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POLLINATION REQUIREMENTS of FRUITS and NUTS

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POLLINATION . . .

is one factor influencing the bearing qualities of fruit trees. Lack of pollination may be a cause of nonbearing. Other causes are: lack of vigor; injurious insects and diseases; unfavorable weather at blossoming time; winter injury; and inability of the male germ cells of the pollen to fertilize the female germ cells of the ovule.

THE CALIFORNIA ORCHARDIST . . .

has a pollination problem if he grows almonds, sweet cherries, certain varieties of apples, plums, and pears, or Calimyrna figs. Facilities for cross-pollination must be provided for these fruits. Such facilities may involve interplanting of varieties that will cross-pollinate one another; placing bouquets of bloom from one variety in trees of another variety; grafting in pollinizing varieties; introducing honey bees into the orchard; caprification or use of hormone sprays (Calimyrna fig); or artificial pollination.

In the case of hand pollination—regardless of how pollen is obtained—the process is time consuming and costly. This is especially true in view of the fact that one colony of bees will effectively cross-pollinate an acre of fruit trees in most years if only a minimum number of pollinizing trees are present.

THIS CIRCULAR . . .

deals only with pollination as a factor in nonbearing; it will be assumed that the orchard is planted in a favorable location and that the trees are kept in normal vigor, free from serious insect and disease troubles.

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For an understanding . . .

of the various pollination problems affecting fruit and nut varieties discussed in this circular, it is necessary to describe their pollination status in certain terms, such as self-fruitful, cross-unfruitful, and the like. These terms and their definitions are listed on the two following pages for convenient reference.

A table of contents appears on page 6.

FOR A BETTER UNDERSTANDING . . .

HERE ARE DEFINITIONS

The terminology used to describe the pollination status of fruit varieties has often been inconsistent and vague throughout the literature as well as in the orchard. The terms have been inadequate for distinguishing between certain relationships such as those described below as cross-compatible, intercompatible, cross-incompatible, and interincompatible. The following terms are offered with the hope that they will be more precise in their descriptions of the pollination status of any one variety or combination of varieties.

Pollination: the transfer of pollen to the stigma; or, in a broad sense, the distribution of pollen. Pollination may be accomplished by insects, wind, gravity, water, birds, and artificial methods devised by man. (Pollination experiments and investigations include not only the study of the transfer of pollen, but also studies of fruit setting associated with pollen transfer and fertilization. In any mention of pollination studies and problems, this broader definition will be intended.)

Self-pollination: the transfer of pollen from the anthers of a flower of one variety to the stigma of a flower of the same variety.

Cross-pollination: the transfer of pollen from the anthers of a flower of one variety to the stigma of a flower of a different variety.

Pollinizer: the variety (plant, tree) used to furnish pollen. The male parent.

Fertilization: the union of the male germ cell, contained in the pollen grain, with the female germ cell, or egg, in the ovule.

Fruitful: a plant or variety that sets and matures a commercial crop of fruit.

Unfruitful: a plant or variety that fails to set a commercial crop of fruit and mature it.

Fertility: the ability to set and mature fruit with viable seed.

Sterility: the inability to set and mature fruit with viable seed. This failure may be due to nonfunction of the pollen, the ovules, or both.

Compatible: ability of pollen to develop in the styles and reach the ovules in time to effect fertilization.

Incompatible: inability of viable pollen to develop in the styles rapidly enough to reach the ovule in time to effect fertilization.

Self-fruitful: a variety which sets and matures a commercial crop of fruit with its own pollen. This term would also describe plants which develop commercial crops of parthenocarpic fruit.

Parthenocarpy: the development of the edible fruit without fertilization. Parthenocarpic fruits are seedless.

Self-unfruitful: a variety which is unable to set and mature a commercial crop of fruit with its own pollen (or as a result of parthenocarpic fruit development).

OF THE TERMS USED IN THIS CIRCULAR

Self-fertile: the ability of a variety to produce fruit with viable seed following self-pollination.

Self-sterile: the inability of a variety to produce fruit with viable seed following self-pollination. (Some varieties may be self-fruitful, even though they are self-sterile, because of their ability to produce parthenocarpic fruits.)

Self-compatible: a variety which produces pollen that is capable of developing in the styles and fertilizing ovules of the same variety.

Self-incompatible: a variety which produces functional sex cells but is self-unfruitful because the pollen tubes grow too slowly to reach the ovules in time to effect fertilization. Such a variety may, however, serve as an effective pollinizer for some other varieties. (Some varieties may be self-fruitful, even though they are self-incompatible, because of their ability to produce parthenocarpic fruits.)

Cross-fruitful: one variety, A, is used as a pollinizer for another variety, B, and B produces a commercial crop.

Cross-unfruitful: one variety, A, is used as a pollinizer for another variety, B, and B fails to produce a commercial crop.

Cross-fertile: one variety, A, is used as a pollinizer for another variety, B, and B produces fruit with viable seed.

Cross-sterile: one variety, A, is used as a pollinizer for another variety, B, and B fails to produce fruit with viable seed.

Cross-compatible: the pollen of one variety, A, is capable of functioning in the styles and fertilizing the ovules of variety B. (Variety B, however, may not be cross-compatible with A.)

Cross-incompatible: variety A produces functional sex cells, but its pollen tubes grow too slowly in the styles of variety B to effect fertilization. Variety A may, however, serve as an effective pollinizer for some other varieties. (Variety B may serve as an effective pollinizer for variety A.)

Interfruitful: varieties A and B both produce commercial crops when pollinated by each other.

Interunfruitful: varieties A and B both fail to produce commercial crops when pollinated by each other.

Interfertile: varieties A and B both produce fruit with viable seed when pollinated by each other.

Intersterile: varieties A and B both fail to produce fruit with viable seed when pollinated by each other.

Intercompatible: the pollen produced by either variety of a combination is capable of functioning in the styles and fertilizing the ovules of the other variety.

Interincompatible: varieties A and B are unfruitful when pollinated by each other because the pollen tubes of each variety grow too slowly in the styles of the other to effect fertilization. Either variety may serve as an effective pollinizer for some other varieties.

Effective bloom: the length of time the tree is in conspicuous blossom.

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POLLINATION REQUIREMENTS of FRUITS and NUTS

W. H. GRIGGS

The reasons for nonbearing, from a pollination standpoint, are not all known. Some of them, aside from weather conditions, are incompatibility, imperfection or degeneration of sex organs, slow growth of the pollen tube, and premature or delayed pollination.

The orchardist has a pollination problem with all almond and sweet cherry varieties, with most apple, plum, and pear varieties, and with the Calimyrna fig. Under certain conditions, cross-pollination will also increase the production of some varieties of walnuts, filberts, pecans, chestnuts, and olives. In general, apricots, peaches, and nectarines set well with their own pollen. The Riland and Perfection apricots, however, are both self-incompatible. The J. H. Hale, Halberta, June Elberta, Candoka, and Alamar peaches are also exceptions since they have nonviable pollen and are, therefore, self-unfruitful.

With fruits having a pollination problem, the grower must provide facilities for cross-pollination. In selecting the pollinizers he should consider the following factors: (1) time and coincidence of bloom; (2) amount of pollen produced; (3) germinability (viability) of pollen; (4) commercial value of pollinizer; and (5) regularity of blossoming of the pollinizers used. Varieties that do not blossom at the same time cannot cross-pollinate each other.

Two factors determine the time of bloom: (1) breaking of the rest; (2)

temperatures suitable for growth of particular species and varieties. To break the rest period, deciduous fruit trees require some chilling; the amount varies with the different species and varieties. (See also University of California Extension Circular 179, "Deciduous Orchards in California Winters.") In the Northwest and the East, where there is extended cold weather during dormancy, the rest period is completely broken. This may not occur in most areas of California, where the climate is milder. As a result, blossoming is delayed and bloom is generally extended over a longer period, thus avoiding early spring frosts and favoring pollination and fruit setting. Less cold than normal may, however, retard blossoming excessively, so that certain varieties may be delayed too long for cross-pollination—for example, Bartlett and Winter Nelis pears (fig. 1). In seasons following normally cold winters, these varieties would blossom practically together (fig. 6, p. 21). In the East and Northwest (where the rest period is completely broken), the Bartlett, which starts growth at a lower temperature, blossoms ahead of the Winter Nelis.

After a warm winter many peach, nectarine, apricot, plum, and prune varieties will drop large percentages of their flower buds before the blossoming period. Dropping usually begins the latter part of January and continues through the blossoming period.

Fig. 1.—When the rest period is not sufficiently broken by cold weather, blossoming may be retarded excessively. Thus, varieties that would normally bloom at about the same time do not do so. For example, the photograph above shows, left, a row of Winter Nelis pears past the full bloom stage; the Bartlett trees, right, have not yet blossomed. Under such conditions, these varieties cannot cross-pollinate.

