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POLLINATION OF DECIDUOUS FRUITS BY BEES

G. L. PHILP[1] and G. H. VANSELL[2]

INTRODUCTION

Most fruit growers are familiar with investigations and field studies in cross-pollination. Beekeepers, however, are generally as unacquainted with the details of fruit pollination as are the fruit growers with bee problems. This circular attempts to summarize the results of deciduous fruit pollination studies and to point out some bee habits and structures, with special reference to the collection and storage of pollen. Such a paper may perhaps serve as a practical handbook for reference, especially in the field, and facilitate satisfactory pollination arrangements between fruitmen and beekeepers.

The pollination data have been prepared by the first author from material contained in various California Agricultural Experiment Station publications, most of which are now out of print, and supplemented with unpublished data from the Division of Pomolgy. The second author has prepared the material on bee habits and structures.

POLLINATION SUMMARY OF DECIDUOUS FRUITS

Among the causes responsible for nonbearing of deciduous fruits are lack of vigor in the tree, presence of injurious insects and diseases, unfavorable weather at blossoming time, winter injury, lack of pollination, and inability of the pollen to fertilize the ovule. This discussion will deal only with pollination as a cause of nonbearing, it being assumed that the orchard is planted in a favorable location and that the trees are kept in normal vigor and free from serious insect and disease troubles.

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[2] Associate in Entomology; resigned.

The following definitions may clarify the discussion:

Pollination[3]*:* the transfer of pollen to the stigma; or, in a large sense, the distribution of pollen. Pollination may be accomplished by insects, wind, gravity, water, artificial methods (in experimental work), and birds.

Pollinizer: a 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 ovary.

Fruitful: the term applied to a plant that sets and matures fruit.

Unfruitful or barren: terms describing a plant or variety that is unable to set fruit and mature it.

Fertility: the ability not only to set and mature fruit but to develop viable seed.

Sterility: the inability to set and mature fruit with viable seed.

Self-fruitful: the term applied to a plant that sets and matures fruit with its own pollen.

Self-unfruitful or self-barren: terms describing a plant that is unable to set fruit and mature it with its own pollen.

Inter-fruitful: the term applied to a variety capable of setting and maturing fruit when pollinized with a different variety.

Inter-unfruitful or inter-barren: terms describing a variety not capable of setting and maturing fruit when pollinized with a different variety.

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 fruit grower has a pollination problem with almonds, cherries, plums and prunes, apples, pears, and berries. In general, apricots, peaches, and walnuts set well with their own pollen and hence present no difficulties from this standpoint. The J. H. Hale peach, however, is self-unfruitful and must be interplanted with some other variety. Recent studies indicate that some varieties of walnuts in certain years do not mature the staminate and pistillate flowers at the same time and therefore, under these conditions, cannot pollinate themselves.

With the fruits having a pollination problem, the grower must consider the following factors in selecting the pollinizers: coincidence of bloom, amount of pollen produced, germinability of pollen, commercial value of pollinizer, succession in ripening, and regularity of production of the pollinizers used. Varieties which do not blossom at the same time will not cross-pollinate each other.

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[3] 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.

Most fruits with showy flowers (fig. 1) require insects to carry the pollen from flower to flower. Bees are the most important insects for this work. The grower should therefore have plenty of bees in the orchard during the blossoming period.

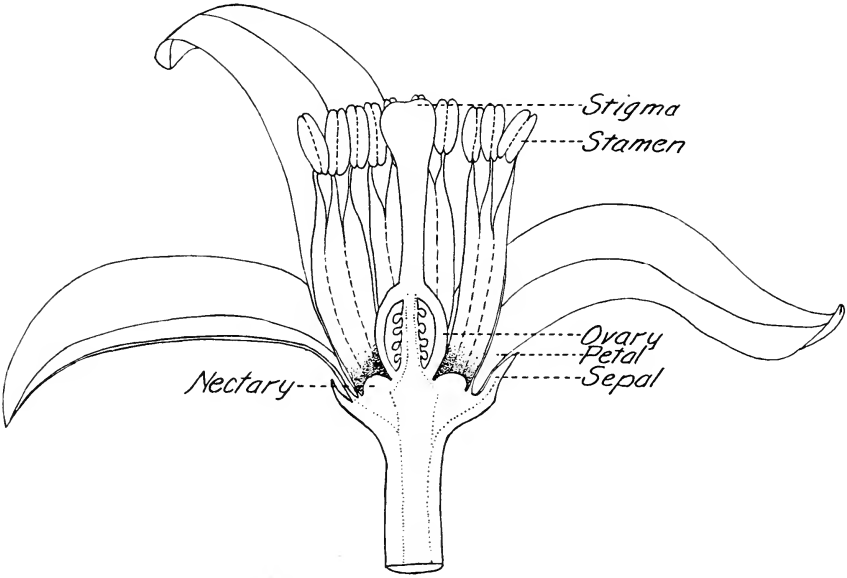

Fig. 1.—Diagram of orange flower in longitudinal section showing location of typical floral parts. The orange blossom has been used rather than the flower of a deciduous fruit because it shows the nectary more conspicuously.

The California Agricultural Experiment Station has conducted pollination experiments with certain fruits. The results may be summarized as follows:

ALMONDS

The following varieties of almonds are self-unfruitful under California conditions and hence should not be planted in blocks of one variety:

Big White Flat	Golden State	King	Nonpareil
California	Harriott	Klondike	Peerless
Drake	I. X. L.	Lewelling	Reams
Eureka	Jordan	Ne Plus Ultra	Texas

Some varieties of almonds are inter-unfruitful—for example, the following:

