

Pollination and Fruit Set of Fruit Crops



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This information bulletin describes mechanisms of pollination, outlines cultural practices favoring good fruit set, summarizes pollination requirements of apples, suggests orchard planting plans for efficient apple pollination, and summarizes pollination requirements of other tree fruits.

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Mechanisms of Pollination

The transportation of pollen from flowers of one variety to those of another 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 to cause fertilization of the ovules in the flower, 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. This results from a biochemical antagonism that 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 certain other varieties are sometimes self-fruitful under the ideal conditions of the northwestern United States, in the Northeast no apple variety should be considered capable of setting a commercial crop by its own pollen.

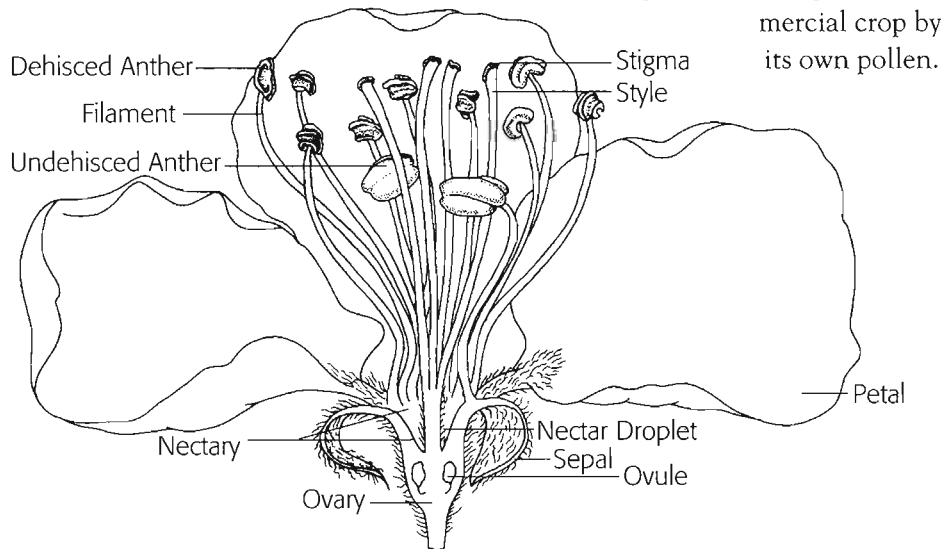


Figure 1. Longitudinal section of an apple blossom, enlarged about 15 times. Some stamens and styles are removed to clarify the diagram.

Baldwin, Rome, and some others, when planted in solid blocks, may set good crops in certain years, but they will crop much more consistently when they are cross-pollinated. In modern orchards where fewer and fewer varieties are grown, it is more important than ever to provide for cross-pollination. A lack of adequate pollination can result in reduced crops or small, misshapen fruits.

GLOSSARY

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

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

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

Diploid—having two sets of chromosomes

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

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

Self-fruitful—pollen from the same tree or from a different tree of the same variety can effectively induce fertilization, such as in most peach varieties

Self-unfruitful—pollen from the same tree or a different tree of the same variety is incapable of inducing fertilization. A biochemical antagonism between pollen and style renders pollen tubes incapable of growing down the styles of flowers of the same variety; all apple varieties are self-unfruitful.

Triploid—having three sets of chromosomes

Flower Structure

Apple flowers (Fig. 1) and those 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, and shed their pollen. Typically, an anther produces about 3,500 pollen grains; each flower produces about 70,000 pollen grains, although this number varies greatly in different varieties. A pollen grain is about $\frac{1}{1,000}$ 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 that join five locules or seed cavities at the base (ovary) of the pistil. Each locule generally contains two seeds. An apple often has 10 seeds, though 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, preferably two, per locule to assure development of normal fruit shape. Though a normal apple flower theoretically needs only 10 pollen grains from another variety to set a full complement of seeds, fruit set is usually enhanced by providing massive quantities of foreign pollen.