Cool weather occurring after the earlier varieties are in bloom is another climatic condition that may interfere with cross-pollination by delaying later blossoming varieties. This condition occurs in some years with almond, the Texas variety being delayed until after most of the blossoms of Nonpareil have fallen. In most years the bloom of the two varieties will overlap sufficiently to permit cross-pollination.

Role of Insects.—Most fruit trees with showy flowers (fig. 2) require insects to carry the pollen from flower to flower. Honey bees are by far the most important insects for this work. To appreciate the role of the honey bee in pollination, the intimate relationship between the bee and flower in the process of pollination and subsequent fertilization must be understood. The honey bee is admirably designed for the job of pollen carrier, for its body is covered with hairs which make it a veritable pollen duster (fig. 3). Its existence depends

wholly upon the plant's pollen and nectar. Many plants, in turn, depend upon the bee's pollinizing work for their productivity.

With the advent of modern methods of cultivation and the widespread use of insecticides and herbicides, the activity of the native, wild pollinating insects is becoming negligible in many areas. Fortunately, the grower can assure the presence of the honey bee in his orchards. During the blossoming season, he should provide at least one strong colony consisting of four or five frames of brood and bees to cover eight or more frames per hive for each acre of fruit to be cross-pollinated. It is not necessary to distribute the hives singly throughout the orchard. Placing them in groups of eight to 10 is just as effective and facilitates moving them to and from the orchard. Even with self-fruitful varieties like the French prune the activity of honey bees on the blossoms may greatly increase production through better pollen distribution. In an

Fig. 2.—Longitudinal section of a flower that produces a stone fruit. Pollination has occurred. The pollen tube formed by the subsequent germination of a pollen grain carries the two sperms to the embryo sac, where one of them unites with the egg (fertilization). This union results in the production of a seed (embryo) and the development of the ovary into a fruit. (Drawing by R. M. Brooks.)

early experiment it was found that French prune trees enclosed in tents, with and without bees, gave sets of 19.0 per cent and 0.34 per cent, respectively.

Beekeeping, like fruit growing, is a specialty. Although some growers may want to own and operate their own colonies, most will find it advantageous to rent them from established beekeepers. Coöperation between grower and beekeeper is essential for mutual benefit.

Some beekeepers are reluctant to rent their bees to orchardists because there is danger of poisoning the insects with spray chemicals. The grower must accept his responsibility for spraying at a time which is least harmful for bees. The safest

Fig. 3.—Honey bee with collected pollen. (Photograph by J. E. Eckert.)

practice is to bring the bees into the orchard just before the blossoms open and to remove them as soon as the petals fall and before any poisonous sprays are applied. Another way the grower can protect bees is to turn under cover crops in and adjacent to the orchard before applying

poisonous sprays. Bees should be moved farther from the orchard than they range in flight—about 2 miles.

(For further information regarding honey bees, see University of California Extension Circular 100, "Beekeeping in California.")

SPECIAL POLLINATION REQUIREMENTS OF FRUITS AND NUTS

Pollination experiments have been conducted at the University of California since 1915. In the following pages you will find recommendations for specific fruits and nuts, based on the findings of the experiments.

ALMONDS

All commercial varieties of almonds are self-unfruitful under California conditions, and should not be planted in blocks of one variety.

A few pairs of almond varieties are interincompatible—for example, Nonpareil with IXL; Languedoc with Texas; Jordanolo with Harpareil. Hence, the orchardist who wants to grow a pair of these interincompatible varieties should plant at least one other variety as a pollinizer.

Almonds may be classified as early blooming or late blooming. They are listed below in order of blooming sequence. Nonpareil is included in both groups since it occupies a position about midway.

EARLY	
Harriott	California
Jordanolo	Lewelling
Jordan	Princess
Ne Plus Ultra	Peerless
Harpareil	IXL
King	Nonpareil
LATE	
Nonpareil	Texas
Drake	Languedoc
Eureka	Reams
Davey	

The date of bloom depends upon many factors, such as soil, season, and location.

Almond buds have a rather short chilling requirement. They tend to open earlier in northern California than in the southern part of the state where there is more warm weather in late winter and spring to start the buds but less chilling in winter to break their rest periods.

Late winter and early spring weather is the most important factor influencing the blooming sequence of the different varieties. If the winter temperatures stay low enough to keep almonds dormant until late in February, and then warm weather prevails, all of the varieties will bloom close together. A mild winter, on the other hand, followed by intermittent warm and cold days in the spring will cause slow and uneven opening of buds and tend to spread the blooming dates of the different varieties over a long period.

Figure 4 shows the average blossoming dates of certain almond varieties. In general, two varieties may be expected to pollinate each other satisfactorily in most years if their average dates of full bloom are not more than a week apart. Therefore, except in the cases of interincompatibility noted above, any variety in either the "early" or "late" group will usually serve as a satisfactory pollinizer for any other variety in the same list. The blossoming periods of very early blooming varieties, such as Harriott and

FIGURE 4
AVERAGE DATES OF FIRST, LAST, AND FULL BLOOM OF ALMOND VARIETIES
AT WINTERS, CALIFORNIA

Jordanolo, however, may not overlap sufficiently to insure adequate cross-pollination with Nonpareil, IXL, and Peerless in certain seasons. Some almond growers have planted only Jordanolo and Nonpareil because of their commercial value, but from a pollination standpoint this combination is often poor.

Almond blossoms are pollinated by insects, mainly honey bees, with very little pollination accomplished by wind. Crops which may have been attributed to wind pollination were undoubtedly set as a result of pollination by either wild bees or bees from neighboring hives. With almonds, the grower wants the heaviest

fruit set possible because nuts with small kernels are in greatest demand and there is no fruit thinning operation to be considered. Since almond trees blossom early, when the weather may be too cool for great insect activity, more bees and more trees of the pollinizing variety are required for almonds than for later blossoming fruits. There should be at least one row of pollinizers for every three rows of the main variety, and in sections where adverse seasons may occur frequently, it would pay to have alternate rows of the main variety and the pollinizer. At least one strong colony of bees per acre should be supplied, and many

TABLE 1—ALMOND VARIETY COMBINATIONS FOR INTERPOLLINATION*
(Based on compatibility and coincidence of blooming period)

Variety to be pollinated (In order of blooming sequence)	Value of variety as a pollinizer †																	
	Harriott	Jordanolo	Jordan	Ne Plus Ultra	Harpareil	King	California	Lewelling	Princess	Peerless	IXL	Nonpareil	Drake	Eureka	Davey	Texas	Languedoc	Reams
Harriott	0	G	F	G	G	G	G	G	F	P	P	P	P	P	P	P	P	P
Jordanolo	G	0	F	G	G	G	G	G	F	P	P	P	P	P	P	P	P	P
Jordan	F	F	0	F	G	G	G	G	F	F	F	F	F	F	F	F	F	F
Ne Plus Ultra	G	G	G	0	G	G	G	G	G	G	G	G	F	F	P	P	P	P
Harpareil	G	0	G	G	0	G	G	G	G	G	G	G	G	F	P	P	P	P
King	F	G	G	G	G	0	G	G	G	G	G	G	G	F	P	P	P	P
California	F	G	G	G	G	G	0	G	G	F	G	G	G	F	P	P	P	P
Lewelling	F	F	F	G	G	G	G	0	G	F	G	G	G	F	P	P	P	P
Princess	F	F	F	G	G	G	G	G	0	F	G	G	G	F	P	P	P	P
Peerless	F	F	F	G	G	G	G	G	G	0	G	G	G	F	P	P	P	P
IXL	F	F	F	G	G	G	G	G	G	G	0	0	G	F	P	P	P	P
Nonpareil	P	F	G	G	G	G	G	G	G	G	0	0	G	F	P	P	P	P
Drake	P	F	F	F	F	G	G	G	G	G	G	0	G	G	F	G	G	G
Eureka	P	F	F	F	F	F	G	F	G	F	G	G	G	0	F	G	G	G
Davey	P	F	F	F	F	F	G	G	G	G	G	G	G	0	G	G	G	G
Texas	P	P	P	F	F	F	F	F	G	F	G	G	G	G	0	G	0	G
Languedoc	P	P	P	F	F	F	F	F	G	F	G	G	G	G	G	0	0	G
Reams	P	P	P	F	F	F	F	F	G	F	G	G	G	G	G	0	0	G

* Data from Bulletin 346, with supplementary data of G. L. Philp and W. H. Griggs.

† G = good; F = fair; P = poor; 0 = no value.

growers now feel that two or three colonies per acre are needed.

Table 1 summarizes the pollination requirements for almonds. Names at the left indicate the variety, and the names across the top indicate the pollen used. For example, if pollen from the variety Drake were used on a tree of the variety California, a good set would result, as indicated by the symbol G at the point of intersection in the table.