Nonpareil with I. X. L.
Languedoc with Texas

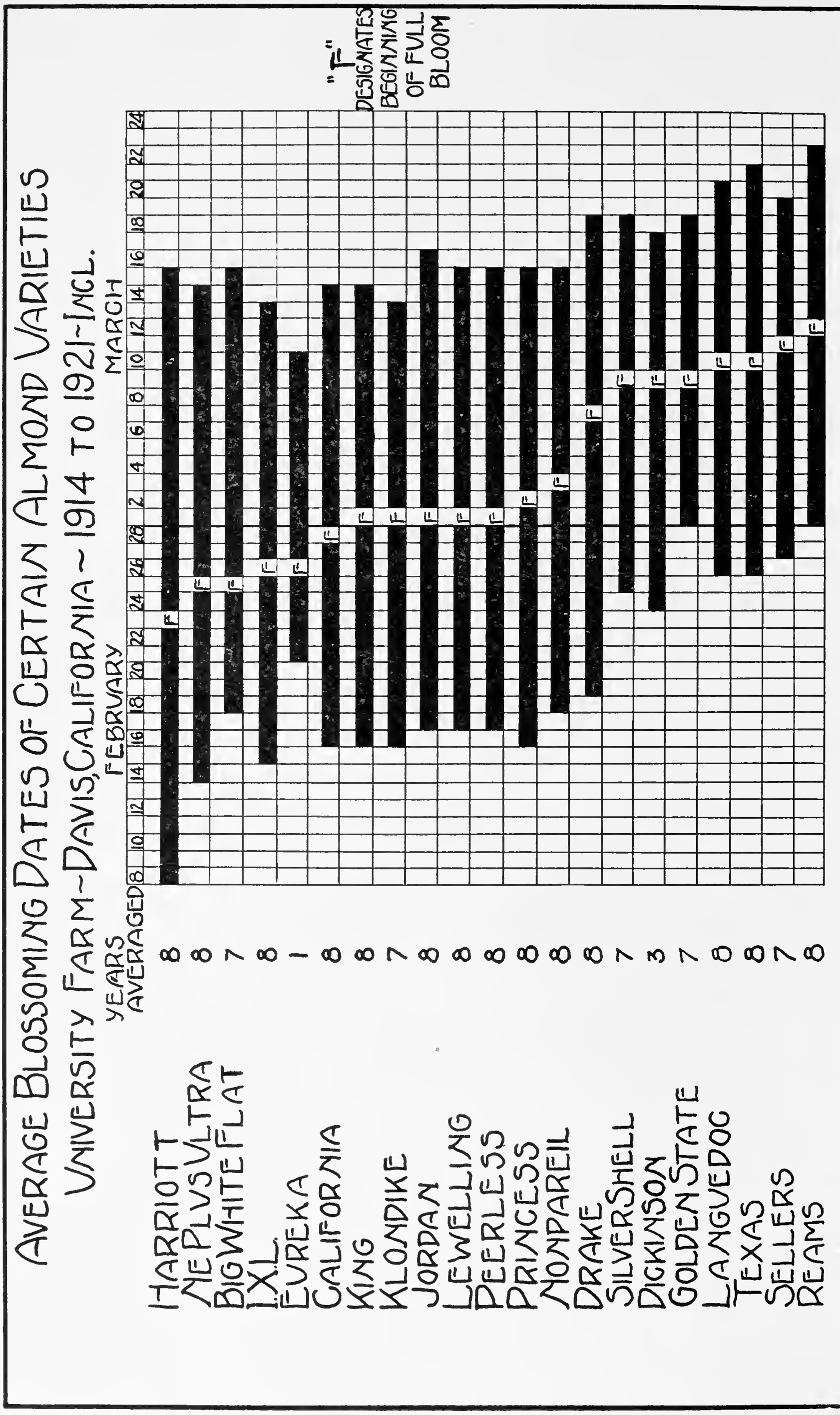

Fig. 2.—The average dates of the first, last, and full bloom of certain almond varieties covering a period, in nearly all instances, of eight years. The number of years averaged is shown in a separate column for each variety. (From Bul. 346.)

Almonds may be classed as early or late in time of blossoming, as given below. Nonpareil has been given in both lists since it occupies a position about midway.

Early		*Late*	
Big White Flat	Lewelling	Dickinson	Nonpareil
California	Ne Plus Ultra	Drake	Reams
Harriott	Nonpareil	Eureka	Sellers
I. X. L.	Peerless	Golden State	Texas
Jordan	Princess	Languedoc	
King	Silver Shell		
Klondike			

The accompanying chart, figure 2, gives the average blossoming dates of certain almond varieties. The date of bloom is dependent upon many factors, such as soil, season, and location.

With the exception of the above-noted cases of inter-unfruitfulness, any variety in either of the above lists may be used in most instances as a satisfactory pollinizer for any other variety in the same list. Table 1, compiled from the experiments of Tufts and Philp,[4] summarizes the pollination requirements for almonds. Variety names at the left of the chart indicate the tree, 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* in the table.

APPLES

Although this is not a complete list, apple varieties may be segregated according to their pollination requirements as follows:

Self-fruitful	*Self-unfruitful*	*Doubtful*
Baldwin	Arkansas	Ben Davis
Early Harvest	Arkansas Black	Esopus Spitzenburg
Grimes Golden	Delicious	Gano
Oldenburg	Fameuse	Jonathan
Wagener	Gravenstein	Rome Beauty
Wealthy	McIntosh	Tompkins King
Yellow Newtown	Northern Spy	York Imperial
Yellow Transparent	Rhode Island Greening	
	Stark	
	Stayman	
	Twenty Ounce	
	White Pearmain	
	Winesap	
	Winter Banana	
	Yellow Bellflower	

[4] Tufts, W. P., and G. L. Philp. Almond pollination. California Agr. Exp. Sta. Bul. 346:1–35. 1922.