Unusual Flower Structure of Delicious

Unlike the flowers of most apple varieties, the stamens of Delicious flowers are arranged in an upright position so that honey bees are able to push their proboscises into the nectary from the side without rubbing over the stigmas at the top of the flower. Thus a bee may visit a Delicious flower and fail to leave any foreign pollen on the stigmas or to pick up any Delicious pollen. This accounts partially for the low yields

of Delicious that are sometimes obtained in the northeastern United States. Delicious requires better provision for cross-pollination than do most other varieties. It may be necessary to provide a row of a pollinizer variety adjacent to every row of Delicious in the orchard.

Fertilization of the Apple Egg

After pollen from a suitable variety is deposited on the five sticky stigmas, pollen grains germinate there (Fig. 2a), sending out many pollen tubes (Fig. 2b) that 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.

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

Seed initiation causes hormone production, which, in turn, causes the ovary walls to grow into a fleshy apple fruit. If cross-pollination does not occur, fertilization and seed initiation do not take place, and the apple flower dries up and drops off without setting a fruit. Fruits rarely develop if no seeds have been initiated. 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.

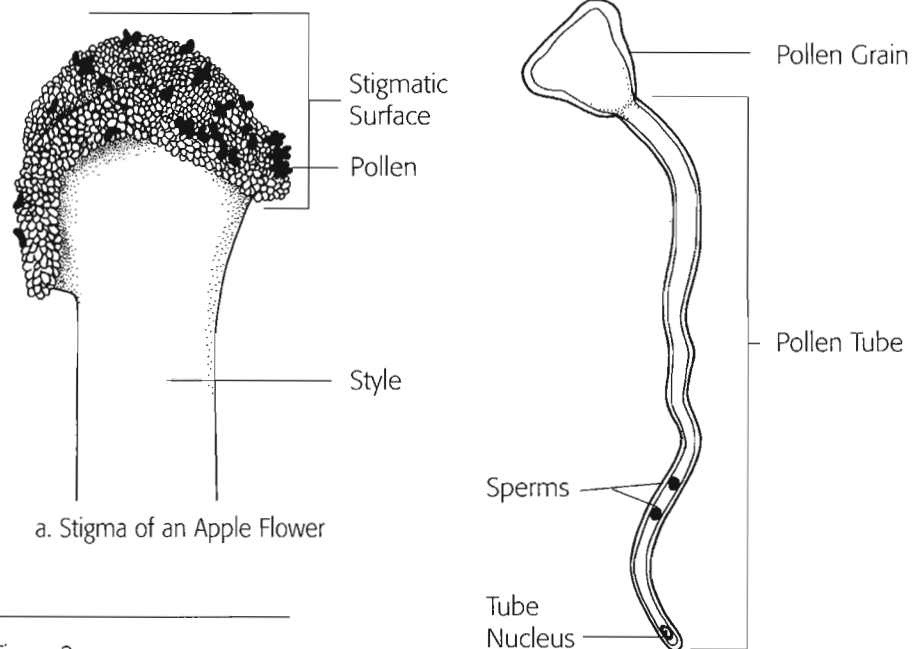
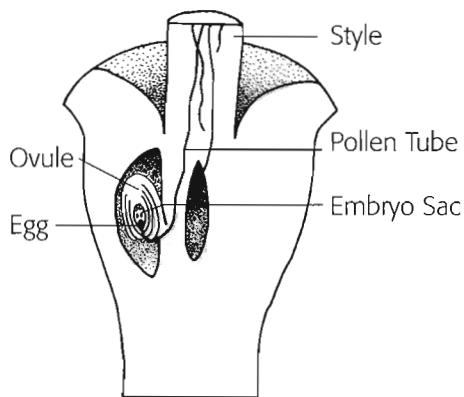


Figure 2. Pollination and fertilization in the apple flower, enlarged 50 to 100 times (after MacDaniels and Heinicke, 1929. Pollination and other factors. Cornell Bull. 497:56).

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. Presence of seeds on only one side may cause the fruit to develop normally only on the pollinated side, resulting in asymmetrical fruit.



c. Ovary of an Apple Flower

Flavor of Fruit

Contrary to popular belief, the variety of foreign pollen has no effect on the color or flavor of the fruit that develops from the pollinated flower. For example, Golden Delicious pollen on McIntosh flowers does not cause McIntosh fruits to be conical 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.