A new almond variety, Davey, was released in September, 1952, by research workers at the University of California in coöperation with workers in the United States Department of Agriculture. One of the strong points in favor of this new variety is that it blooms with Nonpareil and is intercompatible with it. The nuts produced by Davey have light-colored, smooth, thin, well-sealed shells, and kernels that are medium-sized, smooth, and light-colored, with good texture and flavor. The nuts mature early, about the same time as Nonpareil.

APPLES

Table 2 segregates the apple varieties that are grown in California according to their pollination requirements, blooming sequence, and value as cross-pollinizers.

The self-fruitful varieties generally produce larger crops when cross-pollinated. Under most conditions, however, they give commercial crops when planted in solid blocks (self-pollinated). The partly self-fruitful varieties will produce commercial crops in some years without cross-pollination, but better crops will result if provisions for cross-pollination are made. The self-unfruitful varieties cannot safely be planted alone, and should be interplanted with some other variety for cross-pollination.

The blooming periods of two varieties must overlap if cross-pollination is to be accomplished. The time of bloom varies considerably in different sections, and in

different seasons, but the relative order of blooming is usually the same for any one locality.

In general, apple trees require more chilling than do most other fruits, before their buds will open evenly in the spring. Since apple varieties differ in their chilling requirements, mild winters may widen the gap between the blooming dates. High spring temperatures following winters which have been sufficiently cold to meet the chilling requirements will tend to shorten the blooming periods of all varieties. Under these conditions, all but the very early and late blooming varieties will overlap sufficiently. On the other hand, cold spring weather will tend to cause the blooming periods of the early and late varieties to be much more widely separated. In most years, however, varieties that bloom in midseason would overlap with the early and the late blooming ones sufficiently to provide an adequate pollen supply.

Varieties differ in their effectiveness as cross-pollinizers. Those in Table 2 marked with (E) have proved unusually good pollinizers, and generally cause excellent sets of fruit on most other varieties. Those marked with (P) have non-viable pollen and are consequently very poor cross-pollinizers. The remaining varieties in the table, marked with (S), usually serve as satisfactory pollinizers.

Interunfruitful combinations are rare except among closely related varieties and those having infertile pollen. Parent varieties are ineffective as cross-pollinizers for their fruit color mutations ("bud sports"), and the mutations, in turn, are of no value as cross-pollinizers for the parent variety. For example, Delicious is interincompatible with any of its color strains, such as Redwin, Richard, and Starking. An apple orchard planted to a mixture of Arkansas, Rhode Island Greening, Stayman Winesap, and Winesap could not be expected to produce much fruit since these varieties all produce infertile pollen.

TABLE 2—APPLE VARIETIES CLASSIFIED ACCORDING TO SELF-FRUITFULNESS, BLOOMING SEQUENCE, AND VALUE AS CROSS-POLLINIZERS

Usually self-fruitful	Partly self-fruitful	Self-unfruitful
Early blooming		
Early Harvest (S)* Oldenburg (S) Yellow Transparent (E)	Ben Davis (E) Black Ben† Gano Hyslop (crab) (S) Red Astrachan (S) Wagener (E) Whitney (crab) (S)	Arkansas (P) Fameuse (E) Gravenstein (P) Banks Red Gravenstein McIntosh (E) Blackmack Red McIntosh Transcendent (crab) (S) Twenty Ounce (S)
Midseason blooming		
Baldwin (P) Double-Red Baldwin Grimes Golden (E) Wealthy (E) Wealthy Double Red Yellow Newtown (S) Yakima Newtown	Esopus Spitzenburg (S) Golden Delicious (E) Jonathan (E) Blackjon Jonared York Imperial (E) Colora York-A-Red Yorking	Arkansas Black (S) Delicious (E) Redwin Richared Starking Red June (E) Rhode Island Greening (P) Stark (P) Miami Stayman Winesap (P) Blaxtayman Dark-Red Staymared Scarlet Staymared Staymared Tompkins King (P) White Astrachan (S) White Pearmain (S) Winesap (P) Seeando Winesap Winter Banana (E) Yellow Bellflower (S)
Late blooming		
Rome Beauty (E) Red Rome Rome Beauty Double Red Seeando Red Rome		Northern Spy (E) Red Spy

* Explanation of symbols: (E) = excellent cross-pollinizer; (S) = satisfactory cross-pollinizer; (P) = poor cross-pollinizer.

† Fruit color mutations ("bud sports") are indented under parent variety.

Grimes Golden is ineffective as a pollinizer for Arkansas. This is an exception since Grimes Golden is an excellent pollinizer for other varieties and is presumed to be unrelated to Arkansas.

According to the present evidence, based mainly on orchard observations, fruit color mutations of apple varieties have the same pollination requirements and the same value as cross-pollinizers as do their parent varieties.

SWEET CHERRIES

All sweet cherry varieties are self-unfruitful and must be cross-pollinated for satisfactory yields. Not all varietal combinations are fruitful. The following variety combinations are interincompatible and will not produce crops when planted together unless other effective pollinizing varieties are provided:

Early Purple and Rockport; Advance and Rockport; Windsor and Abundance; Napoleon (Royal Ann), Bing, and Lambert; Black Tartarian, Knight's Early Black, and Early Rivers. (Some strains of Black Tartarian may be interfruitful with Knight's Early Black and Early Rivers.)

Further research will undoubtedly show that other variety combinations should be added to this list. All of the important sweet cherry varieties produce good viable pollen. Therefore, with the exceptions noted above, most variety combinations should be cross-fruitful if their blooming periods overlap sufficiently.

From a pollination standpoint, there are evidently different strains of certain cherry varieties. This may be due to the fact that seedlings of these varieties which now exist are so similar to the original varieties that they cannot be distinguished from their parents. There are at least five strains of Black Tartarian which vary greatly in their ability to pollinize the Napoleon. There are also strains of Black Republican which do not respond equally to pollination tests. Most

strains of Black Tartarian and Black Republican are satisfactory pollinizers for Napoleon. The grower should, however, select trees of strains known to be capable of fertilizing the desired variety.

Cherry varieties may be classed as early and late blooming:

EARLY	
Black Heart	California Advance
Black Republican	Chapman
Black Tartarian	Early Purple Guigne
Burbank	Knight's Early Black
LATE	
Abundance	Long Stem Bing
Bush Tartarian	Napoleon (Royal Ann)
Bing	Parkhill
Deacon	Pontiac
Early Rivers	Rockport
Giant	Saylor
Gil Peck	Schmidt
Lambert	Windsor

The blooming periods of the varieties within either group will usually coincide well enough for effective cross-pollination. The blooming periods of Black Tartarian and Black Republican generally overlap well enough with those in the late group for satisfactory cross-transfer of pollen.

Figure 5 gives the average period of effective bloom for the varieties listed above, and Table 3 classifies them according to their value as pollinizers. When planting a sweet cherry orchard, plant more than one variety. If the two or three varieties chosen are in an interincompatible group, an additional variety that is not in the same group should also be planted.

In general, only sweet cherries should be planted for cross-pollination of sweet cherries. Sour cherries, such as Dye-house, Early Richmond, Montmorency, and English Morello, however, may serve as satisfactory pollinizers for sweet cherries in the late blooming group. The blossoming periods of the sour cherries do not usually overlap those of the sweet cherries in the early blooming group

FIGURE 5
AVERAGE DATES OF FIRST, LAST, AND FULL BLOOM OF SWEET CHERRY VARIETIES
AT DAVIS, CALIFORNIA

sufficiently for effective cross-pollination. Duke cherries are not satisfactory pollinizers for sweet cherries.

Gil Peck and Sodus are two relatively new sweet cherry varieties that have been introduced by workers at the New York Agricultural Experiment Station. According to information received from that station, Napoleon, Bing, and Lambert are satisfactory pollinizers for either variety.

SOUR CHERRIES

The commercially important varieties of sour cherries, such as Early Richmond, Montmorency, Dyehouse, and English Morello, are self-fruitful provided sufficient pollinizing insects are available. Better crops may be expected, however, if a sour cherry orchard contains more than one variety. Almost any sour cherry variety will serve as an effective pollinizer

for the other sour varieties. The later blooming sweet cherries will also satisfactorily cross-pollinate the sour varieties. The pollen of Duke cherries usually does not give satisfactory fruit sets on sour cherries.

