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Experiment Station

POLLINATION OF THE APPLE

By C. I. LEWIS and C. C. VINCENT

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SUMMARY.

This bulletin treats of the following phases of pollination:—First, the technique of pollination; second, the determination of the sterility and fertility of a large number of varieties of apples; third, the determination of the best pollenizers for the Spitzenburg; fourth, the improvement by crossing of self-fertile varieties like the Yellow Newtown. The contents of this bulletin can be summarized as follows:

1 It was due to early writers such as Sprengel, Knight, and Darwin, that light was thrown upon pollination problems. This work served as a stimulus for horticulturists to investigate these problems.

2. The unsatisfactory method of emasculating the blossom has been one of the principal reasons why pollination experiments have not been conducted on a larger scale. A system of emasculation is outlined in this bulletin which greatly facilitates matters, allowing for greater rapidity in making the operation and insures against mutilation of the blossom and malformation of the fruit.

3. The small camel's hair brush is a practical and efficient way of applying the pollen to the stigmas of the pistils. Considerable controversy has arisen as to the time of making the application. We have obtained very satisfactory results by applying the pollen at the time of emasculation.

4. The question of collecting an adequate supply of pollen for pollination purposes is a serious one. A solution to this problem is found by resorting to the forcing house. Here pollen can be ripened quite rapidly.

5. Out of 87 varieties of apples worked with, 59 varieties were found to be self-sterile; 15 varieties self-fertile; and 13 varieties partially self-fertile.

6. Many varieties of apples naturally tend to be self-sterile, when limited to their own pollen.

7. Results indicate that cross-pollination is the rule, and self-pollination the exception.

8. A knowledge of the mutual affinities between the different varieties must be gained.

9. Some pollenizers for the Spitzenburg have been ascertained. Sixteen varieties of apples were found to cross successfully with this variety. A few, such as the Yellow Newtown, Ortley, Arkansas Black, Jonathan, Baldwin, and Red Cheek Pippin (Monmouth Pippin), are very promising.

10. In some instances the immediate effects of pollen on the color of the fruit were perceptible.

11. With an increase in the weight of the crossed apple, there was a proportional increase in the weight of the seeds.

12. The action of foreign pollen on the Yellow Newtown, a self-fertile variety, was very pronounced.

13. Many of the self-fertile varieties of apples, when self-pollinated, were found to be seedless, or devoid of plump seeds.

14. An improvement in the size of the self-fertile varieties can be made by crossing.

15. Out of 18 varieties that we have found to cross with the Yellow Newtown, a few, such as Spitzenburg, Jonathan, and Grimes Golden, have given excellent results.

16. The pollen-producing powers of 87 varieties of apples are given.

17. Some pollenizers for 20 different varieties of apples have been determined.

18. Wind is a poor agent in transferring pollen from tree to tree. Bees and insects appear to be the principal pollen distributers.

19. The floral envelope serves to attract the attention of the bees. They will, however, to a certain degree, visit blossoms in which the floral envelope has been removed.

20. The blooming period is given of 95 varieties of apples, 31 varieties of pears, and 17 varieties of cherries. A classification into early and late bloomers is made showing what varieties will blossom together for cross-pollination.

21. Climatic conditions influence, to a certain degree, the relative blooming periods of the different kinds of fruits.

22. In frosty localities varieties can be selected with reference to their time of blooming, thus partially eliminating the difficulty of a failure of fruit.

23. We found that pollen was capable of maintaining its viability for three weeks, provided it was not allowed to ferment.

24. The length of time different kinds of fruits remain in blossom at this Station are as follows: Apples 13 days, pears 11 days, and cherries 10 days.

POLLINATION OF THE APPLE.

By C. I. LEWIS and C. C. VINCENT.

INTRODUCTION.

It was not until the close of the last decade, that the significance of pollination of apple and pear blossoms came into prominence. Through the efforts of M. B. Waite, in the U. S. Department, of Agriculture, intelligent light was thrown upon this important question.

As far back as 1793, the importance of insects in pollination was impressed upon the minds of many investigators, and Mr. Sprengel, a German writer, published a book, entitled, "The Secret of Nature in the Form and Fertilization of Flowers Discovered," which proves to be an effective stimulus for future work upon this interesting study.

While Sprengel's work was practically forgotten, other investigators were making acute observations on the cross-fertilization of flowers, which completely overthrew the theory advanced by Sprengel, of the independent creation of species. Not long after Sprengel's book appeared, Andrew Knight carried on some very interesting experiments on the cross, and self-fertilization of the pea and arrived at the conclusion that in no plant does self-fertilization occur for an unlimited number of generations.