Weather Damage to Apple Blossoms

Apple blossoms are killed at about 27°F; the exact temperature differs by variety. 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 varieties 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. Early bloomers, however, have already sometimes 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 around the circumference of the fruits.

Cold periods just before flower opening can injure ovules and prevent fruit set. Young fruits can be killed by cold weather 7 to 10 days after bloom as well, even if they were properly pollinated during bloom. Although there are varietal differences, pollen will fail to germinate below 41°F, and pollen tube growth is extremely slow below 51°F. Thus even if temperatures are warm enough (65°F) for bee flight to ensure good pollination, cold temperatures later can prevent pollen tubes from growing down the styles of the flowers. Consequently, no fertilization can occur and there is little fruit set. Fortunately, even in most cold springs, occasional brief, warm periods will enable both bee flight and pollen tube growth. It is in unfavorable seasons that the presence of nearby pollen sources is most beneficial. Overhead sprinklers, wind machines, and heaters in orchards during bloom are sometimes effective in preventing excessive frost damage.

Excessively high temperatures after bloom (above 85°F) can also impair fruit set.

June Drop

Even with provision for good cross-pollination, a high proportion of apple flowers will fall during the June drop. This self-thinning occurs because an excessive fruit set creates an internal physiological competition for hormones and food reserves. Indeed, in commercial orchards, it is generally to the grower's advantage when most flowers fail to set fruits because there would otherwise be an overset.

Cultural Practices Favoring Good Fruit Set

Percentage of Flowers That Need to Set

A mature standard apple tree with a heavy bloom may have as many as 100,000 flowers. Only a small portion of these flowers, perhaps 8 to 10 percent, will eventually develop into fruits. Because of competition for food reserves, 90 percent may fall off even if they were adequately pollinated. Even if only one-quarter of the flowers on a heavily blooming tree proceeded to 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 to 20 percent, is needed on trees that have sparse bloom.

Flower buds are formed during the summer before the spring in which they unfold into blossoms. Thus density of bloom often depends on the past health and cropping of the tree. The amount of bloom can sometimes be augmented by taking the following steps the previous summer: increasing exposure of leaves to the sun; branch bending; trunk ringing; and providing sufficient water, proper fertilizer applications, or both. A slight overset may be desirable because thinning sprays after bloom can be used to regulate cropping density.

Cross-Pollination by Honey Bees

Honey bees usually carry apple pollen from one apple variety to another. Contrary to popular belief, bees do not exist solely to carry pollen for the apple grower or the apple tree; rather, they inadvertently carry pollen on their bodies while they are searching for nectar or pollen. Some bees collect only pollen, which can be stored as food; others collect only nectar that has been secreted from the nectaries just above the ovaries of the flowers (Fig. 1). Pollen-gathering bees do more pollinating than those that are gathering nectar. Honey bees usually do not collect large surpluses of honey to store in the hive during apple bloom. Their use in orchards is beneficial mainly to the grower for increasing fruit set, not for making honey.

Honey bees inadvertently rub against the sticky stigmas of the flowers and deposit some foreign pollen. Pollen clings to the bee's body while she is visiting the orchard, then she carries it back to the hive, and then out to the orchard again. Bees also pick up pollen by rubbing against other bees inside the hive. 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 65°F and it stops below 55°F. Honey bees are responsible for 90 percent of apple pollination; solitary



bees, wild bees, and bumble bees may also do some pollinating.

Even when proper pollinizer varieties are accurately placed in an orchard, it may still be necessary to bring honey bees into the orchard. Bees produce their most striking results in seasons that have 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.

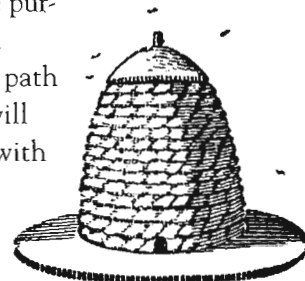
Apple blossoms are very attractive to bees because they produce more nectar than most other kinds of fruit at that season. For this reason, honey bees are efficient transferers of pollen.