DUKE CHERRIES

Duke cherries are hybrids between the sweet and sour cherries. Some of the Duke varieties, such as Royal Duke and May Duke, may be partly self-fruitful, but cross-pollination is essential for commercial crops. Duke cherries will generally set heavier crops when cross-pollinated by either sweet or sour cherries rather than by other Duke varieties. The pollen of Duke cherries gives low percentages of germination when tested in the laboratory. This low viability undoubtedly explains why Duke cherries serve as poor

TABLE 3—SWEET CHERRY COMBINATIONS FOR INTERPOLLINATION*
(Based on compatibility and coincidence of blooming period)

Variety to be pollinated (In order of blooming sequence)	Value of variety as a pollinizer†														
	Burbank	Chapman	California Advance	Black Heart	Black Knight's Early	Early Purple Guigne	Black Republican	Black Tartarian	Napoleon (Royal Ann)	Windsor	Parkhill	Early Rivers	Rockport	Bing	Pontiac
Burbank	0	G	F	G	G	F	G	G	-	-	-	-	F	P	-
Chapman	G	0	G	G	-	G	F	G	-	-	-	-	F	F	-
California Advance	P	G	0	G	-	G	-	G	-	-	-	0	0	-	-
Black Heart	G	G	G	0	-	G	0	G	-	-	-	F	F	G	-
Knight's Early Black	-	-	-	0	-	0	0	G	-	-	-	F	0	-	-
Early Purple Guigne	F	F	F	G	G	F	G	G	-	-	-	0	P	0	-
Black Republican	-	G	G	-	G	G	G	G	-	-	G	0	F	G	-
Black Tartarian	-	-	-	-	G	-	-	G	-	-	0	0	-	-	-
Napoleon (Royal Ann)	-	-	-	-	G	-	-	G	-	-	-	-	-	-	-
Windsor	-	-	-	-	-	-	-	G	-	-	-	-	-	-	-
Parkhill	-	-	-	-	-	-	-	G	-	-	0	-	-	-	-
Early Rivers	-	-	-	-	-	-	-	G	-	-	-	0	0	-	-
Rockport	F	F	0	-	-	0	G	G	-	-	-	-	-	-	-
Bing	-	-	-	-	-	G	-	G	-	-	-	-	-	-	-
Pontiac	-	-	-	-	-	-	-	G	-	-	-	-	-	-	-
Abundance	-	-	-	-	-	-	-	G	-	-	-	-	-	-	-
Bush Tartarian	P	-	-	-	-	P	-	G	-	-	G	-	-	-	-
Schmidt	-	-	-	-	-	-	-	G	-	-	-	-	-	-	-
Giant	-	-	-	-	-	-	-	G	-	-	-	-	-	-	-
Lambert	P	-	-	-	-	-	-	G	-	-	-	-	-	-	-
Saylor	-	-	-	-	-	-	-	G	-	-	-	-	-	-	-
Long Stem Bing	-	-	-	-	-	-	-	G	-	-	-	-	-	-	-
Gil Peck	-	-	-	-	-	-	-	G	-	-	-	-	-	-	-
Deacon	P	-	-	-	-	-	-	G	-	-	-	-	-	-	-

* Data from Bulletin 346, with supplementary data of G. L. Philp, R. M. Brooks, and W. H. Griggs.

† G = good; F = fair; P = poor; 0 = no value.

pollinizers for sweet and sour cherries as well as for other Dukes. Sweet cherries in the late blooming group make satisfactory pollinizers for earlier blooming Duke cherries, such as Olivet, Reine Hortense, and May Duke. On the other hand, the sour cherry varieties may best serve as pollinizers for the later blooming Dukes, such as Late Duke, Royal Duke, and Abesse d'Oignies.

Insects—mainly honey bees—are the only important agents for cross-pollinating cherries. The grower should therefore make certain that bees are present during the blooming period by providing an average of one colony per acre. Although wide distribution of the hives would be desirable, they are usually grouped to facilitate handling.

PEARS

Pear varieties may be segregated into three groups, according to their degree of self-fruitfulness, as follows:

USUALLY SELF-FRUITFUL	
Doyenne du Comice	Beurre Hardy
Flemish Beauty	Howell
PARTLY SELF-FRUITFUL	
Duchesse	Dana Hovey
d'Angouleme	Easter Beurre
Beurre d'Anjou	Beurre Giffard
Bartlett	Glou Morceau
Beurre Bosc	Kieffer
Clapp Favorite	P. Barry
Beurre Clairgeau	Seckel
Colonel Wilder	
SELF-UNFRUITFUL	
Doyenne d'Alençon	Forelle
Bloodgood	Le Conte
Bernard S. Fox	Madeleine d'Angers
Lawson (Comet)	Winter Nelis

Although the self-fruitful varieties will usually give commercial crops when planted in solid blocks, they will generally produce larger crops when cross-pollinated.

Whether or not it pays to interplant Bartlett pears with pollinizers is an old

question. In spite of the fact that research workers at the University of California have recommended such a practice since 1919, the trend has been toward growing Bartletts in solid blocks. Odd varieties have been grafted over, and new plantings are almost invariably solid Bartletts. Very few growers make any effort to provide bees for their orchards during the blooming period. In certain interior valley orchards it is difficult to find a single bee working pear blossoms even when they are in full bloom.

Table 4 summarizes a study on the value of cross-pollination of Bartletts. It will be noted that, in the counties studied, there was very little difference between the average open-pollinated fruit set of orchards planted with pollinizers and that of orchards planted in solid blocks. When the Bartlett blossoms were emasculated and either self-pollinated or cross-pollinated with Winter Nelis pollen, however, the value of cross-pollination became apparent.

The fact that the trees which were cross-pollinated by hand gave higher sets than those which were open-pollinated in the presence of pollinizing varieties indicates that more bees should have been available in the open-pollinated orchards. The low order of self-fertility of the Bartlett is indicated by the extremely low seed content of fruits following self-pollination.

Table 5 shows the results of an extensive study of the fruit set in orchards, with and without provision for cross-pollination, throughout most of the pear growing districts of the state. In certain counties, such as Lake and Santa Clara, there seemed to be no advantage to providing other varieties for cross-pollination. The average fruit sets for all districts, however, again show a definite advantage in favor of providing pollinizers for Bartlett.

It may be noted that a very low seed content results when Bartletts are grown in solid blocks. Under certain conditions,

**TABLE 4—FRUIT SET OF BARTLETT PEARS, IN VARIOUS COUNTIES,
RESULTING FROM NATURAL POLLINATION, SELF-POLLINATION,
AND CROSS-POLLINATION**

(1916 through 1923, and 1948 through 1950)*

Counties	Years studied	Number of blossoms	Per cent fruit set	Average number seeds per fruit
Natural pollination (pollinizers present)				
Yolo, Nevada.....	1916-1923	17,110	6.6	....
El Dorado, Yolo, Lake, Santa Clara.....	1949-1950	19,972	11.0	3.74
Natural pollination (solid blocks of Bartlett)				
Solano, Santa Clara, Sonoma.....	1920-1922	11,667	8.2	....
El Dorado, Sacramento, Lake, Santa Clara.....	1948-1950	15,473	9.4	0.53
Self-pollination†				
Yolo, Nevada, Solano, Santa Clara, Sonoma	1916-1922	8,712	3.9	....
El Dorado, Yolo, Sacramento, Lake, Santa Clara.....	1949-1950	4,464	10.1	0.26
Cross-pollination (with Winter Nelis pollen)‡				
Yolo, Nevada, Solano, Santa Clara, Sonoma	1916-1922	5,060	14.6	....
El Dorado, Yolo, Sacramento, Lake, Santa Clara.....	1948-1950	4,500	18.2	3.69

* Data for 1916 through 1923 from Bulletin No. 343; data for 1948 through 1950 by W. H. Griggs.

† Blossoms emasculated, and Bartlett pollen applied by hand.

‡ Blossoms emasculated, and Winter Nelis pollen applied by hand.

therefore, the Bartlett pear will set commercial crops of parthenocarpic (seedless) pears without the benefit of cross-pollination.

Certainly no one would recommend providing pollinizers for solid plantings of Bartlett trees which have been producing consistently high yields year after year. There are many orchards planted solidly to Bartletts in the state, however, which often give unsatisfactory and inconsistent yields. The data presented in

Tables 4 and 5 indicate that the yields would be increased if these orchards were provided with adequate facilities for cross-pollination.