TABLE 1

CHART SHOWING POLLINATION COMPATIBILITIES OF ALMOND VARIETIES*

Variety	Big White Flat	California	Drake	Eureka	Golden State	Harriott	I. X. L.	Jordan	King	Klondike	Languedoc	Lewelling	Ne Plus Ultra	Nonpareil	Peerless	Princess	Reams	Sellers	Silver Shell	Texas
	Source of pollen																			
Big White Flat	O					F							P							
California		O	G				G	F					F	G		F				
Drake		G	O	G			G	G			G		G	G	G					G
Eureka			G	O										G						
Golden State			G		O									G						
Harriott	G					O	G						G							
I. X. L.		G	F			F	O	G				F	G	O	G					
Jordan		P					P	O					F	F						
King									O				G	G						
Klondike										O			G							
Languedoc		G	G	G			F				O		F	F	F		F			O
Lewelling		F					G					O	G	G						
Ne Plus Ultra		F	F			G	G	G	G			F	O	G	F					
Nonpareil		G	G	G	G		O	G			G	G	G	O	G					G
Peerless		F	G	F			P	F			G		G	F	O					G
Princess													G	G		O				
Reams		G	G				G				G		G	G			O			G
Sellers			F											G				O		
Silver Shell			G																O	
Texas		G	G	G			G				O		G	G	F		G			O

G—Good; F—Fair; P—Poor; O—No affinity.

* Data from Bul. 346.

The varieties in the self-fruitful list will generally produce larger crops when cross-pollinated. Under most conditions, however, commercial crops will result when they are planted in solid blocks (self-pollinated).

The varieties in the unfruitful list are unsafe to plant alone and should be interplanted with some other variety for cross-pollination.

The varieties in the doubtful list will in some years, under certain conditions, produce commercial crops. The evidence indicates, however, that better commercial crops will result if provisions for cross-pollination are made.

Few cases of inter-unfruitfulness appear among apple varieties. Winesap, Arkansas, Arkansas Black, and Stayman seem to be inter-unfruitful and should therefore not be planted together. The Arkansas, Stayman, and Gravenstein are generally unsatisfactory pollen producers, a fact which makes them undesirable pollinizers for other varieties. Except for the cases indicated above, varieties which blossom together will cross-pollinate each other. The Delicious and Yellow Newtown seem to be the best varieties to cross-pollinate the Gravenstein.

CHERRIES

All commercial varieties of sweet cherries are self-unfruitful. Tests show that the following are self-unfruitful under California conditions:

Abundance	Burbank	Mezel
Advance	Chapman	Napoleon (Royal Ann)
Bing	Centennial	Pontiac
Black Heart	Cleveland	Rockport
Black Republican	Early Purple	Windsor
Black Bigarreau	Lambert	Wood
Black Tartarian	Major Francis	

Some varieties of sweet cherry are inter-barren—for example, the following, under certain conditions:

Bing, Lambert and Napoleon with each other
Rockport with Advance
Early Purple with Rockport

There are, apparently, different strains of certain cherry varieties or else different varieties so similar as to be indistinguishable. This condition exists particularly with Black Tartarian, of which there are at least five strains which vary greatly in their ability to pollinize, especially the Napoleon. More than one strain of Black Republican, from a pollination standpoint, exists.

No entirely satisfactory pollinizer has as yet been determined for Napoleon. In most cases, however, certain strains of Black Tartarian and Black Republican yield satisfactory results. Findings in Oregon show that the long-stemmed Waterhouse variety is a fairly good pollinizer for Napoleon.

Cherry varieties may be classed as early or late blossoming, as follows:

Early		*Late*	
Advance	Burbank	Bing	Pontiac
Black Heart	Chapman	Lambert	Rockport
Black Republican	Early Purple	Napoleon	
Black Tartarian			

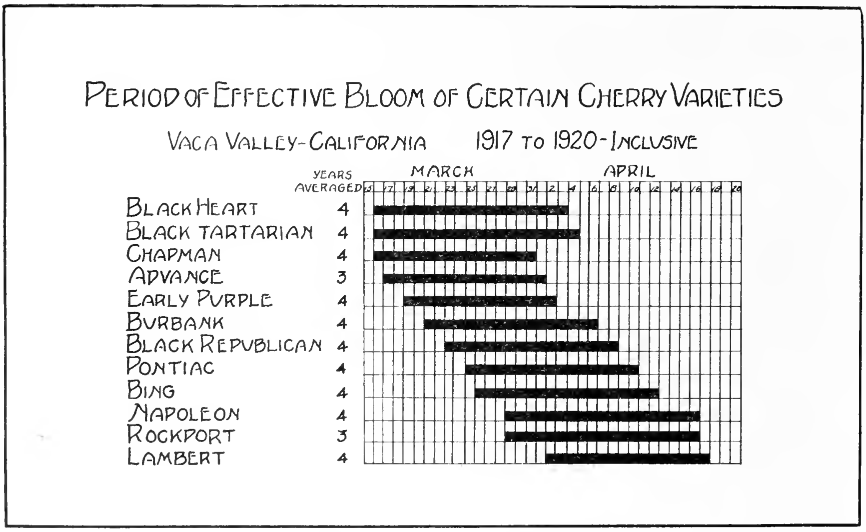

Fig. 3.—The period of effective bloom of certain cherry varieties, covering a period in nearly all cases of four years. The number of years averaged is shown in a separate column for each variety. (From Bul. 385.)

Black Tartarian and Black Republican generally overlap enough to pollinize most varieties in the second column.

The accompanying chart, figure 3, gives the average period of effective bloom for certain cherry varieties. The term *effective bloom* indicates the length of time the tree is in conspicuous blossom.

Table 2, compiled from the experiments of Tufts and Philp,[5] summarizes the results of cherry pollination. In some cases different results may be secured but in general this information will apply.