Number of Hives Required

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

Groups of three to five hives loaded on pallets that can be picked up with a tractor's forklift have proven to be more efficient than single colonies placed throughout the orchard. When hives are grouped together in this manner, the bees are more competitive in staking out their own territory and are therefore more active in pollinating. Remove hives from the orchard as petals are beginning to fall from the latest-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, when placed in the path of the bees, will dust the bee with pollen, but the use of



such inserts is not necessarily recommended.

Dandelions bloom at the same time as apples and should be controlled before bloom to reduce their competition. Toxic insecticide sprays in the orchard during bloom can kill bees and severely weaken colonies. Do not use insecticides during bloom.

Use of Wild Bees for Apple Pollination

Because today's honey prices are so high, beekeepers are sometimes reluctant to rent their hives for apple orchard pollination. The use of wild bees may help overcome this shortage. In Utah, the USDA has been experimenting with *Osmia lignaria*. This wild bee may be superior to the honey bee because it will fly and pollinate apples in the cool, damp weather that is so often characteristic of bloom season in the Northeast.

Nitrogen Fertilization

Cultural practices that result in strong spurs with a good supply of stored foods will help to ensure good fruit set. In particular, a good supply of nitrogen at bloom time is important for setting fruits, although too much nitrogen causes excessive vegetative growth and reduced fruit bud formation later in the season. When the trees are low in nitrogen status, a urea spray applied at the pink stage of bloom may help to increase the nitrogen content of the flowers and prepare them for fruit setting.

Flower quality depends on a proper balance of all of the essential elements as determined by leaf analysis. An adequate supply of boron is required for normal development of ovules and pollen grains, pollen germination, and normal growth of pollen tubes. Proper levels of zinc and copper, which are deficient in some New York orchards, are

especially important for good fruit set. Proper pruning in winter is also beneficial. Trees that grew weakly the previous summer or were seriously injured by insects or diseases may fail to set good crops even with prolific blooming. Although starved trees often blossom profusely, their flowers can be very weak and incapable of setting fruit. This is why abandoned orchards may blossom heavily but set very little crop.

Effect of Pest Management Requirements on Variety Layout

Rome and Golden Delicious are both late bloomers and will effectively pollinate each other. Their pest management requirements may differ, however. Golden Delicious may require a captan schedule to prevent skin russet, but in a Rome orchard the use of stronger fungicides might be desirable.

Captan sprays can kill pollen of Delicious but not McIntosh. Lime sulfur or wettable sulfur applied for apple 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 another good pollen source variety can be topgrafted onto trees of the main variety. The fruits of Winter Banana have no market value and therefore will not be picked at harvest time. 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 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 that are about 18 inches deep. Several floriferous branches that are 2 inches thick at their bases should be cut from trees of the pollen source variety and placed in the half drums just as the first blossoms are beginning to open. Bouquets should be placed throughout the orchard; the more, the better—at least one bouquet per every four trees. The use of bouquets is a poor substitute for pollinizer trees planted in the orchard and should be considered only a temporary, makeshift pollination system.

Pollen Sources

Diploid versus Triploid Varieties

Nearly all diploid varieties produce a thousand times more pollen than is needed. Delicious and Golden Delicious are among the most prolific, whereas only about 50 percent of the pollen produced by McIntosh is viable. Winesap is one of the few diploid varieties that does not produce viable pollen. Quality of pollen is as important as amount.

Triploids have three sets of chromosomes instead of the two sets carried by diploid varieties. When the nucleus in the triploid mother cell divides to produce two sperm cells, the three sets of chromosomes rarely divide evenly and the sperm carries more or fewer chromosomes than the normal 17. Because of this abnormal cell division, pollen from triploids is not viable.

Remember

- Triploid varieties do not produce good pollen and thus cannot serve as sources of pollen for other varieties.
- Triploids do, however, produce good fruits and therefore must be pollinated by viable pollen from a diploid variety.