Honey bees usually prefer flowers of other plants to those of pears. This is undoubtedly due to the fact that pear flowers provide a relatively small quantity of nectar which is low in sugar concentration. Bees do work pear blossoms for pollen, which is produced in abundance by most pear varieties. Therefore,

TABLE 5—FRUIT SET AND SEED CONTENT OF BARTLETT PEARS, IN VARIOUS COUNTIES, RESULTING FROM NATURAL POLLINATION WITH AND WITHOUT OTHER VARIETIES AS POLLINIZERS

Counties	Year	Pollinizers present		Solid blocks of Bartlett	
		Number of fruits set per 100 flower clusters	Average number seeds per fruit	Number of fruits set per 100 flower clusters	Average number seeds per fruit
Mendocino	1949	40.4	4.73	34.8	0.10
	1950	38.4	2.47	27.9	0.27
Lake	1949	51.5	1.73	63.9	0.08
	1950	84.2	3.30	82.3	0.14
Sonoma	1949	54.8	0.40	31.4	0.11
	1950	150.4	1.95	128.2	0.35
Yuba	1949	32.7	1.81	27.1	0.01
	1950	40.2	5.90	35.4	1.65
Placer	1949	22.5	0.99	29.1	0.22
	1950	81.3	3.78	21.8	0.62
El Dorado	1949	39.4	3.13	31.6	0.54
	1950	65.3	2.03	29.1	1.47
Sacramento	1949	35.1	5.31	20.6	0.07
	1950	100.4	6.00	31.9	0.04
Solano	1949	44.2	5.06	22.0	0.17
	1950	84.0	1.17	60.8	0.13
Contra Costa	1949	57.2	6.03	39.0	0.42
	1950	207.5	7.37	109.5	1.06
Santa Clara	1949	48.9	2.87	49.1	0.26
	1950	71.6	5.04	115.0	0.36
Yolo	1949	28.3	8.21	....	....
	1950	66.1	7.24	....	....
San Joaquin	1949	....	....	22.4	0.31
	1950	....	....	34.7	0.36
Averages:	1949	41.4	3.66	33.7	0.21
	1950	89.9	4.20	61.5	0.59
	1949-1950	65.6	3.93	47.6	0.40

FIGURE 6
AVERAGE DATES OF FIRST, LAST, AND FULL BLOOM OF CERTAIN PEAR VARIETIES
AT DAVIS, CALIFORNIA

if the concentration of bees is great enough, effective cross-pollination will undoubtedly result in orchards adequately provided with pollinizing varieties. In orchards where heavier fruit set is desired, probably two or three colonies of bees per acre should be provided.

Although no cases of complete inter-incompatibility have been found among the pear varieties listed above, very poor sets result from the reciprocal crossing of Bartlett and Seckel. Most of the other varieties should serve as satisfactory pollinizers for Bartlett if their blooming periods overlap sufficiently.

Pears have a comparatively short period of bloom. Figure 6 gives the aver-

age blossoming dates of several of the pear varieties. It should be remembered that the average dates of bloom give the impression that there is a greater overlapping of the blooming periods of the different varieties than is actually the case. The blooming dates for any one year give a better picture of the blooming sequence of the different varieties.

The following varieties, tested in California, have proved satisfactory pollinizers for Bartlett in most years: Duchesse d'Angouleme, Beurre d'Anjou, Beurre Bosc, Beurre Clairgeau, Howell, Beurre Hardy, Doyenne du Comice, Dana Hovey, Easter Beurre, Forelle, and Winter Nelis.

JAPANESE PLUMS

Most of the Japanese plums are self-unfruitful. Beauty, Climax, Methley, Red Rosa (Late Santa Rosa), and Santa Rosa are partly self-fruitful. These five varieties, like the others, will generally set fruit much better when interplanted with other varieties for cross-pollination. The degree of self-fruitfulness of these varieties apparently varies from one section of the state to another, depending upon local environmental conditions. Thus Santa Rosa is considered highly self-fruitful in certain sections of Tulare County where it is often grown in solid blocks, and only slightly self-fruitful in Yuba County. Some of the fruit set that is attributed to self-fruitfulness, however, may actually be the result of cross-pollination effected by bees from neighboring orchards.

Several of the Japanese plum varieties are usually poor pollinizers because, in most years, they produce only scanty amounts of pollen which is relatively low in viability. Others are poor, even though they produce an abundant amount of pollen, because only a small percentage of it will germinate. Varieties such as Burbank, Elephant Heart, Red Rosa, Santa Rosa, and Wickson usually produce large amounts of viable pollen, and have generally proved good pollinizers. Although usually a deficient pollen producer, Beauty has proved a good pollinizer for several varieties in most years.

Formosa and Gaviota are apparently interincompatible, and should not be planted together. Pollination tests at Davis and Winters show that poor fruit sets may be expected when any of the following combinations are planted together even though they may not be completely interincompatible: El Dorado and Satsuma; El Dorado and Formosa; Formosa, Sharkey, and Apex; Red Rosa and Becky Smith; Santa Rosa, Kelsey, and Apex; Beauty and Kelsey; Gaviota, Kelsey, and Apex; Duarte and Kelsey;

Kelsey, Elephant Heart, and Becky Smith; Kelsey and Sharkey; Kelsey and Burbank; Burbank and Apex; Becky Smith, Apex, and Kelsey; Mariposa and Inca; seedling 26-26 and Formosa.

Red Rosa (Late Santa Rosa) is a bud sport of Santa Rosa, and a combination of these two varieties would therefore be no better in regard to cross-pollination than would a solid block of either variety.

There are also several instances of cross-incompatibility in the Japanese plums. For example, Elephant Heart pollen will give heavy fruit sets on Formosa, Red Rosa, Red Ace, Santa Rosa, Duarte, Burbank, and Climax, but not one of these varieties will give a satisfactory set on Elephant Heart.

The importance of finding a specific pollinizer is emphasized in the case of Elephant Heart. This attractive fruit is one of the largest of all Japanese plums. It has high quality, is a good shipper, and would undoubtedly be an important late-season plum except for its shy bearing habit. Between 1936 and 1948, 21 plum varieties were tested as pollinizers for Elephant Heart. None of the pollinizers gave satisfactory fruit sets. Finally, in 1948, Myrobalan 5Q, a selected Myrobalan plum seedling, which was one of 47 varieties tested as pollinizers for Elephant Heart that year, gave a satisfactory fruit set. Extensive tests in 1949 proved that Elephant Heart can produce heavy crops with this source of pollen. Since the fruit of Myrobalan 5Q has no commercial value, the search for a suitable pollinizer was continued. In 1950 it was discovered that a promising new Japanese plum seedling, 10-29, developed in breeding work at the University of California, will also effect heavy fruit sets on Elephant Heart. (Elephant Heart is also an effective pollinizer for seedling 10-29.)

The blossoming season of the European plum, Tragedy, coincides with the blooming time of several late Japanese varieties. Tragedy is also a moderately effective pollinizer for several Japanese

TABLE 6—JAPANESE PLUM COMBINATIONS FOR INTERPOLLINATION*
(Based on compatibility and coincidence of blooming period)

Variety to be pollinated (In order of blooming sequence)	Value of variety as a pollinizer†																					
	Mariposa	Inca	Seedling 26-26	Satsuma	Wickson	Formosa	Red Rosa (Late Santa Rosa)	Myrobalan 5Q	Red Ace (Florida)	El Dorado	Santa Rosa	Beauty	Seedling 10-29	Gaviota	Duarte	Kelsey	Apex	Elephant Heart	Burbank	Sharkey	Becky Smith	Climax
Mariposa.....	0																					
Inca.....		P																				
Seedling 26-26.....			P																			
Satsuma.....				P																		
Wickson.....					P																	
Formosa.....						P																
Red Rosa (Late Santa Rosa).....							P															
Myrobalan 5Q.....								P														
Red Ace (Florida).....									P													
El Dorado.....										P												
Santa Rosa.....											P											
Beauty.....												P										
Seedling 10-29.....													P									
Gaviota.....														P								
Duarte.....															P							
Kelsey.....																P						
Apex.....																	P					
Elephant Heart.....																		P				
Burbank.....																			P			
Sharkey.....																				P		
Becky Smith.....																					P	
Climax.....																						P

* Data from Extension Circular 34 with supplementary data by A. H. Hendrickson, C. O. Hesse, and W. H. Griggs.
† G = good; F = fair; P = poor; 0 = no value.

plums, but it does not set fruit following cross-pollinization by them.

Table 6 summarizes the pollination requirements of the Japanese plums. Figure 7 shows the average dates of the first, last, and full bloom of certain Japanese plum varieties at Davis and Winters, California.

There is a great deal of variation from year to year in the blossoming time of the Japanese plums. In years when the blooming season is very short, there may be sufficient overlapping for cross-pollination between the earliest and latest blooming varieties. When the blooming

season is long, however, there are usually distinct gaps between the blooming periods of the early and late blooming varieties. In Figure 7, the varieties from Mariposa through seedling 10-29 may be grouped as early blooming, and those from Gaviota through Climax as late blooming. In most years the blooming periods of the varieties within each group usually overlap well enough for cross-pollination. Usually the blossoming periods of the late members of the first group and the early members of the second also overlap well enough for cross-pollination.