But it was not until after the appearance of Darwin's "Origin of Species" that Knight's theory was emphasized as a general law of nature. At this time the real value of Sprengel's work was realized and his discoveries opened up new paths for investigation, especially along the lines which were to determine the forms of flowers.

In Darwin's "Origin of Species," cross-fertilization was emphasized, but no special significance was attached to this discovery until the appearance of his second work, entitled, "Various Contrivances by which British and Foreign Orchids are fertilized by Insects." When summing up his work he states, "Nature abhors perpetual self-fertilization." Not content with these results, he explored new lines of investigation and from his careful observations noted differences in the action of pollen on the same and another flower. Darwin's work, "Variation of Animals and Plants under Domestication," suggests many interesting lines for original research work, and from these suggestions experimenters have branched out into new fields of investigation.

It was largely through the efforts of Darwin, that Waite carried out the experiments outlined in his bulletin, "The Pollination of Pear Blossoms." Since then many investigators, such as, F. A. Waugh, S. A. Beach, C. P. Close, M. M. Munson, S. W. Fletcher, U. P. Hedrick and many others from the Agricultural Colleges in the United States have worked on pollination problems. Likewise H. Mueller-Turgau, O. Kirchner, Dr. Ewert, of Europe, have also carried on many investigations and experiments on this subject. The many reports sent into this station from various parts of our State complaining of the lack of setting of fruit have led to investigations on this problem by this Department, some of which are reported in this bulletin.

The authors wish to acknowledge the valuable assistance given by other members of the Department, namely, Messrs. Wicks, Cole, Allen and Palmer.

METHOD OF EMASCULATION.

Any one contemplating the carrying on of pollination experiments must have a thorough knowledge of the parts of a flower before a high degree of success can be obtained. Next, it is necessary to learn the operation of emasculating, which consists in removing the anthers from the the flower. The object of this process is to prevent self-pollination. To remove these anthers in the best possible way is a serious question with many investigators. At this station, the writers have received excellent results by the use of the method outlined below and have made from 600 to 1,000 emasculations per day. In carrying on work of this nature rapidity as well as efficiency must be sought.

Method.—Grasp the blossom with the thumb and forefinger of one hand and grasp the tips of the petals with the thumb and

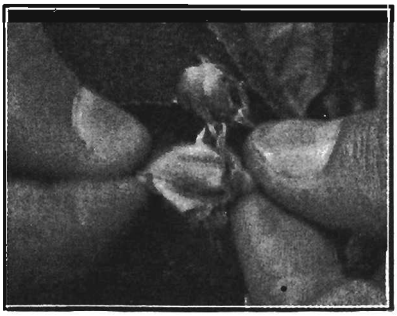


Plate 1.—First step in emasculation.

forefinger of the other hand (Plate 1), then by simply giving the wrist a quick upward or downward movement, the petals can be easily detached from the blossom, (Plate 2). Now with one or two

quick movements with the scissors, (Plate 3), the anthers are removed and the pistils are ready to receive the pollen, (Plate 4). After the application of pollen is made, the emasculated blossom is enclosed

Plate 2.—Removing the petals.

Plate 3.—Removing the stamens.

Plate 4.—Applying pollen to the pistils.

within a bag (Plate 5), and allowed to remain until fecundation has taken place and all danger from the action of foreign pollen is over.

After every pollination, label each bag in such a way that there will be no question as to what variety of pollen is used. As the apples approach maturity it is essential that they be inclosed in cheese-cloth bags. This protects the fruits from being picked accidentally. The object in removing the petals, is to tell just where to make the cuts without injuring the other parts of the flower. Since this greatly facilitates the method of emasculating, it may serve as an impetus for greater work along this line.

Several methods of emasculating the blossoms are used by different investigators throughout the United States. Waite, of the Department of Agriculture, removes the corolla with the aid of a small sharp pair of scissors, leaving the emasculated blossom as seen in Plate 6, Fig. 1. Others have been fairly successful in using a sharp scalpel to perform the work. We have found that in every case when the sepals were removed with the petals, it caused a malformation of the apple as shown in Plate 7, Fig. 1. Fig. 2 shows normal apple when sepals are unmolested.