It is necessary to have a diploid pollenizing variety in the orchard where a triploid variety is being grown; a second diploid variety is required to pollinate the pollenizing variety. In orchards where triploids are grown, at least three varieties (one triploid and two diploids) must be planted if fruit production is

desired from all the varieties in the orchard.

Common triploid varieties include 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. For example, Golden Delicious pollen cannot fertilize Jonagold; Cortland and Early McIntosh cannot fertilize each other; Delicious and Melrose cannot fertilize each other. In addition, the several red sports or spur types of a variety will not cross-pollinate. 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 of all varieties that have sports, such as Rome, Golden Delicious, and Northern Spy. Any McIntosh will pollinate any Delicious, however, 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 not be sufficient pollen to pollinize the main variety. The whole orchard would have a light crop even though the main variety had bloomed profusely. The main variety itself

would then be thrown into a biennial bearing habit. Early McIntosh, Yellow Transparent, Wealthy, and others are strongly biennial and should not be planted as the only pollenizing variety. Alternate bearing can be partially controlled with the use of thinning sprays.

Pollen sources should bloom at a young age. For example, the very nonprecocious Northern Spy on seedling roots may require 12 years to produce the first bushel of fruit on a tree. Although Northern Spy has good pollen, it should not be planted as a pollen source for precocious croppers such as Golden Delicious. Wayne, Yellow Newtown, and some others do not bloom at a young age.

Bloom Period

As every grower knows, apples can bloom in early May or not until late May. In fact, the bloom date for one variety will differ more from one year to the next than several varieties differ from each other in the same year. For example, the 13-year average range between the earliest bloomer shown in Fig. 3, Idared (May 15) to the latest, Rome (May 20) may be only five days, but apple bloom can vary as much as three weeks from one year to the next. Within a single variety, for example, McIntosh has bloomed as early as May 2 and as late as May 25, a range of 23 days between the different years.

Whether spring is early or late, varieties generally remain relatively constant with respect to each other, that is, early-blooming varieties bloom early in both early and late bloom seasons. Sometimes, however, the different varieties may bloom at slightly different times relative to each other, depending on weather patterns. Bloom time near the shores of the Great Lakes is several days later than bloom a few miles inland. Young trees bloom a day or two later

Pollen Source Variety

Figure 3. Apple varieties to be used as pollenizers

Variety Planted

	Idared	McIntosh	Twenty Ounce	Liberty	Empire	Jonamac	Cortland	Spartan	Jonathan	Jonafree	Jerseymac	Tydeman Early	Delicious	Gala	Braeburn	Macoun	Ben Davis	Empress	Paulared	Monroe	Fuji	Freedom	Golden Delicious	Northern Spy	Granny Smith	Rome	
Very early bloom																											
Idared		x	x	x	x	x	x	x	x	x	x																
Early																											
McIntosh	x		x	x	x	x	x	x	x	x	x	x	x	x	x												
Twenty Ounce	x	x		x	x	x	x	x	x	x	x	x	x	x	x												
Liberty	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x											
Empire	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x										
Jonamac	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x								
Midseason bloom																											
Cortland	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x							
Spartan	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x			
Jonathan	x	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x			
Jonafree	x	x	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x			
Jerseymac	x	x	x	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x			
Tydeman Early	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x			
Delicious		x	x	x	x	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x			
Gala		x	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x			
Braeburn		x	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x			
Macoun		x	x	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x			
Stayman*		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x			
Ben Davis		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x	x	x	x			
Empress		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x	x	x			
Paulared		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x	x			
Mutsu*				x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Monroe				x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x	x	x	x
Jonagold*					x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x
Late bloom																											
Rhode Island Greening*					x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Fuji									x	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x	x	x
Freedom									x	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x	x
Golden Delicious									x	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x	x
Spigold*									x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Very late bloom																											
Northern Spy									x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x	x
Granny Smith									x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x
Rome									x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		

*Triploid, cannot serve as pollen source

than mature trees of the same variety. Blossoms from lateral buds on one-year-old twigs bloom later than those from buds on spurs that develop along the sides of twigs that are two years old or older. Differences in bloom dates for different varieties are much greater in southern states where temperatures warm gradually than they are in the Northeast where temperatures may reach 80°F the week after winter ends.