FIGURE 7
AVERAGE DATES OF FIRST, LAST, AND FULL BLOOM OF CERTAIN JAPANESE PLUM VARIETIES AT DAVIS AND WINTERS, CALIFORNIA

EUROPEAN PLUMS AND PRUNES

European plum (including prune) varieties may be classified according to differences in their response to self-pollination, as follows:

USUALLY SELF-FRUITFUL

California Blue	Stanley
French	Sugar
Giant	Yellow Egg

PARTLY SELF-FRUITFUL

Coates 1418 (French XX)	Pond (Hungarian Prune, Gros)
Conquest	Reine Claude
Diamond	(Green Gage)
Italian Prune (Fellenburga)	Shropshire Damson

SELF-UNFRUITFUL

Anita	Rayburn Tragedy
Burton	(Late Tragedy)
Clyman	Robe de Sergeant
Earliana	Silver
Early Tragedy	Splendor
Emilie	Standard
Grand Duke	Stuart
Imperial Epineuse	Sultan
Jefferson	Tragedy
President	Washington
Quackenboss	

The partly self-fruitful varieties should generally not be planted without provision for cross-pollination. However, there are apparently favorable locations in the state where certain European plums will set much heavier crops with their own pollen than they will in other locations. For example, several prune

FIGURE 8
AVERAGE DATES OF FIRST, LAST, AND FULL BLOOM OF CERTAIN EUROPEAN PLUM
VARIETIES AT DAVIS AND WINTERS, CALIFORNIA

TABLE 7—EUROPEAN PLUM COMBINATIONS FOR INTERPOLLINATION *
(Based on compatibility and coincidence of blooming period)

Variety to be pollinated (In order of blooming sequence)	Value of variety as a pollinizer †														
	Earliana	Clyman	Tragedy	Grand Duke	Rayburn Tragedy (Late Tragedy)	Anita	Diamond	Imperial Epineuse	Jefferson	Sugar	President	Splendor	French	Standard	Coates 1418 (French XX)
Earliana.....	0														
Clyman.....		0													
Tragedy.....		G	0	G	P	P	G		G	G	G				
Grand Duke.....		F	G	P	G		G								
Rayburn Tragedy (Late Tragedy).....		G	G	G	0	G	G	F	G	G	G				
Anita.....			G	G		0	F	F		G	G				
Diamond.....			G	G	G			0		F					
Imperial Epineuse.....															
Jefferson.....								G	0	G	F				
Sugar.....								G	G	G	G				
President.....								G		G	0	G			
Splendor.....								G		G		G			
French.....								G		G		0			
Standard.....								G		G		G			
Coates 1418 (French XX).....								G		G		G			
Giant.....															
Conquest.....															
Robe de Sergeant.....															
Burton.....															
Emilie.....															
Pond (Gros).....															
Italian Prune (Fellenburg).....															

* Data from Extension Circular 34 with supplementary data by A. H. Hendrickson and W. H. Griggs.
† G = good; F = fair; P = poor; 0 = no value.

varieties, when grown in solid blocks, will set much heavier under the interior valley conditions of Sutter County than under the coastal influence of Sonoma County. It is possible that a portion of the set attributed to self-pollination in these apparently favorable locations may actually be the result of cross-pollination effected by bees from another orchard in the vicinity.

There are apparently no cross-incompatible European plum varieties among those grown commercially in California. Since most produce a high percentage of viable pollen, any variety should be effective in cross-pollinating another, provided blooming seasons overlap enough.

Figure 8 shows the average dates of first, last, and full bloom of a number of European plum varieties at Davis and Winters. They may be classed as early, midseason, and late blossoming. Earliana, Clyman, and Tragedy would make up the early group; Grand Duke, Rayburn Tragedy, Anita, Diamond, Imperial, Sugar, President, Splendor, French, and Standard the midseason group; and Coates 1418, Giant, Conquest, Robe, Burton, Emilie, Pond, and Italian (Fellenburg) the late group. Earliana and Clyman bloom early enough to cross-pollinate Tragedy effectively. The blossoming season of Tragedy also extends into those of Grand Duke, Rayburn Tragedy, Anita, and Diamond. The blossoming periods of the latest blossoming varieties of the midseason group usually overlap well enough with the earliest blossoming varieties of the late group for satisfactory cross-pollination.

Table 7 summarizes the accumulated data on the pollination requirements of European plums.

Studies have shown that bees must be provided in plum orchards established for commercial crops even though the varieties are highly self-fruitful. Thus a French prune tree which was caged in mosquito bar to exclude insects gave a fruit set of only 0.43 per cent. A paired

tree of the same variety which was enclosed with a hive of bees brought in from an area where no fruit trees were grown, set 19.0 per cent of its blossoms.

PERSIAN WALNUTS

Walnut pollen is distributed by wind, rather than by insects. It may be carried as far as a mile, but it generally is distributed effectively only within 200 or 300 feet.

Although walnuts are self-fertile, walnut pollination is not satisfactory in many cases. The pollination problem with walnuts arises from the fact that several varieties, in certain years, fail to mature their staminate and pistillate flowers at the same time. Under these conditions, therefore, they cannot pollinate themselves.

The walnut tree is monoecious, which means that the male and female flowers are borne at different locations on the same tree. The staminate flowers, or catkins, are the elongated structures that develop on the previous season's growth and produce pollen. The small, pistillate flowers are borne on the tips of the first spring flush of growth of new shoots.

In so far as is known from studies of the walnut, pollen of one variety is capable of fertilizing the ovules of that variety and all other varieties.

In the inland districts of the state, varieties such as Payne, Eureka, Hartley, and Franquette tend to shed their pollen before their pistillate flowers are receptive. In young trees of these varieties, the pollen may be practically all gone before the first pistillate flowers are ready to receive pollen. In the southern California coast district, on the other hand, varieties such as Placentia and others of the Santa Barbara soft-shell seedling group tend to shed their pollen after the pistillate flowers have ceased to be receptive. The difference in the time of maturity of the two types of flowers, however, is rarely great enough to prevent the setting of at least part of a crop in either the inland or coastal districts.

Differences in the weather may influence the rate of flower development. Hot spring weather with warm winds tends to hasten the development of catkins and makes them shed their pollen quickly. Warm weather does not have so great an effect on the development of pistillate flowers. Hence, in the inland districts the problem of too early pollen shedding is increased because of climate, whereas, in the cool climate of southern California coast districts, the late production of pollen is further retarded. Wind can add to the problem by blowing off the catkins before the pistillate flowers are receptive.

In established orchards with a pollination problem, the grower may improve the pollination facilities by gathering catkins from a variety other than the one established and placing them high in the windward side of the trees that need increased pollination. The catkins should be picked when they are fully elongated and just beginning to shed pollen. Catkins of the same variety as those in the orchard will be satisfactory if they can be found in the proper stage of maturity in another locality. The catkins may be placed in mosquito netting. Put a double handful of catkins on a 1-foot square of netting, tie into a bag, leaving a long string attached, and throw one bag up high in the windward side of each tree. A small rock may be added to each bag to give it sufficient weight for throwing. The pollen may be dispersed from the bags by tapping them with a long pole or by jerking the attached strings.

Care in storage of the collected catkins is essential until they are hung in a tree as they will heat and spoil very quickly. If the catkins are picked and placed in paper sacks, each sack of catkins should be stored by itself in the shade. Even under this care, the catkins will heat in about four hours. Heating quickly kills the pollen. It is desirable to transport the catkins in a portable icebox and to hang them in the trees as quickly as practicable. After they are hung in the trees,

the catkins will remain effective for from three to five days if the weather is favorable, but one hot day with wind will dry them up and cause all of the pollen to be shed quickly.

The pollination facilities in established orchards may be permanently improved by grafting in other varieties. The scions should be placed high in the windward side of the trees where the branches are only 4 or 5 inches in diameter. Grafting one such limb in every second or third tree in every third row should be sufficient. Mixing varieties by grafting is undesirable from a harvesting and marketing standpoint, and should not be done unless the varieties are similar in type and in time of maturity. Waterloo grafted into Eureka trees and Hartley grafted into Payne trees are examples of desirable combinations from a pollination standpoint since these varieties could be marketed together because of their similarity.

When setting out young orchards, improved pollination facilities may be obtained by planting a mixture of varieties which bloom in proper sequence. In the southern California coastal districts the varieties Ehrhardt, Placentia, and other Santa Barbara types would insure a succession of blooming and cross-pollination. In the inland areas of northern and central California a mixture of Payne, Eureka, Hartley, and of Waterloo, San Jose Mayette, and Franquette could be used. Franquette would be the one most likely to be short of pollen because its pollen sheds very early in relation to the development of pistillate flowers of this variety and it is the last of the group to bloom. Late blooming varieties, such as Conway Mayette and XXX Mayette, would help insure pollination for Franquette.

Young trees just coming into bearing often do not produce enough catkins to supply pollen for all their pistillate flowers. The catkins on young trees also have a greater tendency to shed their

pollen and to drop before the pistillate flowers are receptive. This tendency is more pronounced in the interior districts during hot spring weather. Young Franquette trees are also inclined to drop their catkins following mild winters. As the trees grow older, more catkins are produced and pollen is usually shed over a longer period. This tends to make pollination more satisfactory in older trees.

PECANS

The pecan tree, like the walnut, is monoecious. The male, or staminate, flowers are in the form of hanging, three-branched catkins and are produced in the leaf axils of two-year-old wood. Pollen carried from the catkins by wind pollinates the pistillate, or female, flowers borne in clusters of two to eight at the terminals of the first spring flush of growth.

