

PLANT SCIENCES

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Pollination and fruit set of fruit crops

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The purposes of this bulletin are (a) to describe mechanisms of pollination, (b) to outline cultural practices favoring good fruit set, (c) to summarize pollination requirements of apples, (d) to suggest orchard planting plans for efficient apple pollination, and (e) pollination of other fruits.

POLLINATION ESSENTIAL FOR FRUIT SETTING

Moving pollen from the flowers of one variety to the flowers of another variety is probably the most critical single process in the series of events leading to the production of a good crop of fruit. Pollination is simply the transfer of pollen from anthers to stigmas (Fig. 1). Effective cross-pollination between varieties is essential in order to cause fertilization of the ovules in the flower and subsequent initiation of seed development and finally, fruit set.

In the eastern United States, apple varieties are generally self-unfruitful; that is, they do not set fruits by their own pollen. They are self-unfruitful because a biochemical antagonism prevents pollen grains from growing on the stigmas of the same variety.

Provision for cross-pollination is best made at the time an orchard is planted. Although Golden Delicious and some other varieties are sometimes self-fruitful under the ideal conditions of northwestern United States, in the Northeast, no variety should be considered capable of setting a commercial crop by its own pollen. Even though Baldwin, Rome, and some others, when planted in solid blocks, have been known to set good crops, in some years, they will crop much more consistently with cross-pollination. In modern orchards where fewer and fewer varieties are grown, greater consideration than ever must be given to provide

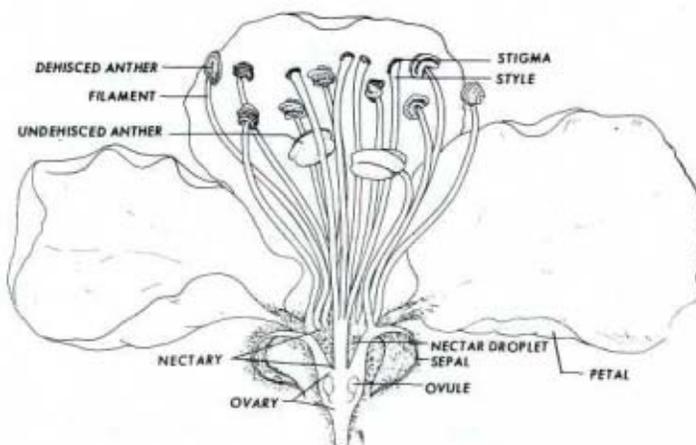


Figure 1.—Longitudinal section of an apple blossom. Some stamens and styles removed to clarify the diagram; enlarged about 15 times.

for cross-pollination. A lack of adequate pollination can result in reduced crops or small, misshapen fruits. This bulletin discusses factors affecting fruit set and methods of providing for cross-pollination.

Following are definitions of some of the words used in this bulletin.

Pollination—transfer of pollen from anthers to stigmas, which may or may not be on the same flower or on the same plant.

Self-fruitful—pollen from the same tree or a different tree of the same variety can effectively induce fertilization.

Self-unfruitful—pollen from the same tree or a different

tree of the same variety is incapable of inducing fertilization because a biochemical antagonism between pollen and style renders pollen tubes incapable of growing down the styles of flowers of the same variety.

Cross-pollination—transfer of pollen from the anthers of one variety to the stigmas of another; cross-pollination is necessary when a variety is self-unfruitful.

Cross-compatible—two varieties are capable of effectively pollenizing and fertilizing each other.

Cross-incompatible—a variety is not receptive to pollen of another variety.

Fertilization—union of sperm and egg to initiate the development of a seed.

Flower Structure

Apple flowers (Fig. 1) and flowers of other fruits have four major parts: pistil (ovary, styles, and stigmas combined), stamens (anthers and filaments), petals and calyx (sepals combined). Each apple flower has about 20 anthers. After flowers are fully opened and under dry, sunny conditions, the anthers dehisce or pop open to expose their pollen. Typically an anther produces about 3,500 pollen grains; each flower about 70,000 pollen grains, though the number is highly variable for different varieties. A pollen grain is about 1/1,000 inch in diameter. Each pistil contains an ovary at its base. The sugary, sticky tops (stigmas) of the pistil receive the pollen. Each apple flower has five stigmas and five styles which join five locules or seed cavities at the base (ovary) of the pistil. Each locule generally contains two seeds. There are often 10 seeds per apple, though certain varieties such as Jonagold may have only 3 or 4 and Northern Spy sometimes has as many as 20. It is important to have at least one seed per locule for smooth fruit

development. Thus, the normal apple flower which produces 70,000 pollen grains, theoretically, needs only 10 pollen grains from another variety to set a full complement of seeds. However, fruit set is enhanced by providing massive quantities of foreign pollen.