It is evident that emasculation must be skillfully done, for the slightest mutilation causes a malformation of the calyx end of the apple. When the sepals were not injured in any way a larger percent of the emasculated blossoms set fruit. Plate 6, Figs. 1 shows the wrong way of emasculating, and Fig. 2 the correct way of emasculating. The method of removing the blossoms as outlined by the writers leaves the sepals in perfect condition with the fruit unharmed.

COLLECTING POLLEN.

One of the greatest problems the plant breeder has to meet is the collecting of an adequate supply of pollen for work on a large scale. It is evident that where many of our leading varieties blossom together, pollen must be gathered in sufficient quantities beforehand, if extensive experiments in cross-pollination are to be carried on.

Since this is the case, means must be provided by which the blossoms can be forced. To accomplish this, a forcing house is very desirable, although for work on a small scale any house having quite a few windows on the south side would answer the purpose. The following picture, (Plate 8) shows a house that has given good satisfaction at this station.

Selecting Twigs.—Small twigs from 10 to 20 inches in length, having from three to six clusters of blossoms, are gathered from the variety which is to be used as a pollenizer and taken to the forcing house. First, all the open blossoms are removed from the twigs which are then placed in jars of water and properly labeled, then covered with hoods so as to prevent the transfer of pollen by insects.

Usually the twigs are placed in the forcing house a week or two before the trees come into blossom. If the weather is good the blossoms will open in three or four days. If, however, it is desired

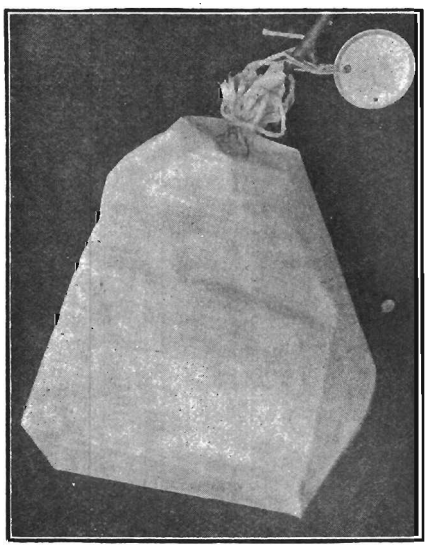


Plate 5.—Method of bagging the blossom.

Plate 6.—Figs. 1 and 2. Fig. 1. Improper emasculation, sepals being injured. Fig. 2. Proper emasculation, sepals intact.