5 Tufts, W. P., and G. L. Philp. Pollination of the sweet cherry. California Agr. Exp. Sta. Bul. 385:1–28. 1925.

TABLE 2

CHART SHOWING POLLINATION COMPATIBILITIES OF SWEET CHERRIES*

Variety	Source of pollen																
	Abundance	Advance	Bing	Black Heart	Black Republican	Black Tartarian	Burbank	Chapman	Early Purple	Early Rivers	Knight	Lambert	Napoleon	Pontiac	Rockport	Schmidt	Windsor
Abundance	O	......	......	......	......	......	......	......	......	......	......	......	F	......	......	......	O
Advance	......	O	......	G	......	G	P	G	G	......	......	......	......	......	O	......	......
Bing	......	......	O	......	G	G	......	......	G	......	......	O	O	G	F	......	......
Black Heart	......	G	......	O	......	G	G	G	G	......	......	......	......	......	......	......	......
Black Republican	......	......	G	......	O	G	......	......	G	......	......	G	G	......	G	......	......
Black Tartarian	......	F	F	F	......	O	F	G	F	......	......	......	......	......	F	......	......
Burbank	......	F	......	G	G	G	O	G	F	......	......	......	......	......	F	......	......
Chapman	......	G	......	G	F	G	G	O	P	......	......	......	......	......	F	......	......
Early Purple	......	P	......	P	P	F	P	P	O	......	......	......	......	......	O	......	......
Early Rivers	......	......	......	......	......	......	......	......	......	O	......	......	G	......	......	......	......
Knight	......	......	G	......	......	G	......	......	......	......	O	......	......	......	......	......	......
Lambert	......	......	O	G	G	......	......	......	......	......	......	O	O	G	F	O	......
Napoleon	G	......	O	......	G	G	......	......	......	F	......	O	O	G	P	F	F
Pontiac	......	G	F	......	G	P	......	......	......	......	......	G	G	O	......	......	......
Rockport	......	O	......	F	G	P	G	P	F	......	......	F	P	F	O	......	......
Schmidt	......	......	O	......	O	O	......	......	......	......	......	O	O	......	......	O	......
Windsor	O	......	......	......	......	......	......	......	......	......	......	......	G	......	......	......	......

G—Good F—Fair P—Poor O—No affinity

* Data from Bul. 386, with supplementary data prepared by G. L. Philp.

PEARS

Twenty-six varieties of pears have been tested by the Pomology Division under various California conditions.

Only the Hardy variety has proved to be self-fruitful under all conditions and during all seasons. Fifteen of these twenty-six varieties tend, under certain conditions, toward self-fruitfulness.

Bartlett pears are, to a certain extent, self-fruitful under valley conditions, and, in most instances, self-barren under foothill conditions.

Winter Nelis showed a tendency toward self-unfruitfulness under all conditions tested.

No cases of inter-barrenness have been found to exist between pear varieties.

A summary of the pollination results secured by Tufts and Philp[6] segregates pear varieties into three groups, as shown in table 3.

[6] Tufts, W. P., and G. L. Philp. Pear pollination. California Agr. Exp. Sta. Bul. 373:1–36. 1923.

Those varieties in the doubtful list, although setting satisfactory crops under certain conditions, should for best crops be interplanted with some other variety.

TABLE 3

SUMMARY OF POLLINATION RESULTS WITH PEARS

Self-barren		Self-fruitful		Doubtful		
Variety	Years tested	Variety	Years tested	Variety	Number years self-fruitful	Number years self-barren
Alencon	2	Comice	4	Angouleme	1	1
Bloodgood	2	Flemish Beauty	1	Anjou	2	1
B. S. Fox	1	Hardy	3	Bartlett	5	2
Comet	1	Howell	3	Bosc	1	1
Forelle	2			Clapp Favorite	1	1
Le Conte	3			Clairgeau	2	2
Madeline	1			Col. Wilder	2	2
Winter Nelis	3			Dana Hovey	1	2
				Easter	1	2
				Gifford	1	1
				Glou Morceau	1	1
				Kieffer	1	4
				P. Barry	1	2
				Seckel	3	1

Pears have, in most cases, a comparatively short period of bloom. The varieties tested may be divided roughly as early and late blossoming, as follows:

Early		*Late*	
Alencon	Angouleme	Anjou	Bartlett
Bartlett	Clairgeau	Bloodgood	Bosc
Clapp Favorite	Easter	B. S. Fox	Comice
Dana Hovey	Howell	Comet	Glou Morceau
Forelle	Le Conte	Gifford	Winter Bartlett
Kieffer	P. Barry	Hardy	Winter Nelis
		Seckel	Col. Wilder

The following varieties, tested under California conditions, have proved to be successful pollinizers for the Bartlett:

Angouleme	Comice
Anjou	Dana Hovey
Bosc	Easter
Clairgeau	Forelle
Howell	Winter Nelis
Hardy	

PLUMS AND PRUNES

Nearly all Japanese plums are self-unfruitful. Methley, Climax, Beauty, and Santa Rosa are partially self-fruitful. Like the rest, however, these four varieties set much better when interplanted for cross-pollination purposes. The self-barren list of Japanese plums follows:

Abundance	Duarte	Prize
Amador	El Dorado	Satsuma
Apex	Formosa	Sultan
Becky Smith	Gaviota	Upright
Burbank	Kelsey	Wickson
Combination	Los Gatos	

The early Japanese varieties, being usually deficient pollen producers, are unreliable for cross-pollination. The late blossoming varieties are satisfactory pollen producers and may be interplanted safely. The Japanese varieties may be divided as early or late blossoming, as follows:

Early		*Late*	
Beauty	Kelsey	Abundance	El Dorado
Combination	Satsuma	Amador	Los Gatos
Formosa	Santa Rosa	Apex	Methley
Gaviota	Wickson	Burbank	Prize
		Climax	Sultan
		Duarte	Upright

Formosa and Gaviota are apparently inter-barren, or at least unsafe for planting together. Tragedy is able to pollinate several Japanese varieties but is not pollinated by them. Table 4, by Allen,[7] summarizes the pollination requirements of Japanese plums.

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[7] Allen, F. W. Plum growing in California. California Ext. Cir. 34:1–65 1929.