Unusual Flower Structure of Delicious

Unlike the flowers of most varieties, Delicious flowers have stamens arranged in an upright position so that bees are able to reach into the nectary from the side without rubbing over the stigmas. Thus, a bee may visit a Delicious flower and completely fail to leave any foreign pollen on the stigmas and also fail to pick up any Delicious pollen. This partially accounts for the low yields of Delicious sometimes obtained in northeastern United States. Delicious requires better provision for cross-pollination than most other varieties; a pollenizer row in the orchard may be needed next to every Delicious row.

Fertilization of the Apple Egg

After pollen from a suitable variety is deposited on the sticky stigmas, pollen grains germinate on the five stigmas (Fig. 2A), sending out many pollen tubes (Fig. 2B) which penetrate downward through the styles and eventually reach the ovules (Fig. 2C). The pollen tube carries the male gametes, two sperms (Fig. 2B), one of which fertilizes an egg (potential seed) in the ovary (Fig. 2C). The new embryo begins to develop into an apple seed. Fertilization is usually necessary for fruit development to begin.

Fertilization here refers to the process of the sperm joining with the egg to initiate seed development inside the apple flower; this fertilization is to be clearly distinguished from the application of chemical fertilizers to the orchard floor.

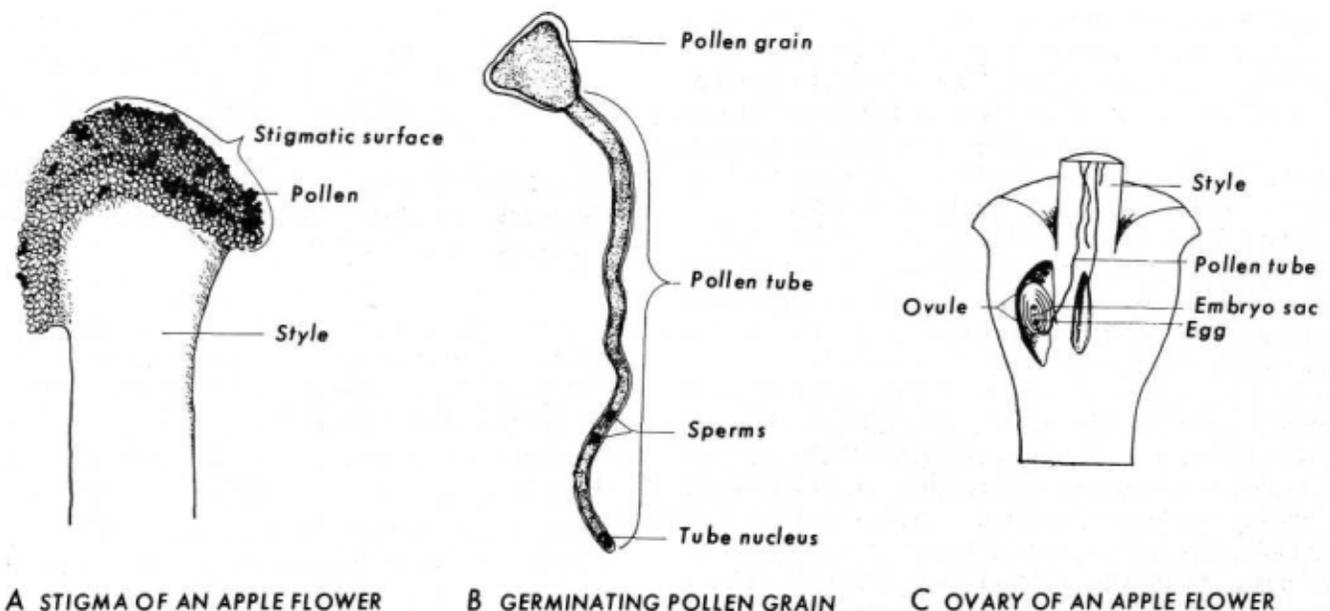


Figure 2.—Pollination and fertilization in the apple flower. Enlarged 50-100 times. After MacDaniels and Heinicke. 1929. *Pollination and other factors. Cornell Bul. 497, p. 56.*

Seed initiation causes hormone production which causes the ovary walls to grow into a fleshy apple fruit. If cross-pollination does not occur, fertilization and seed initiation do not occur, and the apple flower dries up and drops off without setting a fruit. Fruits rarely develop without seeds. When there are fewer than three seeds, fruits usually drop. Fruits with many seeds are generally larger and more uniform in shape than those with few seeds.

Misshapen Apples

Lopsided and misshapen McIntosh or Idared fruits often result from inadequate pollination. When pollen from another variety is deposited on only two or three of the five stigmas of the flower, seeds will develop only in those two or three locules, and none will develop in the unpollinated locules. The one sided presence of seeds may cause the fruit to develop normally only on the pollinated side, resulting in the fruit having unequal segments.