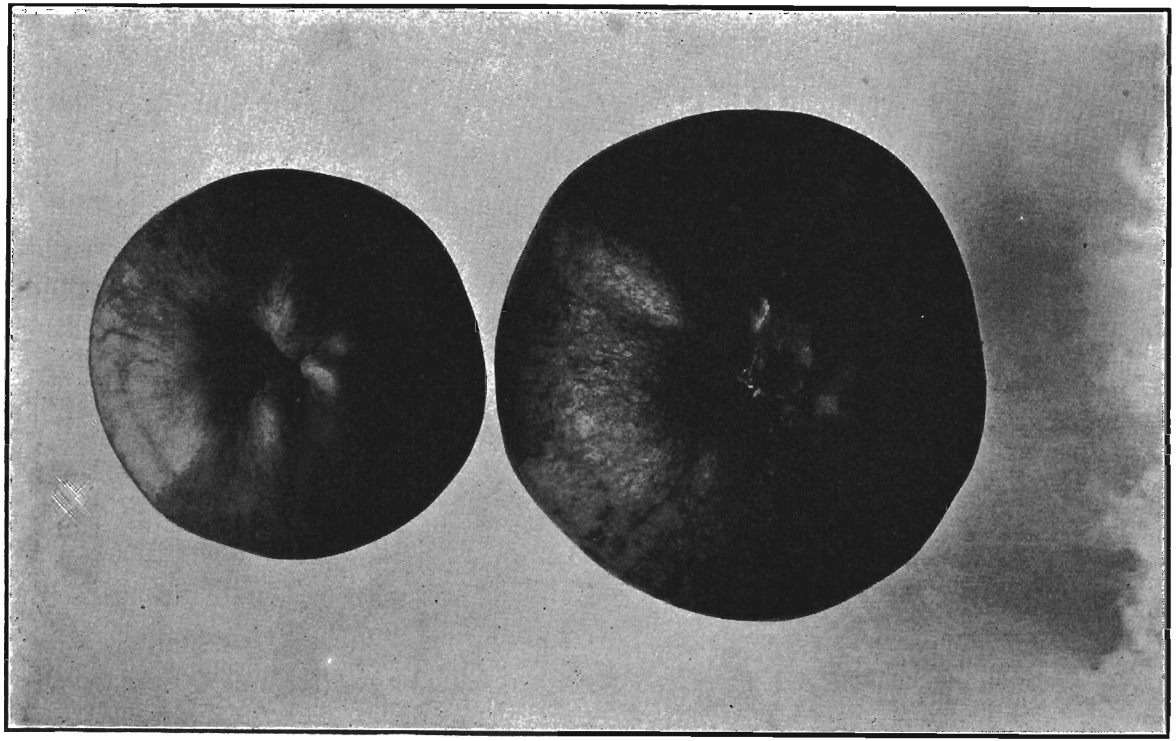


Plate 7.—Figs. 1 and 2. Fig. 1. Malformation, caused by cutting sepals when emasculating. Fig. 2. Normal apple, as a result of allowing sepals to remain.

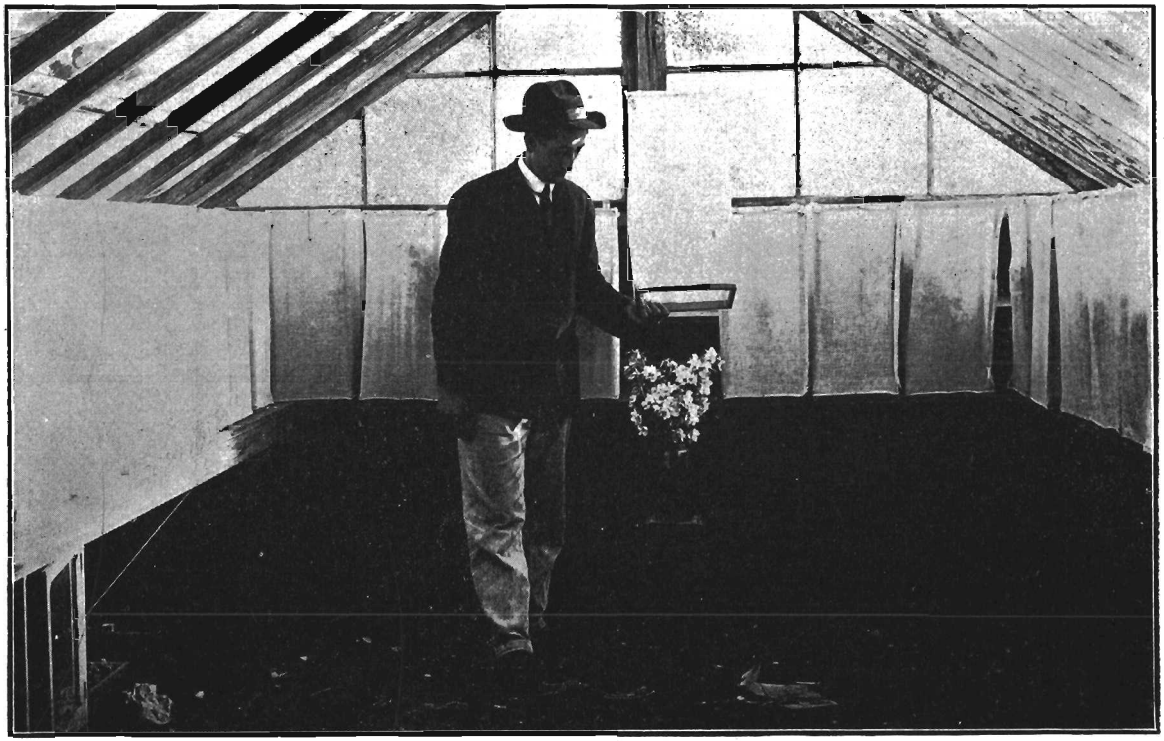


Plate 8.—Showing method used in forcing blossoms for pollen production. The hoods prevent introduction of foreign pollen by insects.

to obtain quicker results it can very easily be accomplished by using warm water in place of cold water. By splitting the stems of the different twigs the blossoms can be forced open from three or four hours earlier. In the experiments carried on a gain of from one to two days was realized by the use of warm water and the splitting of stems.