TABLE 4

CHART SHOWING POLLINATION COMPATIBILITIES OF JAPANESE PLUMS*

Variety	Source of pollen																				
	Self	Abundance	Amador	Apex	Beauty	Becky Smith	Burbank	Climax	Combination	Duarte	El Dorado	Flickinger	Formosa	Gaviota	Kelsey	Los Gatos	Methley	Prize	Santa Rosa	Satsuma	Upright	Wickson
Abundance	O	O					F	G														G
Amador	O		O			G		G							P							
Apex	O			O							P		P	P	P				P			
Beauty†	F			P	F		G			F	P		F	F	P				F			F
Becky Smith	O		O			O	F	F							O							
Burbank	O			P	G		O	G		G	P		P	P	P	G				G		G
Climax	G			P	G		G	G		G	P		P	P	P				F			F
Combination	O								O						O					P		P
Duarte	O			P	G		G			O	P		P	G	P				G			G
El Dorado	O										O								G			G
Flickinger	O											O										
Formosa	O			P	F		G			G	P		O	O	P				G			G
Gaviota	O			P	G		F			G	P		O	O	P				F			F
Kelsey	O			P	F			O			P		P	P	P				F			O
Los Gatos	O						G	G								O						G
Methley	F			G	G		G										F					G
Prize	O																	O				
Santa Rosa	F			P	G		P			P	P		P	P	P				F			G
Satsuma	O			P							P		P	P	P					P		
Upright	O												P	G					P		O	P
Wickson	O			P	F		F	P			P		G	F	P				G	G		O

G—Good; F—Fair; P—Poor; O—No affinity.

* Data from Extension Circular 34.

† Tragedy, an early blooming European variety, will also effectively pollinate Beauty, Formosa, Gaviota, Methley, and perhaps other Japanese varieties.

European plums (including prunes) may be classed as self-barren, self-fruitful, or doubtful, as follows:

Self-barren	*Self-fruitful*	*Doubtful*
Anita	California Blue	Conquest
Burton	Coates 1418 (Double X)	Grand Duke
Clyman	French	Pond (Hungarian)
Diamond	Giant	Stuart
Fellenberg (Italian)	Sugar	
Imperial	Yellow Egg	
Jefferson		
President		
Robe de Sergeant		
Quackenboss		
Silver		
Standard		
Sultan		
Tragedy		
Washington		

The doubtful list includes varieties which in some years may produce satisfactory crops with their own pollen but which one should probably not plant without providing for cross-pollination.

There is apparently no inter-unfruitfulness among Europeon plums. In some years, however, certain varieties do not set satisfactory crops. In general, varieties blossoming at the same time will cross-pollinate effectively. Although this is not a complete list, the following varieties may be grouped together according to the time of blossoming:

Early	*Mid-season*	*Late*
Clyman	Burton	California Blue
Tragedy	Coates 1418 (Double X)	Fellenberg (Italian)
	Diamond	Giant
	French	President
	Grand Duke	Pond (Hungarian)
	Imperial	Quackenboss
	Jefferson	Silver
	Robe de Sergeant	Washington
	Sugar	Yellow Egg
	Standard	
	Stuart	

Table 5, by Allen,[8] summarizes the pollination requirements of European plums.

[8] Allen, F. W. Plum growing in California. California Ext. Cir. 34:1–65. 1929.

TABLE 5

CHART SHOWING POLLINATION COMPATIBILITIES OF EUROPEAN PLUMS*

Variety	Source of pollen																										
	Self	Anita	Burton	California Blue	Clyman	Coates 1418	Conquest	Diamond	Fellenberg (Italian)	French	Giant	Grand Duke	Hungarian	Imperial	Jefferson	Pond	President	Quackenboss	Rose de Sergeant	Silver	Splendor	Standard	Stuart	Sugar	Sultan	Tragedy	Washington	Yellow Egg
Anita	P	P								G												F	F	G				
Burton	P		P							G											G		O	G				
California Blue	G			G				G			O	F		O			G											
Clyman	O				O			G				G	G			G										G		
Coates 1418	F					F				F				G										G				
Conquest	P						P			G														G				
Diamond	F			G				F				G					G									G		
Fellenberg (Italian)	P								P											G								
French	F									F				G					F					G				
Giant	G										G																	
Grand Duke	P			G	F			G			F	P					G									G		
Imperial	O									F				O										F				
Jefferson	P													G	P									G				
Pond (Hungarian)	F			G							G	F		F		F												G
President	O		G	G	F			G		G	G	G	F	G		F	O	F			G			G		F		F
Quackenboss	P			G				G				G					G	P										
Robe de Sergeant	P									G			G			G			P					G		G		
Silver	P								G											P								
Splendor	O	G								G											O		G	G				
Standard	O	G						G		G											G	O	G	G				
Stuart	F					G								O									F					
Sugar	G									G				G					F					G				
Sultan	O																								O			
Tragedy	O				G			G				F				P			G					P		O		F
Washington	O																										O	
Yellow Egg	G																											G

G—Good; F—Fair; P—Poor; O—No affinity.

* Data from Extension Circular 34 with supplementary data by A. H. Hendrickson, Associate Pomologist.

ARRANGEMENT OF POLLINIZERS

In planting an orchard where pollinizers are required, one should, if possible, have every sixth and preferably every fourth row 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. In some instances it is desirable to have a minimum number of pollinizers. Under these circumstances, one tree to eight, planted as every third tree in every third row, is recommended. This arrangement places a pollinizer next to every tree of the main variety in the orchard.

Certain conditions may make it advisable to graft a pollinizer into every tree to insure satisfactory cross-pollination. Such an arrangement will, of course, tend toward confusion in harvesting; when the pollination problem is serious, however, the grower can afford to forget the commercial value of the fruit on the pollinizing branch.

The suggestion given above is primarily for the orchardist whose mature trees, because of the planting of self or inter-barren varieties, have failed to fruit. During the years when one is waiting for the trees grafted over to pollinizing varieties to come into bearing, some relief may be obtained by cutting off branches of pollinizing varieties, placing the cut ends into vessels of water, and distributing them throughout the orchard during the blossom period. Such branches will live for several days and continue to bloom, forming pollen for the bees to transfer to the unfruitful variety.

THE HONEYBEE AS A POLLEN DISTRIBUTOR

The intimate relationship between bee life and plants is well known to students of nature. Certain bees require pollen and nectar for sustaining life; the pollen, in the case of the hive bee, is fed, along with other substances, to the larval forms; while nectar is converted to honey primarily for adult food. In many cases, the plants require the pollen from other varieties of the species for the setting of fruit and seed. Nectar, a weak sugar solution, attracts many insects; and its presence in close proximity to the stamens better assures visitation by the living pollen carriers. The bee wholly depends for existence upon the plant products—pollen and nectar; while, on the other hand, many plants would fail in productivity except for the presence of insects suitable for effecting cross-pollination.