Pollen Does Not Influence Fruit Flavor

Contrary to popular belief, the variety of foreign pollen has no effect on the color or flavor of the fruit which develops from the pollinated flower. For example, Golden Delicious pollen on McIntosh flowers does not cause McIntosh fruits to be conic in shape, yellow in color, or sweet in flavor. McIntosh fruits will always be characteristically McIntosh, without any detectable effects from the pollen except to cause the flower to set a fruit. On the other hand, in the next generation, if the seeds of the McIntosh are planted, the resulting seedlings will be different with different pollen sources, such as Golden Delicious or Northern Spy.

Late Spring Frosts Can Kill Apple Blossoms

Apple blossoms are killed at about 27F, but there are varietal differences. In general, McIntosh and Idared blossoms are more cold hardy than those of some other varieties. Delicious and Empire blossoms are especially tender to frosts, and crops of these two are sometimes drastically reduced by a light frost. Blossoms of spur Delicious are said to be hardier than those of nonspur Delicious. Early bloomers are hit more frequently than late bloomers because killing frosts are more apt to occur in the early part of the bloom season. Sometimes early bloomers have already formed little apples before a frost hits. These little fruits will endure more frost than open blossoms, but frost rings in the form of russeted skin may develop on the fruits.

Cold Weather Damage to Blossoms

Cold periods just before flower opening can injure ovules and prevent fruit set.

Later, during the first 7 to 10 days following bloom, cold weather can also kill young fruits even though good pollination had properly occurred during bloom. Although there are varietal differences, pollen will fail to germinate below 41F, and pollen tube growth is extremely slow below 51F. Thus, in some situations, temperatures could be warm

enough for bee flight (65F) to ensure good pollination, but if it then turns cold, even with good pollination, pollen tubes would fail to grow. No fertilization could occur and there would be little fruit set. However, even in most cold springs, there will be occasional brief warm periods in which both bee flight and pollen tube growth can occur. It is in bad seasons that the presence of nearby pollen sources are most beneficial. Growers sometimes use heaters, overhead sprinklers, or wind machines in orchards during bloom to prevent frost damage.

Excessively high temperatures after bloom can also impair fruit set.

June Drop

Despite good provision for cross-pollination, a high proportion of apple flowers will drop off during the June drop. This is because an excessive fruit set creates an internal physiological competition for hormones and food reserves; self-thinning takes place. Indeed, in commercial orchards, it is generally beneficial that most flowers do fail to set fruits because there would otherwise be an overset.

CULTURAL PRACTICES FAVORING GOOD SET

Only 8 Per Cent Set of Flowers Needed

A mature standard apple tree with a heavy bloom may have as many as 100,000 flowers. Only a small portion of these, perhaps 10 per cent of the flowers opening, will eventually develop into fruits. Because of competition for food reserves, 90 per cent may fall off even if they had been adequately pollinated. Thus, satisfactory pollination of a flower may or may not lead to eventual fruit set. Even if only a quarter of the flowers on a heavily blooming tree did set fruits, the tree would greatly overcrop, resulting in small unmarketable fruits. A set of 1 flower in 20 will often be sufficient to produce a good yield. More set, perhaps 15-20 per cent, is needed on trees with sparse bloom.

Flower buds are formed during the summer previous to their unfolding into blossoms. Thus, bloom density is often dependent on the past health and cropping of the tree. The amount of bloom can sometimes be increased the previous summer by increased exposure of leaves to the sun, branch bending, trunk ringing, or alar sprays. Alar spray increases bloom the following spring but does not necessarily increase fruit set. A slight overset may be desirable since thinning sprays after bloom can regulate proper cropping density.

Cross-pollination by Honey Bees

Apple pollen is usually carried from one apple variety to another by honey bees. They do not purposely carry it for the apple grower or for the apple tree, but they inadvertently carry pollen on their bodies while they are foraging for nectar or pollen. Some bees collect only pollen which can be stored as food, while others collect only nectar which has been secreted from the nectaries just above the ovaries of

the flowers (Fig. 1). Pollen gathering bees do more pollinating than nectar gathering bees. Honey bees usually do not collect large surplus supplies of honey for storage in the hive during apple bloom. Their use in orchards is beneficial mainly to the grower for increasing fruit set, not making honey. They accidentally rub against the sticky stigmas of the flowers and deposit some foreign pollen. Pollen will cling to the bee's body from one visit to the orchard, be carried back to the hive, and out to the orchard again. Also, they can pick up pollen by rubbing against other bees. A bee will carry about 100,000 pollen grains on her body, and she will visit 10 or 15 flowers per minute or about 5,000 flowers per day. Bees do not fly over wide areas of the orchard but to just a few trees in each flight. Their flight is much reduced below 65F and it stops below 55F. Honey bees do 90 per cent of apple pollination; solitary bees, wild bees, and bumble bees do the rest.