Duration of Bloom Period

Individual apple blossoms may be open for about 5 days, but the entire bloom period for the tree may range from 7 to 15 days, depending on the temperature. Flowers on lateral buds borne on one-year shoots bloom later than flowers on spurs. For this reason, late blossoms on one-year shoots may escape late spring frosts, when most other early blossoms from spurs have been killed.

Blossom Time of Apple Varieties

The most important apple varieties being planted in New York State are listed by time of bloom in Figure 3. This information must be considered when planning for cross-pollination in a new orchard. If an early-blooming variety is desired as the main variety, the pollinizer chosen should preferably also bloom early or no later than midseason to give adequate overlap of bloom every year. In most years, overlap of bloom between early and late bloomers may be sufficient to give adequate fruit set, but in one year in 10, there may be no overlap.

Suggested Pollen Source Varieties

Delicious (including spurs and red sports)—Empire, Spartan, Cortland, 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, Tydeman

Idared—McIntosh, Cortland, Empire, Jonamac, Spartan, Jonathan

Rome (including spurs and red sports)—Golden Delicious, Delicious, Macoun, Northern Spy, Paulared

Empire—Cortland, Delicious, McIntosh, Spartan, Jonamac, Jonathan, Idared, Jersey mac, Tydeman

Golden Delicious (including spur sports)—Delicious, Rome, Macoun, Monroe, Paulared

Cortland—McIntosh, Idared, Empire, Delicious, Spartan, Jonathan, Twenty Ounce, Jersey mac, Tydeman

Spartan—Delicious, Empire, Golden Delicious, Cortland, Jonathan, Tydeman, Jonamac, Twenty Ounce

Mutsu (triploid, needs two pollinizers)—Cortland, Empire, Jersey mac, Delicious, Tydeman, Spartan, Paulared, Golden Delicious, Rome

Suitable pollen sources for other varieties can be determined from Figure 3 by combining varieties that have similar bloom seasons.

Features of a Good Pollen Source Variety

- ✓ Has viable pollen that germinates well
- ✓ Is cross-compatible with the main variety
- ✓ Bloom period overlaps that of the main variety
- ✓ Blooms at a young age
- ✓ Blooms annually
- ✓ Is not excessively susceptible to diseases
- ✓ Is winter hardy
- ✓ Produces pollen at relatively low temperatures
- ✓ Bear good, attractive, marketable fruits (except for crab apple pollinizers)

Blossom Time of Pollen Varieties

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 vice versa (Fig. 3). This is because flowers that are pollinated early have more available time to be fertilized.

In addition, the king (primary) flowers bloom earlier and develop into larger fruits than the side flowers of a cluster.

The fruits of the pollen variety should be different enough in appearance from the main variety that pickers can distinguish between the two at harvest time and not put both varieties into the same bin.

Planting Plans for New Orchards

Pollination Arrangements in New Apple Plantings

One pollinizer tree should be planted for every eight trees of the main variety (a minimum of every third tree in every third row). By this arrangement, every tree is adjacent to a pollen source tree. The use of two or more pollinizing varieties will improve fruit production. Another good arrangement is planting every fifth row as a pollen source variety. For most varieties, pollinizer trees should not be more than 100 feet apart. For Delicious, however, pollinizer trees should be no more than 50 feet apart, that is, a pollinizer row every third row. Because of the extra expense in harvesting single pollinizer trees, it is usually more practical to plant solid rows of pollinizing varieties. The amount of fruit set on a tree is inversely proportional to its distance from the pollen source tree.

Orchard Layout

To provide for proper cross-pollination, orchards can be laid out as shown in Table 1. In column one, 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 the grower's preference, 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 pollinizing variety. At least every fifth row must be a pollinizer. No more than two rows of one variety should be planted at the outside edge of the orchard.