POLLEN MANIPULATION BY THE BEE

The structures over the body of the worker bee are admirably designed for the efficient collection and transportation of pollen. In the first place, the whole body is densely clothed with hairs (fig. 4),

Fig. 4.—The body of the hive bee is completely covered with hair, in which the pollen grains become entangled. The bee, before it starts its return flight to the hive, combs the grains into the pollen basket. See figure 7.

which are barbed in such a way that pollen grains of varying size (figs. 5 and 6) cling to them. The legs, too, bear pollen-manipulating devices: each front leg, for example, has a notch of the proper diameter for stripping the antennae clean; the middle and hind legs have spines, spoon-shaped depressions (called pollen baskets), hair combers, etc.

The bee partially cleans its body of pollen grains by means of the combs and other structures. A large ball of pollen is finally formed in the pollen basket, on the outside of each rear tibia (fig. 7), from which it is removed after being carried to the hive. Many pollen grains remain scattered over the bee's body, even after combing, and it is believed that it is this pollen which effects cross-pollination. The labor and time expended in collecting a load of pollen are con-

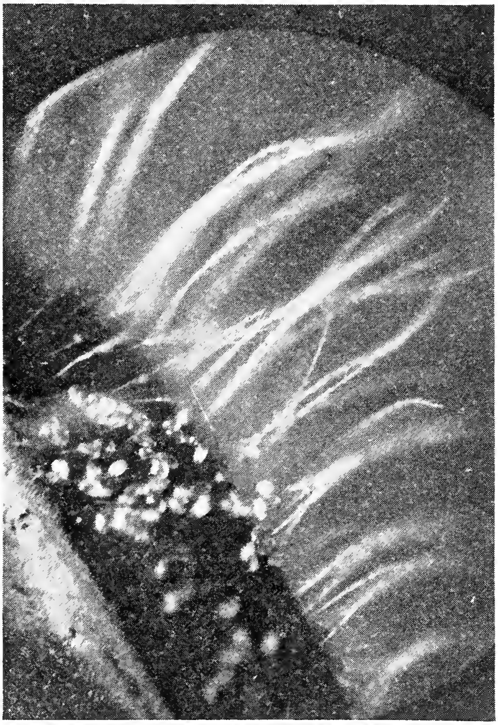

Fig. 5.—Photograph of femur from a bee's leg, showing hairs with pollen grains from some plant. This field bee was caught entering the hive, as it returned from a collecting trip. These grains come in contact with the viscid surface of the stigma as the bee pushes into the blossom for nectar or pollen, and bring about cross-pollination. Also see figure 6.

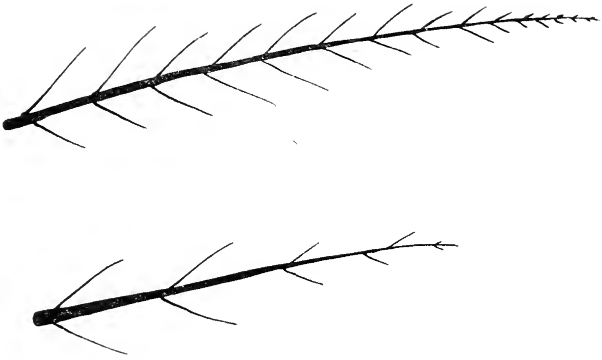

Fig. 6.—Diagrammatic sketches showing arrangement of barbs on the hairs of bees. The pollen grains cling on the hair between these barbs. The irregular spacing of barbs on the hair shaft is an adaptation suited to picking up pollen grains of varying size and shape. See also figures 5 and 8.

Fig. 7.—Hind legs of hive bee with large mass of pollen in the pollen basket upon the outside of the tibia. Note the combs on the first tarsal segment. The parts of the leg are the coxa (a), the trochanter (b), the femur (c), the tibia (d), and the five tarsal segments (e).

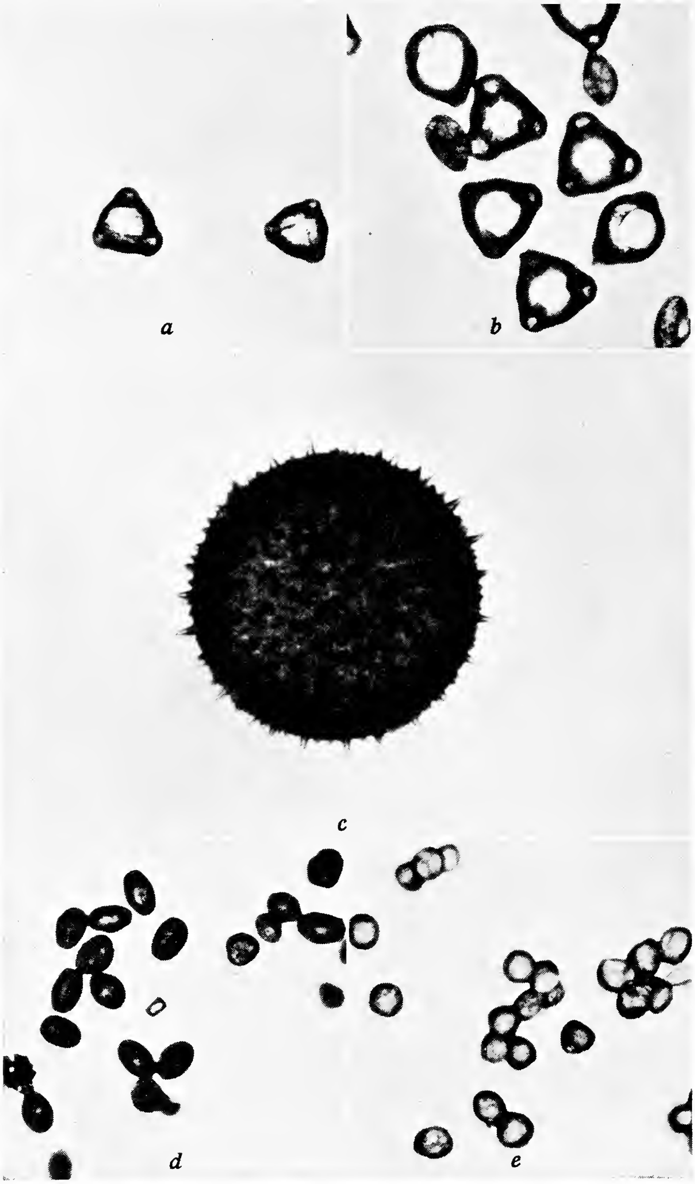

Fig. 8.—Photographs of pollen grains, indicating comparative size and shape: (a) cherry, (b) almond, (c) hollyhock, (d) olive, and (e) date palm. Magnification of all, × 250. Also see figures 5 and 6.