One Hive Per Acre

Even when proper pollinizer varieties are accurately placed in the orchard, bringing in honey bees may still be necessary. Bees produce their most striking results in seasons having only a few hours of favorable weather during bloom. It is during these bad seasons that apples are usually scarce and bring the highest prices.

Apple blossoms produce more nectar than most fruits and are very attractive to bees. For this reason, honey bees are efficient transferers of pollen.

One strong hive of honey bees is needed for each acre of apple orchard. Bees should be brought into the orchard just as bloom begins. One hour of good bee flight might be sufficient to set a good crop.

Hives in groups of three to five loaded on pallets which can be picked up with a tractor's forklift have proven to be more efficient than single colonies through the orchard. When hives are grouped together in this manner, the bees are more competitive in staking out a claim and are therefore more active in pollinating. Remove hives from the orchard as petals are beginning to fall from the late blooming varieties. Bringing hives into the orchard will be of little benefit if the trees are suffering from poor drainage, nutritional deficiencies, or severe insect and disease damage.

Hive inserts for which apple pollen can be purchased and when placed in the path of the bees dust the bee with pollen, but this is not necessarily recommended.

Dandelions blossom at the same time as apples and should be sprayed with 2,4-D before bloom to reduce their competition. Toxic insecticide sprays in the orchard during bloom can kill bees and can have a very damaging influence on colony strength. Do not use insecticides during bloom.

Wild Bees for Apple Pollination

Because today's honey prices are so high, bee keepers are sometimes reluctant to rent out their hives for apple orchard pollination. The use of a wild bee may help over-

come this shortage. In Utah, the United States Department of Agriculture has been experimenting with *Osmia lignaria*. This wild bee may be superior to the honey bee because it will fly and pollinate apples in cooler and damper weather which is so characteristic of bloom season weather in the Northeast.

Nitrogen Fertilization Aids Fruit Set

Cultural practices which result in strong spurs with a good supply of stored foods will increase fruit set. Apple flowers set fruits better if trees have a good supply of nitrogen at bloom time, although too much nitrogen causes too much vegetative growth and loss of fruit bud differentiation. Nitrogen fertilizer applied just as the snow finishes melting in late April and an urea spray at the pink stage of bloom cause greater retention of flowers for fruit set. Proper pruning in winter is beneficial to fruit setting. Trees which make weak growth the previous summer or were seriously injured by insect attacks may fail to set good crops even with prolific blooming. Although starved trees often blossom profusely, the flowers can be very weak and difficult to set. This is the reason why abandoned orchards may blossom heavily but set very little crop.

Spray Schedule May Affect Variety Layout

Rome and Golden Delicious are both late bloomers and will effectively pollinate each other. However, their spray requirements may differ. Golden Delicious may require a captan schedule to prevent skin russet development, and in a Rome orchard, this might be difficult.

Captan sprays can kill pollen of Delicious but not McIntosh pollen. Lime sulfur or wettable sulfur for scab control can reduce set.

Topgrafting of Pollen Source Varieties

If an orchard has not been provided with cross-pollination at planting time, scions of spur Winter Banana or some other good pollen source variety can be topgrafted onto trees of the main variety. The fruits of Winter Banana have no market value. A pollen source can be introduced into an orchard more quickly by topgrafting than by planting new young trees. Be careful not to remove the pollen source grafts during routine orchard pruning operations.

Bouquets in the Orchard

If an orchard is old enough for flowering and no provision whatsoever has yet been made for cross-pollination from another variety, bouquets of flowers of an appropriate pollen variety can be brought in and placed in water during the bloom season. Fifty-five gallon metal drums cut cross-sectionally through their middles make good water containers about 18 inches deep. Several branches which are 2 inches thick at their bases are cut from trees of the pollen source variety and are placed in the half drums just as the first blossoms are beginning to open. Bouquets are placed throughout the orchard; the more, the better, at least one bouquet per every four orchard trees. The use of bouquets is a poor substitute for pollinizer trees planted in the

orchard and should be considered only as a temporary, make-shift pollination system.

FEATURES OF A GOOD POLLEN SOURCE VARIETY

Most Diploid Apples Produce Adequate Pollen

Some varieties of apple produce more pollen than others. Delicious and Golden Delicious are among the most prolific pollen producers. Only about 50 per cent of the pollen produced by McIntosh is viable. However, quantity of pollen produced is of little importance because nearly all diploid varieties produce a thousand times as much pollen as is needed. Winesap is one of the few diploid varieties which does not produce viable pollen. Quality of pollen is as important as the amount.

