give a satisfactory set when pollenized by McIntosh; Gravenstein by Cortland.

Wagener is unusual in that Gravenstein and Rhode Island Greening have proven satisfactory pollenizers for this variety while McIntosh has failed.

Certain variety mixtures are not to be considered in relation to their pollenizing qualities because of the small chance of the period of bloom coinciding under New Hampshire conditions. Such relationship exists between Golden Delicious and Gravenstein, Golden Delicious and McIntosh, Gravenstein and Northern Spy, and McIntosh and Northern Spy.

Fortunately, among a few varieties interfertility exists. The following lists indicate first, cases where two varieties may be planted together and each will satisfactorily pollenize the other; and, second, cases in which two varieties are inter-sterile and neither will pollinate the other.

To illustrate inter-fertility of two varieties, it may be seen from Table VII that in many cases where two varieties are concerned, each pollenizes the other satisfactorily. Thus one may have a Cortland orchard interplanted with Delicious and expect a good commercial crop on both varieties. Other varieties that prove satisfactory when planted alone with Cortland are McIntosh, Northern Spy and Wealthy.

Delicious may be interplanted with any one of the following varieties and both will set a good crop: Cortland, Oldenburg, Wealthy, Yellow Transparent.

Similarly Early McIntosh and Wealthy are inter-fruitful, as are Fameuse and McIntosh, and Gravenstein and Wagener.

McIntosh is inter-fruitful with each of the following varieties: Cortland, Fameuse, Oldenburg, Wealthy, Yellow Transparent.

Milton is interfruitful with Wealthy.

Northern Spy is interfruitful with Cortland, Golden Delicious, Oldenburg and Wealthy.

Wagener is inter-fruitful with Delicious and Gravenstein.

Oldenburg is inter-fruitful with Delicious, McIntosh, Northern Spy and Wealthy.

Wealthy is inter-fruitful with Cortland, Delicious, Early McIntosh, McIntosh, Milton, Northern Spy and Oldenburg.

Yellow Transparent is inter-fruitful with Delicious and McIntosh.

On the other hand, in some combinations, two varieties may be planted together and neither can successfully pollenize the other. Naturally such combinations should be avoided unless other varieties are planted as pollenizers. They include the following: Baldwin and Rhode Island Greening or Gravenstein; Cortland and Gravenstein; Delicious and Rhode Island Greening; Gravenstein and Baldwin or Cortland; McIntosh and Rhode Island Greening; Northern Spy and Rhode Island Greening; Rhode Island Greening and Baldwin, Delicious, McIntosh, Northern Spy or Wealthy; Wealthy and Rhode Island Greening.

From this list the following combinations would be recommended where desirable, because of coincidence of time of bloom and superior commercial quality:

Cortland and Delicious
Cortland and Wealthy
Delicious and Wagener
Delicious and Wealthy
Gravenstein and Wagener
McIntosh and Cortland
McIntosh and Wealthy
Northern Spy and Wealthy

Often the choice of varieties is such that a third or occasionally even four or more varieties need to be inter-planted to satisfy all needs for pollination. As an example of the latter, if Gravenstein, Baldwin, Delicious and McIntosh were the varieties to be planted in the orchard, all except Delicious would be properly taken care of as far as pollenizers are concerned. To insure a full set on Delicious, some other variety, such as Cortland, Wagener or Wealthy, would also have to be planted in the orchard.

If Rhode Island Greening, Gravenstein, Baldwin and Delicious were the varieties desired for the commercial crop, it would be necessary to introduce pollenizers for Delicious and Rhode Island Greening. Cortland is the only variety which has sufficient data to recommend it in this case. The capability of untested varieties as pollenizers for Rhode Island Greening can only be conjectured.

Usually it is advisable to interplant three varieties, or one variety and enough trees of two other varieties to insure cross-pollination and set of fruit.

Some of the better combinations and the reasons for choosing them are given below:

Earlier-blooming desirable orchard varieties capable of pollenizing McIntosh are not easy to find. Wagener blossoms early enough and the period of bloom is ample so that one need not worry about the blooming periods not coinciding. Delicious is a desirable second sort because it will pollenize both McIntosh and Wagener. Another good triple combination is McIntosh, Cortland and Delicious. These combinations satisfactorily overcome any possible difficulty due to lack of coincidence of bloom or ability to pollenize.