siderable: often a bee spends an hour in working over the anthers of the blossoms (fig. 1) before returning to the hive. The different kinds of pollen (fig. 8) are stored in the cells of the comb until needed for feeding the bee larvae. Pollens from different plant species are of various color (white, yellow, brown, blue, red, etc.), a fact which facilitates their identification in the comb cells.

SOME COLLECTING HABITS OF BEES OF VALUE IN FRUIT POLLINATION

Bees, whether collecting pollen or nectar, usually visit on a particular trip but one species of plant. Where blossoms are scarce, the bee may be forced to collect from more than one species; but such is not the case during fruit blossoming. Some species of plants are definitely preferred to others. The time of day influences availability of both nectar and pollen, so that activity shifts from one plant to another: for example, filaree, in the orchards, is very attractive during the early morning; but most of the blossoms close by 10 o'clock on sunny days. Apparently some of the fruits secrete nectar most freely during the night; bees quickly harvest this in the morning and then shift to some other plant. During certain seasons, for example, this change from prunes to mustard is particularly noticeable. Very often pear blossoms are less attractive than others which are open at the same time. Bees like apple blossoms particularly: they will sometimes leave pear for cherry and cherry for apple. In certain areas, at least, bees visit pear blossoms for pollen only, ignoring the nectar which is plainly visible. Some recent work indicates a variation in sugar concentration for various nectars, which may explain the periodic preference shown by bees for certain flowers.

SPRAYING DETRIMENTAL TO BEES

The problem of spray poisoning is often acute for bees near orchards where arsenic or nicotine is used on the plants. Not only are the nectar and pollen of trees contaminated, but those of the covercrop as well. In addition, bees drink up dew from leaves and thus may secure a fatal dosage of poison, so that one cannot entirely eliminate this source of loss even by properly timed spraying. Wherever covercrops occur in orchards, the spray poison problem is particularly serious. Beekeepers and fruit growers must, in short, cooperate if loss of bees is to be reduced to a minimum; and the beekeeper should receive timely warning to move out before spraying operations begin.

SET OF FRUIT NOT DEPENDENT UPON BEES ALONE

The need for more insects to bring about cross-pollination in areas of fruit concentration is well recognized by scientific workers and many orchardists. One must emphasize the fact that a supply of pollinating insects alone is not sufficient to cause a commercial set of fruit, but that other factors, such as favorable weather and suitable varieties properly planted, are also important. The fact that hive bees are efficient pollen distributors which can be placed where and when wanted, needs only to be mentioned.

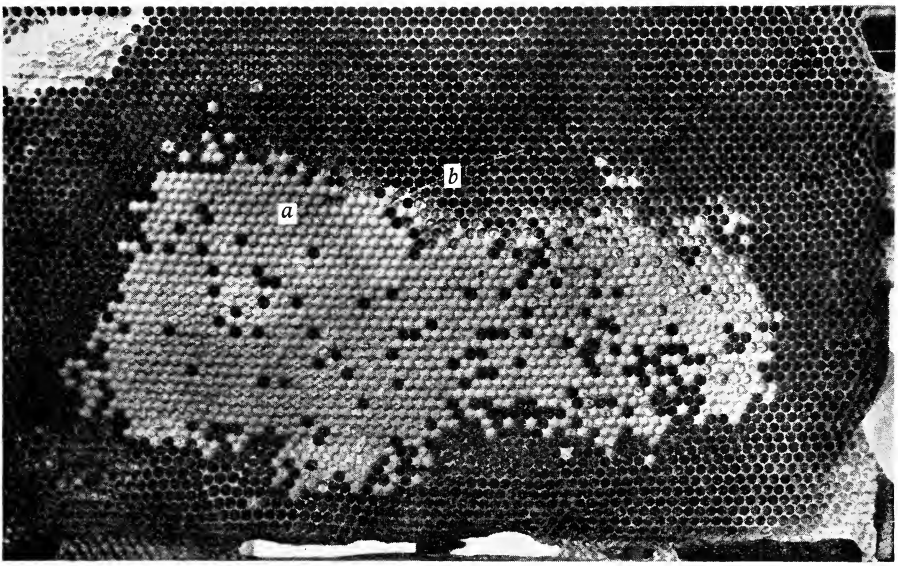

Fig. 9.—A bee comb illustrating the large area occupied by brood during fruit blossoming time; five to ten combs are necessary. Both sealed (a) and unsealed brood cells (b) as well as honey (upper left) may be seen. During periods of low temperature, as often occur during fruit blossoming time, all the bees in a weak colony may be needed in the hive to keep up the temperature for brood; therefore, it is only in the case of strong colonies that there are bees available for field work.

BEEKEEPING A SPECIALTY

The fruit-grower is usually too busy with orchard problems to become an efficient beekeeper. Bees require considerable attention *throughout the year* if they are to be strong in numbers at the end of winter. Only strong colonies will prove of much value during early spring, when a large number of bees are required in the hive to maintain the brood nest temperature at 95° F (fig. 9). Generally, the most feasible plan for securing pollinating insects is to rent bees from highly skilled beekeepers. The importance of an early agreement must be stressed, because many cases of bee shortage are annually reported too late for correction.