Most pecan varieties bear viable pollen and are considered to be self-fruitful. Experimental work in Texas, however, has shown that nuts resulting from cross-pollination filled better, were larger, and were less likely to drop before they matured.

With some varieties, the female flowers become receptive to pollen at about the same time that it is shed from the catkins, and cross-pollination is not required. With other varieties, the female flowers open and are receptive before the pollen is shed, so that, by the time this happens, they are no longer receptive. Other varieties may shed nearly all their pollen before their pistils are receptive. The behavior of any variety in this respect is not constant under different climatic conditions. The catkins of a given variety may shed their pollen too soon in some years, at just the right time in others, and too late in still others.

To be sure that there is always some pollen available in a planting throughout the period that all the female flowers are receptive, a commercial orchard should contain two or more varieties. Although

wind may carry pollen over distances up to a mile, at least one row of a pollinizing variety should be planted for every nine rows of the main variety. Full rows of these pollinating varieties may be planted, and rows should run at right angles to the prevailing spring winds.

In the varieties Stuart, Frotscher, Moneymaker, Success, and San Saba, the female and male flowers mature at about the same time. With Curtis, Delmas, Van Deman, and Schley, the female flowers usually open and are receptive before the pollen is shed.

FILBERTS

Filberts, like walnuts and pecans, are monoecious and wind-pollinated. Most varieties of filberts are considered to be either partly or completely self-unfruitful, but no evidence of cross-incompatibility has been reported. Hence, almost any variety which sheds its pollen at the right time in the district concerned may be used as a pollinizer. Some of the varieties used to pollinate Barcellona are White Aveline, Nottingham, Daviana, Du Chilly, Bolwyller, and Du Provence. Brixnut may be pollinated by Bolwyller, and Du Chilly may be pollinated by Daviana, Alpha, Gasaway, Clackamas, and Nook-sack.

Filbert varieties are variable in time of shedding pollen and maturing of pistillate flowers. For satisfactory pollination it is necessary, therefore, to include several pollinizers that shed pollen at different times.

Filbert trees may produce fair crops in northern California at elevations of 2,000 feet or higher. They usually do not fruit well at elevations below 2,000 feet, apparently because of the tendency of the young catkins to shed in late summer, fall, and early winter.

FIGS

Of the five varieties of figs grown commercially in California, only the Calimyrna requires caprification (polli-

nation) for fruitfulness. The Adriatic, Kadota, Mission, and Turkey varieties produce fruits parthenocarpically without pollination or fertilization.

Caprification.—The Calimyrna fig bears only pistillate flowers. Pollination of these flowers is accomplished by the tiny fig wasp (*Blastophaga psenes*) from the profichi figs (spring crop) of the male, or caprifig, and the process is called caprification. When the fig wasps emerge from the flowers of the caprifig, they are dusted with pollen from the staminate flowers near the ostium (opening, or mouth) at the apex of the caprifig. The pollen-dusted fig wasps then enter the Calimyrna figs instead of other caprifigs—hence, pollination is unwittingly accomplished.

Caprifigs are the only figs that produce pollen, and the only type in which the fig wasp can complete its life cycle. Although their fruits have no commercial value, they must be provided for the pollination of the Calimyrna fig, at the rate of three or four caprifig trees to every 100 Calimyrna trees. Merely providing the caprifig trees is not sufficient, however. It is necessary to transfer the caprifigs to the trees that are to be pollinized, thus modifying the normal cycle of the fig wasp. This process should be carried out as follows: Pick the profichi from which wasps are ready to emerge either in the early morning, for immediate distribution, or in late afternoon, for distribution early the following morning. (Fig wasps emerge during the warm hours of the morning, but not during the heat of the day.) Place the caprifigs in containers (usually of galvanized wire netting), and hang them in the Calimyrna trees.

The number of caprifigs suspended in each Calimyrna tree during the caprification period varies with size of tree, condition of caprifigs, and weather. In general, however, for medium-sized trees, three to five caprifigs are placed in each tree at about three-day intervals over a period of three weeks. Counts made dur-

ing three years of sampling (1944–1946) showed that an average of 235 female wasps emerged from each caprifig. Unfortunately, the fig wasps may carry not only pollen into the fig, but also spores of endosepsis, a fungus disease which causes internal rot. For this reason, the number of profichi distributed in Calimyrna trees should be reduced to the minimum sufficient to insure a reasonable crop.

Calimyrna figs are usually receptive to pollen when about $\frac{1}{2}$ inch in diameter, and may remain receptive for a week or more, depending upon weather conditions. The following standard varieties of caprifigs are available for caprification: Roeding No. 1 and Roeding No. 3, for early-season caprification; Stanford and Samson (Markarian No. 1), for mid-season; and Milco and Roeding No. 4 for late-season.

(For further information regarding caprification of Calimyrna figs, address inquiries to the University of California Agricultural Experiment Station, Davis, California.)

Hormone sprays.—Recently, Dr. J. C. Crane of the University of California Experiment Station, and Dr. Rene Blondeau of the Shell Agricultural Laboratory at Modesto, California, have developed hormone spray treatments which will stimulate parthenocarpic (seedless) fruit production in the Calimyrna fig. These hormone sprays may be substituted for caprification. One of the most satisfactory chemicals recommended for this purpose is parachlorophenoxyacetic acid. Applied as a water spray, at 80 parts per million, this chemical has resulted in better yields of passable figs than were produced when the usual caprification procedure was followed. No injury to the fruit, leaves, or twigs occurred as a result of this spray.

A product under the trade name of "Fig Fix" is now available in which the active ingredient is parachlorophenoxyacetic acid. One-half pint of this concentrate is added to 300 gallons of water in

the spray tank, under agitation. This gives the desired solution containing approximately 80 parts per million of para-chlorophenoxyacetic acid. A satisfactory rate is about 300 gallons per acre of medium-sized trees, applied until there is a slight runoff from the leaves. Since the hormone is taken up through the leaves, it is not necessary that each individual fig be covered with the spray.

Time of application of the spray is very important. Because of differing stages of development, there is no time when all figs on a tree are in the receptive stage for hormone application. Caprification generally extends over a period of two to three weeks. A single hormone spray application, therefore, cannot be expected to set all of the fruit on a tree. Under tests, however, hormone application has usually resulted in an equal or better fruit set than that in comparable caprifried orchards. The spray should be applied early in the normal caprification period to set most of the largest figs near the basal portions of the shoots. At that time these fruits have a dark green color, are glossy, have prominent ribs, and are usually slightly larger in diameter than a 25-cent piece. The time when shoot growth stops may also be used to indicate the time at which the hormone spray should be applied. This is not so accurate a standard, however, as size and appearance of the fruit.

The production of Calimyrna figs by hormone spraying may have several advantages over pollination by the fig wasp. The fruit is free from endosepsis (internal rot) since this disease does not occur unless fig wasps carry it into the fruits. Fruit splitting, which is associated with seed growth and weather conditions, is nonexistent in hormone-produced figs. Hormone application is relatively easy and much less costly than caprification. Harvesting costs are also lower since figs produced by hormone application mature over a shorter period of time, and fewer pickings are required. Time is also saved

at the sorting belt where defective fruits are removed.

At maturity, there is very little difference in the outward appearance of caprifried figs and those resulting from hormone application. Those stimulated by hormone sprays have a light yellow color rather than the golden yellow characteristic of those which have set following caprification. The hormone figs are also somewhat more ribbed, and their necks slightly more flattened than the caprifried ones. Internally, however, the two types differ considerably. The hormone-produced figs are completely seedless and the pulp is light amber yellow as compared with the light strawberry red color in the caprifried figs. The seedless figs have a higher sugar content than those with seeds, and have good flavor. They lack the desirable nutlike flavor, however, that is characteristic of the caprifried figs.

OLIVES

Olive trees usually bloom profusely and produce pollen in great abundance. When the anthers of a flower dehisce (burst open), pollen is thrown upon the stigma, and self-pollination is accomplished. Flowers are also wind-pollinated by air currents which distribute clouds of the tiny, yellow pollen grains throughout the orchard. Honey bees often visit olive flowers to gather pollen, but experiments at the University of California have shown that bees are not important in the pollination of olives.

Whether or not it pays to interplant olive varieties for cross-pollination remains an open question. Many experienced orchardists consider all of the commercial olive varieties grown in California to be self-fruitful and feel that interplanting of varieties is not necessary to insure fruitfulness. Numerous satisfactorily yielding orchards may be cited which are planted to a single variety. Other growers feel that yields are increased by cross-pollination and point to

some of the highest producing orchards in the state in which varieties are interplanted. Italian workers feel that most of the olive varieties grown in central Italy are self-unfruitful. They advise planting one pollinizer tree to 10 or 15 trees of the main variety. In Portugal, an authority reports that there are hundreds of acres of olive orchards consisting of a single variety, where the yields are very high. (The important California varieties are not grown commercially in Italy and Portugal.)