Triploids have three sets of chromosomes instead of the two sets carried by diploid varieties. Triploid varieties do not produce good pollen. When the cell nucleus in the triploid pollen grain divides to produce two sperm cells, the three sets of chromosomes rarely divide evenly, and the sperm carries more or fewer chromosomes than the usual 17. Because of this abnormal cell division, pollen produced is not viable. However, triploid varieties do produce normal fruits. They must be pollinated with good viable pollen from normal diploid pollen sources. Thus, it is necessary to have a diploid pollenizing variety in the orchard where a triploid variety is being grown, and in addition, it is necessary to include a second diploid variety to pollinate the pollenizing variety. In orchards where triploids are grown, at least three varieties must be planted if fruit production is desired from all varieties.

Some common triploid varieties are Gravenstein, Baldwin, Rhode Island Greening, Mutsu, Stayman, Tompkins King, Jonagold, and Spigold.

Cross-incompatible Varieties

Only a few apple varieties fail to fertilize each other because of genetic cross-incompatibility. Three such cases are: Golden Delicious pollen cannot fertilize Jonagold; Cortland and Early McIntosh cannot fertilize each other; Delicious and Melrose cannot fertilize each other.

Sports are Cross-incompatible

The several red sports or spur types of a variety will not cross-pollinate each other. For example, Delicious, Starkrimson, Oregon Spur Delicious, Topred Delicious, Redchief, or any other Delicious sport will not effectively pollinate each other. Similarly, Macspur will not pollinate any of the other McIntosh sports. The same is true with any of the other varieties which have sports, such as Rome, Golden Delicious, Northern Spy, and others. However, any of the McIntosh will pollinate any of the Delicious and vice versa.

Biennial and Nonprecocious Varieties

Spring frosts or improper orchard management can

throw almost any variety into a biennial cycle of bearing. This could mean that in the pollenizer's "off" year, there would be insufficient pollen to pollinize the main variety, and the whole orchard will have a light crop even when there had been a heavy bloom on the main variety, and the main variety itself would become biennial. Puritan, Early McIntosh, Yellow Transparent, and Wealthy are strongly biennial. Strongly alternate bearing varieties such as these should not be planted as the only pollenizing variety. Alternate bearing can be partially controlled with the use of thinning sprays.

Blooming at a young age is important. The very non-precocious Northern Spy/seedling combination may require 12 years to produce the first bushel of fruit on a tree. Even though Northern Spy has good pollen, it should not be planted as a pollen source for young croppers such as Golden Delicious. Other varieties which fail to bloom at a young age are Wayne and Yellow Newtown.

Bloom Period Varies from Year to Year

As every grower knows, apples can bloom in early May as they did in the early springs of 1970 and 1977, or not until late May as in 1971 and 1972. In fact, the bloom date for one variety will vary more from year to year than the sequence of bloom of several varieties in the same year. For example, in Table 1, the average range between the earliest bloomer, Idared, May 15, to Rome, May 20, was only 5 days. Differences in bloom dates for different varieties are much greater in southern states than they are in "the Northeast. But within a single variety, McIntosh bloomed on May 2 in 1977 but not until May 25 in 1966, a range of 23 days in the different years. Whether it is an early or late spring, varieties generally remain relatively constant with respect to each other; i.e., early blooming varieties are early bloomers in both kinds of seasons. Sometimes, however, the different varieties may bloom at slightly different times relative to each other, depending on different weather patterns. Bloom time near the shores of the Great Lakes is several days later than bloom a few miles away from the lakes. Young trees bloom a day or two later than mature trees of the same variety.

Duration of Bloom Period

Individual blossoms on an apple tree may be open for about 5 days, but some of its blossoms may be open for a 7-to 15-day period, depending on the weather. Flowers on lateral buds borne on 1-year shoots bloom later than flowers on spurs. For this reason, late blossoms on 1-year shoots may escape late spring frosts, while most other early blossoms could be killed.

Blossom Time of Apple Varieties

The most important apple varieties being planted in New York State are listed by time of bloom in Table 1. These dates are averages of 13 years of data. It is most important that this information be taken into consideration in planning for pollination in a new orchard. If an early blooming variety

is desired as the main variety, the pollinizer chosen should preferably also be an early blooming sort or not later than midseason to give adequate overlap of bloom every year. In most years, there may be sufficient overlap of bloom between early and late bloomers to give adequate fruit set, but in 1 year in 10, there may be no overlap between early and late bloomers.

Table 1.—Average full bloom (80% of flowers open) of 31 important New York State apple varieties at Geneva, New York. Mostly 13-year averages, 1961-1973.