NUMBER OF BEES REQUIRED FOR POLLINATION

The usual recommendations call for one colony of bees to the acre of fruit to be pollinated. The condition of the weather so affects results, however, that often more bees would justify their cost, while at other times even the prescribed number probably exceeds actual requirements. According to one beekeeper at Oroville, a section near him has 10,000 acres of prunes and 3,000 acres of pears with a bee population of only 1,000 colonies (1930). This number of bees must certainly be inadequate for best results, particularly when the general insect population, because of weather conditions or other cause, is low. Table 6 shows the acreage of fruits (exclusive of grapes) and the registered number of colonies of bees in the counties of California. The colony figures are primarly from the State Department of Agriculture registration list for 1929.

TABLE 6

LIST OF CALIFORNIA COUNTIES WITH FRUIT ACREAGE AND NUMBER OF BEE COLONIES

County	*Bearing fruit acreage**	*Colonies of bees*
Alameda	7,708	2,944
Alpine	1	2
Amador	970	48
Butte	21,864	8,449
Calaveras	507	224
Colusa	3,687	6,322
Contra Costa	12,417	3,321
Del Norte	4	71
Eldorado	5,374	662
Fresno	43,911	16,875
Glenn	8,497	5,931
Humboldt	1,665	1,531
Imperial	4,930	19,639
Inyo	1,102	3,640
Kern	8,470	11,142
Kings	13,191	5,911

* These figures do not include grapes.

TABLE 6—*Continued*

County	*Bearing fruit acreage**	*Colonies of bees*
Lake	7,141	120
Lassen	185	981
Los Angeles	71,567	38,389
Madera	9,079	2,010
Marin	633	443
Mariposa	263	67
Mendocino	5,295	1,068
Merced	20,485	8,188
Modoc	434	1,114
Mono	74	100
Monterey	8,823	4,546
Napa	14,528	1,217
Nevada	2,349	199
Orange	49,159	15,742
Placer	30,910	311
Plumas	34	47
Riverside	39,835	22,585
Sacramento	24,399	5,864
San Benito	15,532	404
San Bernardino	74,055	39,830
San Diego	12,379	30,279
San Francisco	....	67
San Joaquin	21,308	13,573
San Luis Obispo	5,826	3,438
San Mateo	1,843	188
Santa Barbara	3,197	4,846
Santa Clara	102,617	3,275
Santa Cruz	18,775	538
Shasta	2,173	4,510
Sierra	19	118
Siskiyou	364	1,256
Solano	24,062	2,139
Sonoma	42,994	2,157
Stanislaus	31,343	8,200
Sutter	45,329	4,846
Tehama	8,228	4,728
Trinity	26	163
Tulare	76,377	11,446
Tuolumne	2,071	408
Ventura	11,900	14,873
Yolo	15,078	3,511
Yuba	9,663	1,031

* These figures do not include grapes.

PLACING THE BEES IN THE ORCHARD

Bees are moved into orchards of this state almost entirely by motor truck or trailer. The actual move is usually made during the night. The entrances of the hives are as a rule closed, before moving, with some screening device or cloth material. During hot weather a moving-screen, in place of the hive cover, is essential for ventilation.

The recommendation of one hive to the acre does not mean that one hive should be located on each acre. Under normal conditions it is seldom that bees are left in orchards in groups under ten colonies. The manipulation of single colonies is too difficult, particularly after rains; also the increased time and labor required for removal of scattered colonies adds to the expense. Sunshine, wind, temperature, rain, and other factors outside of the hive affect the flight of bees; therefore, general recommendations cannot be given relative to the proper placement of the colonies in the orchard. If the weather is fair and warm, during fruit-blossom time, bees can undoubtedly fly far enough to cover 100 acres or more of fruit from one location; on the other hand, during a cold wet season flight is very limited. The absence of fruit or nuts, except within a few rows distant from the bee location, is occasionally reported following a particularly bad spring.

Under average conditions bees in groups of 10 to 20 colonies, for as many acres surrounding them, have been found very satisfactory both to the fruit grower and the beekeeper. Accessible situations along roadways in the orchards should be chosen, because of mud as well as the difficulty of driving the trucks among the trees at night.

The bee population as is evident in the table is strikingly low, in comparison with the fruit acreage, for several of the important fruit counties in northern California, notably Eldorado, Napa, and Nevada. Some beemen regularly move bees into these fruit areas on a rental basis. A factor partly responsible for this low resident bee population is the presence of the detrimental California buckeye tree. The lack of a major honey plant also greatly reduces the possibility of profitable beekeeping. Undoubtedly the intensive insecticidal spraying operations practiced in many deciduous fruit areas play a part too in further reducing the number of bees.

To the southward, on the other hand, the number of colonies of bees increases greatly in proportion to the fruit acreage requiring pollination. In the upper end of the San Joaquin Valley, for example, at the present time, bees are rarely rented to the fruit grower for pollination purposes. Beemen are, in fact, very desirous of locating near deciduous fruit orchards to enable their colonies to build up early in preparation for the orange honey flow during April. Tulare County alone has some 33,000 acres of citrus fruits.

COST OF RENTING BEES

The rental price paid by the fruit grower for bees in orchards depends upon several factors: for example, necessary moving distance, condition of roads, local rainfall, and supply of bees, coupled with demand. In a given area, like the Santa Clara Valley, rental possibilities change with time: during the World War, for example, with the accompanying high price of prunes, many bees were moved in from the vicinity of Modesto at $5.00 to $7.00 per colony for the blossoming period. Now but few bees are taken in—mostly for cherry orchards, at $2.00 to $2.50 rental. The beekeepers, in fact, find it difficult to surmount the barriers set up by the sentiment of pear growers concerning blight. The present rental demand for bees in California comes largely from almond and plum growers, though the cherry, apple, and foothill pear growers also rent a good many colonies.

The earlier in the fall a fruit grower can place his order for bees, the greater the chance for satisfactory accommodation, because after the orchard becomes muddy, moving is difficult. Experience has taught beekeepers the unprofitableness of renting colonies at current prices when expensive moving problems arise. The average rental price at present is perhaps $2.00. The fruit growers should insist on good, strong colonies, for these are by far the most efficient in pollination.

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