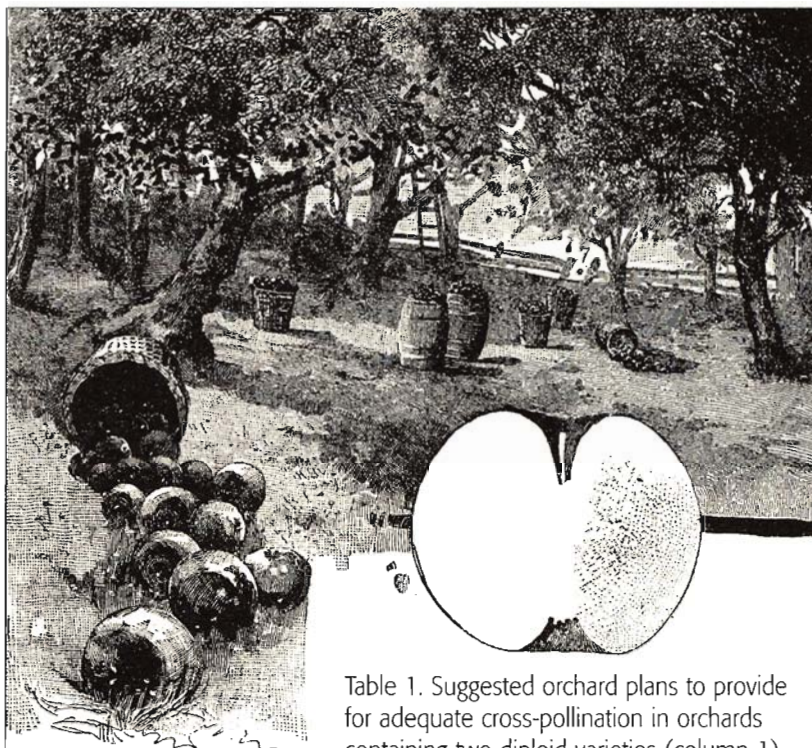


Table 1. Suggested orchard plans to provide for adequate cross-pollination in orchards containing two diploid varieties (column 1) or two diploid varieties and one triploid variety (column 2)

Row number in orchard	Two diploid varieties	Two diploid 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	

High-Density Orchards

Modern, closely spaced, high-density apple orchards in which the trees are allowed to form solid hedgerow-like canopies 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. The solution to this problem is either to increase the proportion of pollinizer trees or the number of beehives.

Ornamental Crab Apple Pollen Sources

For convenience of spraying and harvesting, some growers prefer to plant an entire orchard with a single variety. Ornamental crab apple varieties make this possible. Single-variety orchards are useful in preventing the mixing of McIntosh and Delicious fruits (or any other pollinizing variety) into the same bin at harvest time. Crab pollinizers are also useful when it is inconvenient to switch to another variety in the middle of the orchard while machine harvesting. The fruits of some ornamental crabs are less than one inch in diameter and conveniently fall through the harvester slats, preventing mixing of varieties. In densely spaced hedgerow orchards, crab pollen trees are planted between two already closely spaced main variety trees, giving the ornamental tree no space of its own. Most crabs are more floriferous than commercial varieties. They can be allowed to develop into densely branched trees so that the proportion of pollinizer 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 to 60 feet, and they are staggered in alternate rows. Orchards of Delicious or Delicious sports should have pollinizer trees planted more frequently, every fifth tree in the row.

The ornamental variety must be tolerant to viruses because root grafts that might connect these trees to a nearby virus-infected main variety tree are likely to cause infection of the ornamental tree. Some varieties of ornamentals that are intolerant of viruses die quickly after becoming infected.

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 so as to benefit from differences in bloom dates and bloom densities, thus providing greater assurance of bloom overlap with the main fruiting variety. Manchurian, Pioneer Scarlet, and Rosedale are virus tolerant and early blooming and have induced good fruit sets in five years of controlled pollination tests. Ornamental varieties grafted onto M.26 rootstock produce small trees, although M.26 may grow poorly on some droughty or wet soils. These crabs may also be topgrafted into established single variety orchards. Two years will be needed for the grafts to begin producing sufficient pollen.