		Nearest even date
Early bloom	Idared	May 15
	McIntosh	16
	Twenty Ounce	16
	Empire	16
	Jonamac	16
Midseason	Lodi	17
	Milton	17
	Cortland	17
	Akane	17
	Spartan	17
	Jonathan	17
	Julyred	17
	Jerseymac	17
	Melrose	17
	Tydeman Early	17
	Viking	18
	Delicious	18
	Vista Bella	18
	Burgundy	18
	Macoun	18
	Stayman*	18
	Paulared	18
	Mutsu*	18
Monroe	18	
Prima	18	
Jonagold*	18	
Late bloom	Rhode Island Greening*	19
	Golden Delicious	19
	Spigold*	19
	Northern Spy	20
	Rome	20

*Triploid, cannot serve as pollen source.

Pollen Variety Should Bloom Earlier than Main Variety

Best fruit setting is obtained when the pollen variety blooms a day or two earlier than the main variety. For example, Empire, an early bloomer, makes a better pollen source for Cortland, a midseason bloomer, than Cortland makes for Empire (Table 2). This is because flowers which are pollinated early have more available time to be fertilized.

Suggested Pollen Source Varieties

For **Delicious**, including spurs and red sports, use Empire, Spartan, Cortland, Prima, Jonamac, Jonathan, Tydeman, or almost any early or midseason variety, except triploid varieties and Melrose, which is cross-incompatible with Delicious.

McIntosh, including spurs and red sports. Idared, Cortland, Empire, Delicious, Spartan, Jonathan, Julyred, Tydeman, Milton, Vista Bella, Lodi.

Idared. McIntosh, Cortland, Empire, Delicious, Spartan, Jonathan, Milton, Tydeman, Julyred, Vista Bella, Lodi, Paulared.

Rome, including spurs and red sports. Golden Delicious, Delicious, Melrose, Macoun, Northern Spy, Prima, Paulared.

Empire. Cortland, Delicious, McIntosh, Spartan, Jonamac, Jonathan, Idared, Jerseymac, Tydeman.

Golden Delicious, including spur sports. Spartan, Delicious, Rome, Macoun, Prima, Monroe, Paulared.

Cortland. McIntosh, Idared, Empire, Delicious, Spartan, Jonathan, Twenty Ounce, Jerseymac, Tydeman.

Spartan. Delicious, Empire, Golden Delicious, Cortland, Jonathan, Tydeman, Jonamac, Prima, Twenty Ounce.

Mutsu. (Triploid, needs two pollinizers). Cortland, Empire, Prima, Jerseymac, Delicious, Tydeman, Spartan, Paulared, Golden Delicious, Rome.

Suitable pollen sources for other varieties can be determined from Table 1 by combining varieties that have similar bloom seasons.

Table 2.—Effectiveness of nine important New York State apple varieties as pollen sources for each other.

Main fruiting variety to be pollinated	Pollen Source Variety								
	Early bloom			Midseason bloom				Late bloom	
	Idared	McIntosh	Empire	Cortland	Spartan	Delicious	Mutsu*	Golden Delicious	Rome
Idared	Impossible	V. good	Good	Fair	Fair	Below fair	Impossible	Poor	V. poor
McIntosh	Excellent	Impossible	V. good	Good	Above fair	Fair	Impossible	Below fair	Poor
Empire	Very good	Excellent	Impossible	V. good	Good	Good	Impossible	Fair	Below fair
Cortland	Above fair	Good	Excellent	Impossible	V. good	Good	Impossible	Above fair	Fair
Spartan	Fair	Above fair	V. good	Excellent	Impossible	V. good	Impossible	Good	Above fair
Delicious	Below fair	Above fair	Good	V. good	Excellent	Impossible	Impossible	V. good	Good
Mutsu	Below fair	Fair	Above fair	Good	Very good	Excellent	Impossible	V. good	Good
Golden Delicious	Poor	Below fair	Fair	Good	Very good	Very good	Impossible	Impossible	Very good
Rome	Very poor	Poor	Fair	Fair	Fair	Good	Impossible	Excellent	Impossible

*Mutsu is triploid, does not produce good pollen.

Features of a Good Pollen Source Variety

The variety which is to serve as the pollen source for the main producing variety should have the following attributes: 1) Viable pollen which germinates well, 2) cross-compatibility with the main variety, 3) bloom period overlapping with the main variety, 4) blooming at a young age, 5) annual blooming, and 6) one which is not excessively susceptible to diseases. The fruits of the pollen variety should be enough different in appearance from the main variety so that pickers can distinguish between the two at harvest time and not put both varieties into the same bin. It should be winter hardy. It should produce pollen at relatively low temperatures. Except for crab apple pollenizers, the pollenizing variety should bear good, attractive, marketable fruits.