Pollination experiments conducted during 1950 and 1951 have shown that the commercial olive varieties in California may vary from year to year in their ability to set fruit following self-pollination. Hence in certain years it would pay to have pollinizers available. These pollination studies are being continued.

In planting an olive orchard with more than one variety it is advisable, for convenience in harvesting, to plant four rows of one kind, then four of the pollinizing variety, and repeat.

No instances of cross- or interincompatibility have been found among the commercial olive varieties grown in California. Any two varieties, therefore, that have overlapping blooming periods should satisfactorily cross-pollinate each other.

The olive produces either perfect flowers, which are potentially fruitful, or staminate (male) flowers with tiny abortive pistils (fig. 9). The percentage of perfect flowers is generally small when compared with that of the staminate ones. In some years a tree may not develop enough perfect flowers to give a satisfactory crop even though it has produced a heavy bloom. Professor H. T. Hartmann, of the Experiment Station at Davis, has shown that girdling such trees during December, January, and February will increase yields by increasing the percentage of perfect flowers. The trees must be fairly vigorous, however, for the practice to be effective. Climatic conditions may limit the set of fruit regardless of the percentage of perfect flowers.

Fig. 9.—Left: perfect olive flower with large anthers and well-developed pistil—potentially fruitful. Center: staminate olive flower with large anthers and aborted pistil. Right: plump pistil of perfect olive flower with anthers and petals removed. (Photograph by H. T. Hartmann.)

ARTIFICIAL POLLINATION

Hand-pollination. — Cross-pollination by hand has been practiced in the Pacific Northwest to some extent for the past 20 years. It has been used mainly to insure a fruit set on Delicious apple trees which were planted either in solid blocks or with the Winesap variety which is an ineffective pollinizer. The method is recommended as a temporary expedient to be used only until natural facilities for cross-pollination can be established. The present trend in the Northwest is toward grafting in pollinator varieties in old orchards, and arranging new plantings with adequate pollinizing varieties.

Pollen for hand-pollination may be obtained by gathering flowers from a variety known to be a good pollinizer for the main variety in question, and removing the anthers by rubbing the flowers over a No. 8-mesh hardware cloth. Blossoms should be gathered when many of them are in the "balloon stage"—just before the petals open. The pollen may be cured by holding the anthers in shallow trays at room temperature for about two days. Avoid exposure to direct sunlight. After the pollen is cured, if it cannot be used immediately, it may be placed in bottles and held in a dry, cool place. To allow for respiration of the pollen, the bottles should not be airtight. A plug of cotton makes an ideal stopper.

Various materials, such as lycopodium spores, wheat flour, corn starch, and dried milk have been used to dilute the pollen in order to reduce the cost of hand-pollination. Lycopodium spores have generally proved the most satisfactory carrier.

Either pure or diluted pollen may be purchased from several firms that make a business of collecting, curing, and distributing various fruit pollens to be used in artificial pollination.

The pollen may be applied to the stigmas of the flowers with a No. 4 pig-hair brush, the rubber end of a lead pencil, a

cork, or the bare finger. The pollen should be applied within one to three days after the flowers open. When the tips of the styles turn brown, the flowers are no longer receptive to pollination. The usual practice, when hand-pollinating an apple tree in good bloom, is to touch one flower in every fourth or fifth cluster. A 20-year old apple tree can be pollinated in about an hour by a skilled operator. Naturally it would take much longer to hand-pollinate a fruit tree such as the sweet cherry, where it is necessary for a much higher percentage of the blossoms to set fruit in order to give a commercial crop.

Regardless of how the pollen is obtained or how much it is diluted, hand-pollination is a time consuming and costly procedure. This is especially true in view of the fact that one colony of bees will effectively cross-pollinate an acre of fruit trees in most years if only a minimum number of pollinizing trees are present. One argument in favor of hand cross-pollination is that it will greatly reduce the amount of fruit thinning required to obtain good size where natural pollinating agents are not available. Experiments in Washington state have shown, however, that the idea of reducing thinning costs does not justify the permanent use of hand-pollination as a substitute for pollinizer varieties and honey bees.

Rapid methods of artificial pollination.—Many labor saving methods for applying pollen have been developed and tested. Dust and liquid mixtures of pollen have been applied by airplanes and with conventional spray and dusting equipment. Bombs and shotgun shells containing pollen have also been employed for rapid distribution. **Under controlled experimental tests, however, these rapid methods have failed to give significant increases**

in fruit set. At present, hand-pollination is the most satisfactory artificial method.

A semiartificial method of cross-pollination has been used which involves pollen dispensers designed to force honey bees to pass through prepared pollen as they leave the hive. The idea is that the bees will pick up the pollen and spread it through the orchard. Workers in Washington reported, from a study of two types of these pollen dispensers in apple orchards, that their value was very questionable. Bee activity was greatly reduced and the bees either fanned the pollen away or carried it into the hive for food.

During 1951, in experiments at Davis in coöperation with Mr. George H. Vansell of the United States Department of Agriculture, hives of bees with pollen dispensers were supplied for almond and sweet cherry trees which were caged to exclude outside insects. Only a few fruits were set on the trees even though the dispensers were kept supplied with viable pollen throughout the blooming period and the bees actively worked the blossoms. Satisfactory fruit sets were obtained on branches of these trees to which the same pollen was applied by hand. After crawling through the pollen to leave the hive, the bees cleaned themselves by combing the pollen into their pollen baskets and then carrying it back into the hive.

Use of bee-collected pollen in artificial pollination.—A person collecting pollen by hand can usually gather only enough "green" anthers from fruit blossoms in an eight-hour day to produce from 3 to 5 ounces of cured pollen. A pollen trap, on the other hand, will yield as much as 2½ pounds of pollen per day per colony of bees, under favorable conditions. The traps consist of a perforated screen grid devised to scrape pollen from the legs of bees as they go through it on entering their hives.

The pollen pellets of a honey bee gen-

erally contain pollen grains from only one species of plant, and the pellets of the common fruit species are readily distinguished by their color. Although all bees of a colony do not visit the same species, it is possible to get a nearly pure sample by careful selection of the time and place of trapping.

Recent experiments at Davis, in coöperation with the United States Department of Agriculture, have shown that the percentage viability of freshly trapped pellet pollen is approximately the same as that of hand-collected pollen. When applied by hand with small brushes, the pellet pollen caused fruit sets which compared favorably with those effected by hand-collected pollen. Diluting the bee pollen with an equal amount of lycopodium spores did not significantly reduce fruit set. Although the viability of this pollen is rapidly lost at room temperature, it can be maintained for several days in ordinary cold storage at about 32° F, and for a much longer period at extremely low temperatures. If handled properly, therefore, the pollen in freshly trapped pollen pellets of honey bees may serve as well as hand-collected pollen in hand-pollination.

The fact that bee-collected pollen can be readily obtained in large quantities makes its use in artificial pollination seem promising. Various methods of rapid application of the pellet pollen, however, have been disappointing. The pellets have been dispersed in water, and in salt and sugar solutions, and the resulting solution-pollen mixtures have been sprayed on almonds, sweet cherries, plums, apples, and pears. The various pellet pollens have also been applied as dusts after they were mixed with diluents or carrying powders, such as lycopodium spores, wheat flour, and dried milk. Thus far, commercial fruit sets have not been obtained following these methods of application and therefore cannot be recommended.

ARRANGEMENT OF POLLINIZERS

In planting a deciduous fruit orchard where pollinizers are required, the grower should, if practical, have every sixth row, and preferably every fourth, a pollinizing variety. For convenience in harvesting it is best to plant two, four, or six rows of one kind, then two of the pollinizing variety, and repeat. If the number of pollinizers is to be kept to a minimum, one tree to eight, planted as every third tree in every third row, is recommended. This places a pollinizer next to every tree of the main variety in the orchard.

In orchards lacking varieties for cross-pollination, the situation can be corrected by grafting. Some prefer to graft a pollinizer branch into each tree, while others graft over (topwork) entire trees. The single-branch method has not proved satisfactory in many orchards because growers have not selected large enough branches in the best locations and have not given them proper care. As a result, the branches were choked out. It is more

practical to graft over entire trees, rather than a single small branch. Grafting over every third tree in every third row will usually provide a sufficient number of pollinizers. Whole trees offer a distinct advantage in keeping the fruit separate during harvest. It requires three or four years for grafts to furnish enough blossoms for cross-pollination.

Until provision can be made for permanent cross-pollination, the introduction of bouquets of bloom taken from suitable pollinizing varieties is probably the most effective and economical way of insuring a fruit set in orchards lacking varieties for cross-pollination. A bucket of blossoming branches for each tree, hung on the leeward side, is usually adequate, although the common practice is to place large, blossoming branches in barrels of water on the ground. The bouquets must be kept fresh, and an abundant supply of pollinizing insects is necessary for the success of this method.

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