Crab apple pollinizing varieties that bloom early, either before or along with McIntosh, include Rosedale, Almey, Manchurian, Chestnut, Dolgo, and Transcendent; some midseason bloomers that bloom along with Delicious are Golden Hornet, Pioneer Scarlet, Snowdrift, Profusion, Simpson 10-35, and Whitney; and late bloomers, along with Golden Delicious, are Frettingham and Halliana. Nursery trees of Manchurian and Snowdrift and some others are widely available from commercial fruit tree nurseries.

Pollination of Other Tree Fruits

Pears

Pears bloom a few days earlier than apples and are thus even more apt to be subject to a frost. The blossoms are fairly cold-resistant, however, and usually not all are killed. Like apples, all pear varieties are self-unfruitful, but most varieties can effectively pollinate most other varieties. One exception is Bartlett and Seckel, which are genetically cross-incompatible: neither can be used as a pollen source for the other. Another is Magness, which does not produce viable pollen and therefore cannot serve as a pollen source for any other pear variety. Kieffer is a poor pollen producer and blooms too early to pollinate Bartlett and most other common varieties. Pears will not pollinate apples and vice versa.

Good pollener varieties for Bartlett are Anjou, Aurora, Highland, Maxine, Honeysweet, Clapps Favorite, and Gorham. Seckel and Highland are good pollen sources to plant in Bosc orchards.



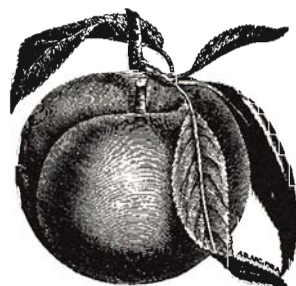
Pear flowers produce less nectar than apple flowers. Bees often work pear bloom only during the first day or even the first few hours after hives are placed in the orchard. Therefore, hives should be brought in early in the morning of the first day that 25 to 50 percent of the flowers are expected to be open. Two hives of bees are needed per acre of pears.

Because dandelion flowers will attract honey bees away from pear flowers, controlling them is probably more important for pears than for any other fruit crop.

Peach, Nectarine, and Apricot

Most peach and nectarine varieties are self-fruitful, meaning that 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 excessive crops and heavy thinning is usually required.

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 Montmorency, English Morello, Meteor, and Northstar. Most tart cherries bloom later than sweet cherries and therefore cannot be used as a pollen source for 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. Stella, Lapins, and Sunburst are self-fruitful as well as being cross-compatible with all other sweet cherry varieties. Most other commercial sweet cherry varieties are self-unfruitful, however, and provision for cross-pollination must be made before the orchard is planted. Furthermore, certain groups of varieties are mutually cross-incompatible but are cross-compatible with varieties in a different incompatibility group. The genetic reason for cross-incompatibility between two varieties is that they possess the same two sterility genes. This means that when pollen of one variety 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 list below. All varieties within a group are cross-incompatible. For example, Emperor Francis is cross-compatible with Windsor but is cross-incompatible with Napoleon.

Incompatibility Groups

- 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

Hives of bees should be brought into sweet cherry orchards on or before the day the first flowers open. Cross-pollination must take place very soon after blossoms open to ensure fruit set.



Plums

European—Prune plums and damson plums are hexaploid, that is, they have six sets of chromosomes. Some European-type plums such as Stanley and Italian Prune (Fellenberg) are self-fruitful or partially self-fruitful; all varieties benefit from cross-pollination to ensure 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—All varieties are self-unfruitful and require compatible pollenizers to ensure 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 ensure 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 pollenizer available for Elephant Heart and should be planted when Elephant Heart is grown.

Japanese-American Hybrids—

Varieties such as Superior and Kahinta are self-unfruitful, and many are also cross-incompatible. The best pollenizers 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 later-blooming hexaploid European plums.





Pollination, the transportation of pollen from flowers of one variety to those of another, is probably the most critical single process in the series of events leading to the production of a good crop of fruit.

This bulletin describes pollination, outlines cultural practices favoring good fruit set, and summarizes pollination requirements of apples and other tree fruits, including pear, peaches, nectarines, apricots, cherries, and plums. It also suggests orchard planting plans for efficient apple pollination.

This bulletin will be useful to commercial orchardists or to anyone who grows fruit trees.