PLANTING PLANS FOR NEW ORCHARDS

Pollination Arrangements in New Apple Plantings

A minimum of every third tree in every third row is necessary; i.e., one pollenizer tree to every eight trees of the main variety. By this arrangement, every tree is adjacent to a pollen source tree. The use of two or more pollenizing varieties will improve fruit production. Another good arrangement is every fifth row as a pollen source variety. For most varieties, pollenizer trees should not be more than 100 feet apart. However, for Delicious, pollenizer trees should be no more than 50 feet apart; i.e., a pollenizer row every third row. Because of the extra expense in harvesting an odd pollenizer tree, it is usually more practical to plant solid rows of pollenizing varieties, especially if inexperienced harvest labor will be employed. The amount of fruit set on a tree is inversely proportional to the distance from the pollen source tree.

Orchard Layout

To provide for proper cross-pollination, orchards can be laid out as shown in Table 3. In 3a, four rows of one variety are followed by four rows of the other variety. This can be reduced to four rows and one row, depending on what the grower wants, as long as a pollen source is planted at least every 100 feet. Two, three, or four rows of the main variety are followed by one, two, three, or four rows of the pollenizing variety. At least every fifth row must be a pollenizer. At the outside edge of the orchard, not more than two rows of one variety should be planted.

Modern Hedgerow Orchards

Modern, closely spaced hedgerow apple orchards can cause problems for cross-pollination. Honey bees tend to fly up and down the rows, making infrequent flights over the tops of the rows. Studies have shown that an average of two trees standing side by side are visited in each bee flight.

Ornamental Crab Apple Pollen Sources

For convenience of spraying and harvesting, some

Table 3.—Suggested orchard plans to provide for adequate cross-pollination in orchards containing (a) two diploid varieties and (b) two diploid and one triploid varieties.

Row number in orchard	(a) Two diploid varieties	(b) Two diploid or varieties and a triploid variety
1	McIntosh	McIntosh
2	McIntosh	Delicious
3	Delicious	Mutsu
4	Delicious	Mutsu
5	Delicious	Mutsu
6	Delicious	Mutsu
7	McIntosh	McIntosh
8	McIntosh	Delicious
9	McIntosh	Mutsu
10	McIntosh	Mutsu
11	Delicious	Mutsu
12	Delicious	Mutsu
13	Delicious	McIntosh
14	Delicious	Delicious
15	McIntosh	
16	McIntosh	

growers would prefer to have an entire orchard as all one variety. Ornamental crab apple varieties are being tested as pollenizers for single variety commercial orchards. Single variety orchards could be useful in preventing the mixing of McIntosh and Delicious fruits into the same bin. They might be useful in mechanical harvesting where it would be inconvenient to switch varieties in the middle of the orchard. The fruits of some ornamental crabs are less than an inch in diameter and would fall through the harvester slats, causing no problem of variety mixtures. In densely spaced hedgerow orchards, these pollen trees are planted between two already closely spaced main variety trees, giving the ornamental tree no space of its own (Table 3). Crabs are more floriferous than commercial varieties. They can be allowed to develop into densely branched trees so that the proportion of pollenizer trees to main variety trees can be reduced without lowering pollinating efficiency. The crab tree is trained as a narrow upright pole whose purpose is simply to produce a small branch of flowers each spring. One pollen tree is planted between every sixth and seventh tree in the row or about every 48-60 feet, and they are staggered in alternate rows. Orchards of Delicious or Delicious sports should have pollenizer trees more frequently, every fifth tree in the row.

The ornamental variety must be tolerant to viruses because root grafts joining a nearby virus infected main variety tree is certain to cause infection of the ornamental tree. Some varieties of ornamentals which are intolerant of viruses quickly die after becoming virus infected. Furthermore, the ornamental varieties should bloom at the same time or slightly earlier than the main variety. It is best to use two or three ornamental crabs to benefit by differences in bloom dates and bloom densities. Our research shows that the following ornamentals are virus tolerant and early blooming and have induced good fruit sets in 5 years of controlled pollination tests: Manchurian, Pioneer Scarlet,

and Rosedale. We suggest M.26 roots to produce small trees, although M.26 may grow poorly on some droughty or wet soils. These crabs also may be topgrafted into established single variety orchards. Two years will be needed for the grafts to begin producing sufficient pollen on grafts.

POLLINATION OF OTHER FRUITS

Pear Pollination

Pears bloom a few days earlier than apples and therefore are even more apt to be hit by a frost. But the blossoms are fairly cold-resistant and usually not all are killed. Like apples, pear varieties are all self-unfruitful, but most varieties can effectively pollinate most other varieties. However, Bartlett and Seckel are genetically cross-incompatible, and neither can be used as a pollen source for the other. Also, Magness does not produce viable pollen and therefore cannot serve as a pollen source for any other pear variety. Kieffer is sometimes a poor pollen producer and blooms too early to pollinize Bartlett and most other common varieties. Pears will not pollinate apples, and apples will not pollinate pears.