When Northern Spy is desired in the orchard, the latest blooming sorts are necessary as pollenizers. Under New Hampshire conditions McIntosh, although known to be able to cause a set of fruit on Spy, is not practical as a pollenizer for this variety under orchard conditions because McIntosh bloom is usually over before Spy buds begin to open. The same may be said for Delicious bloom.

The extended period of bloom of Wealthy, however, normally makes it dependable for pollenizing Northern Spy. The two are inter-fruitful. Golden Delicious also blooms late enough to reach Spy and fortunately the two are inter-fruitful. Since McIntosh and Wealthy are inter-fruitful, a combination of Northern Spy, McIntosh and Wealthy might under some conditions prove a favorable one. Baldwin and Delicious might also be introduced to make the harvest season more continuous.

Where Gravenstein is a profitable variety, Oldenburg and Wagener are good pollenizers. McIntosh would also fit well into such an orchard.

Many other combinations are possible, but the following questions should be remembered and considered in choosing pollenizers:

1. Do the known statistics indicate that the varieties desired as pollenizers are able to cause a set of fruit on the commercial sort to be planted?
2. How well do the periods of bloom of varieties and pollenizers overlap?
3. Is it important to consider the commercial value of the pollenizers?
4. Are the pollenizers regular annual bearers?
5. Are they hardy and highly resistant to frost damage?
6. Are they free from and resistant to such diseases as canker, apple scab, blight, etc.?
7. Are the pollenizer varieties suspectible to railroad worm?

Reworking Orchards to Pollenizers:

After one finds that an older orchard contains certain varieties which have become unprofitable, their replacement by better sorts is desired. Before top-working the undesirable sorts one should consider whether their disappearance will constitute at the same time the removal of necessary pollenizers. In such a case, the data previously presented may be consulted in selecting suitable pollinating sorts to topwork in the orchard.

In many cases the varieties are interplanted in such a way that the permanent rows consist entirely of one variety, no recognition having been taken at the time of planting of the necessity for permanent pollenizers. After removal of the other semi-permanent pollinating varieties, such an orchard will usually be found to set little fruit. The remedy then is to top-work certain of the trees to pollenizers. It will still be several years, however, before the grafts bloom.

In top working an orchard, it is advisable eventually to work over a tree completely to the pollenizing variety, rather than to graft only a portion of the tree permanently. When a tree is only partially worked over, either through accident or neglect, the pollenizing section of the tree may be lost.

Temporary Relief from Lack of Pollenizers:

As soon as one learns that lack of pollenizers accounts for the failure of an existing orchard, a crop may be obtained if bees are present, by placing blossoming branches of pollenizing varieties in buckets or tubs of water throughout the orchard or near the hives of bees. Foreign pollen is thus available for the flowers on the trees and will tide the orchardist over the period during which grafts are becoming old enough to produce bloom.

Summary

1. The increasing importance of planting only certain varieties of apples in orchards has led to the problem of cross-pollination.

2. Flower-bud formation and the relation of various flower parts to successful fruit setting are important.

3. Under New Hampshire conditions where McIntosh is a leading commercial variety, pollination has become important because of the self-unfruitfulness of this variety.

4. The position of the flower in the cluster has a profound effect on the percentage of flowers that set fruit and on the size and shape of the resulting apples.

5. Competition between flowers and fruits for food and water has a profound effect on the number of fruits reaching maturity. The nutrition of the tree is very important in this respect.

6. Certain varieties such as Baldwin, Gravenstein and Rhode Island Greening are rather poor pollenizers, partly because of the low germinating power of the pollen of these sorts.

7. Certain varieties do not make good pollenizers for other varieties when their dates of bloom are widely separated.

8. Bees are of inestimable value to the orchardist.

9. For economy, a careful consideration of the arrangement and distribution of pollenizers is important.

10. When orchards have proven unfruitful because they have been planted in solid blocks, pollenizers should be grafted into some of the trees.

11. Temporary relief from a lack of pollenizers is available through the introduction of bouquets of other varieties at blossom time.