Good pollinizer varieties for Bartlett are Anjou, Aurora, Highland, Maxine, Honeysweet, Clapps Favorite, and Gorham. Bees often work pear bloom only during the first day or even the first few hours after hives are placed in the orchard. Therefore, hives should be brought in early in the morning of the first day that 25 to 50 per cent of the flowers are expected to be open. Two hives of bees are needed per acre of pears.

Dandelion flowers will attract honey bees away from pear flowers; dandelion control with suitable herbicides is probably more important for pears than it is for any other fruit crop.

Peach, Nectarine, Apricot

Most peach and nectarine varieties are self-fruitful; they will pollinate themselves, and solid blocks of a single variety can be planted. The most important exception is J. H. Hale which is self-unfruitful and requires another variety nearby to pollinate it. No bees are needed because peaches normally set too heavy crops and excessive thinning will be necessary.

Apricots bloom before any other fruit. Frost is frequently a serious problem. Some apricot varieties such as Alfred are self-fruitful but others are self-unfruitful; usually two varieties should be planted.

Tart Cherry

Most tart cherry varieties are self-fruitful, including Mont-morency, English Morello, Meteor, and Northstar. St. Medard, an early bloomer, is self-unfruitful and may need sweet cherry to pollinate it. Most tart cherries bloom later than sweet cherries and therefore cannot be used as a pollen source of sweet cherries. Honey bees in the tart cherry orchard during bloom will greatly increase fruit yields.

Sweet Cherry

In the Northeast, most sweet cherry varieties bloom at about the same time. Sweet cherry varieties have a very special situation with regard to cross-incompatibilities. Only Stella is self-fruitful, as well as being cross-compatible with all other sweet cherry varieties. All other commercial sweet cherry varieties are self-unfruitful, and provision must be made for cross-pollination in every sweet cherry orchard. Furthermore, there are certain groups of varieties which are mutually cross-incompatible but are cross-compatible with varieties in other incompatibility groups. The genetic reason for two varieties being cross-incompatible is that they possess the same two sterility genes. This means that when pollen of one falls on the stigmas of the other, the pollen tubes fail to grow down the styles because there is a physiological antagonism. Just as in self-unfruitfulness, two varieties having the same sterility genes repel each other.

Sweet cherry varieties are classified into incompatibility groups based on specific sterility genes they carry according to the table below:

- Incompatibility Group I—Black Tartarian, Early Rivers
- II—Venus, Windsor, Van, Merton Bigarreau
- III—Emperor Francis, Napoleon, Bing, Lambert, Compact Lambert, Vernon
- IV—Viva, Victor, Vogue
- VI—Gold
- VII—Hedelfingen
- VIII—Schmidt
- IX—Rainier, Hudson, Giant, Chinook
- XIII—Ulster, Vic

For example, Emperor Francis is cross-compatible with Windsor but cross-incompatible with Napoleon. Hives of bees should be brought into sweet cherry orchards on or before the day the first flowers open. Cross-pollination must happen very soon after blossoms open to insure set.

Plums

European plums—Hexaploid types including prunes and damsons. Some of the European type plums such as Stanley and Italian Prune (Fellenberg) are self-fruitful or partially self-fruitful; all varieties benefit from cross-pollination to insure satisfactory crops. Many European varieties such as De Montfort and Green Gage are self-unfruitful and require cross-pollination to produce any crop. The interplanting of three cross-compatible varieties is recommended when any one variety might have little or no bloom because of biennial bearing or greater sensitivity to winter injury.

Japanese varieties are all self-unfruitful and require compatible pollenizers to insure cropping. Most varieties grown in the Northeast are cross-compatible and will satisfactorily pollinate other Japanese varieties. Formosa provides little or no pollen and must be interplanted with two

other varieties to insure pollen for all. Elephant Heart is difficult to pollinate although it produces good pollen and pollinates other varieties satisfactorily. Red Heart has been the best pollinizer available for Elephant Heart, and the two should be planted together when Elephant Heart is desired.

Japanese-American Hybrids such as Superior and Kahinto are self-unfruitful, and many are also cross-incompatible. The best pollinizers for the hybrids are

Prunus americana varieties such as North Dakota which are compatible and have similar blooming periods.

The three types of plums mentioned are cross-incompatible and will not pollinate each other. That is, European plums must be used to pollinate European plums and Japanese to pollinate Japanese. The Japanese plums bloom early and are diploids so that they will not pollinate the later blooming hexaploid European plums.