After the anthers dehisce and the pollen become ripe, a small vial, properly labeled, is used to collect the pollen. By removing the hoods the pollen can be very easily dusted into the vials with the aid

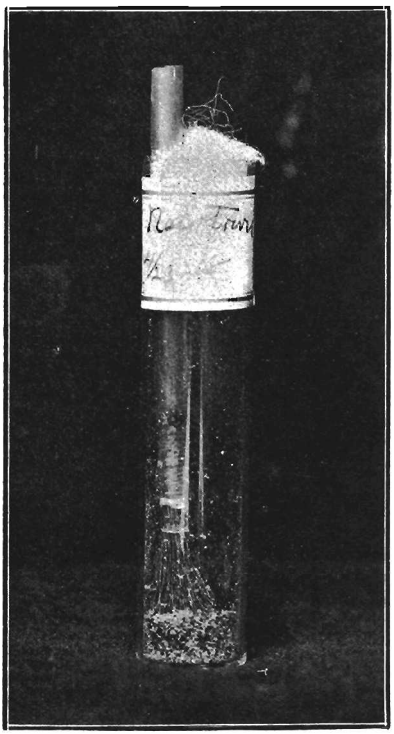


Plate 9.—Showing method of collecting and transfering pollen.

of small camel's hair brushes. Plate 9 shows the vial, properly labeled and plugged with cotton, which is used by the writers to carry the pollen to the orchard. In these vials the pollen will keep until ready for use, if sufficiently dried. If it is not dried enough fermentation will set in quite easily. Very gratifying results have been obtained by collecting the pollen in this manner. At the present time it is unknown just how long pollen can be kept before losing its viability.

At this station good results have been received from pollen that had been gathered three weeks.

One of the simplest ways of procuring pollen is to cover, with paper sacks, branches that are nearly in flower, and the ripened anthers from these blossoms can be used for pollination purposes. Another method is to put in a warm room, unripe anthers from flowers about to open. In a few hours the anthers will dehisce. Many pollenizers use this method in cases of emergency. Perhaps the most popular way of collecting pollen is to pick off the unopened buds, remove the anthers and let them dehisce.

After trying some of these methods outlined we decided that better results could be obtained by the use of the forcing house. In a small house, 12 by 14 feet, containing from 12 to 30 jars of blossoms, sufficient pollen can be gathered to carry on very extensive experiments in cross-pollination.

APPLYING POLLEN TO THE PISTILS.

How to Apply.—We have found that the quickest and most effective way of applying the pollen to the pistils is by the use of a small, pointed camel's-hair brush, having a handle from 6 to 8 inches in length. (See Plate 4.) While in this way more or less pollen is wasted in making the application, nevertheless the disadvantages are greatly offset by the advantages. Brush pollination is very effective, also allowing for great rapidity, and when a great many thousand blosssoms must be pollinated, is the most practicable method used. The simplest way of applying pollen is to touch the stigma with a dehisced anther. Another method is to dip the thumb or forefinger in the pollen, and then transfer to the stigma of the pistil.

When using the camel's hair brush too much care cannot be exercised in making the application. Enough pollen should be placed on the stigma, so that it can be readily perceived. In all cases each kind of pollen for each variety pollinated, must have its own brush, if scientific results are to be obtained. By sterilizing the brushes they can be used over and over again.

When to Make Application.—There appears to be considerable controversy as to the best time of applying the pollen to the pistils. The indications are that much depends upon the maturity of the buds whether or not a pistil is receptive at the time of emasculating. The receptiveness of the pistil is also influenced by such elements as climatic conditions, vigor and age of tree, variety, condition of soil, and general care of orchard.

The paramount question to settle is whether better results can be obtained by applying the pollen at the time of emasculation or waiting until the pistil is receptive. From the deductions made of the work carried on by this station excellent results have been obtained by applying the pollen to the pistil as soon as the blossom is emas-

culated. However, this may have been due to the fact that the blossoms operated upon were those that would probably open under normal conditions in one day from the time the operation was performed.

From the results obtained it is evident that in a great many varieties, the pistils are receptive before the blossoms open. This being the case it tends to show that nature encourages cross-pollination rather than self-pollination. One of greatest advantages of pollenizing at the time of emasculating is the saving of time, as the bags will not have to be removed.

There are many plant breeders that do not make the application until two or three days after the blossoms have opened. These men have also received very satisfactory results. Prof. S. W. Fletcher, of the Virginia Agricultural College, usually waits until the stigma of the emasculated blossom glistens before making the application. Many other investigators pursue the same method. By consulting tables 4 and 7 the percentages of successes of the two methods can be readily seen.

POLLEN TRANSMITTED THROUGH THE AIR.

It has been a question in the minds of many experimenters for some time, just how much the wind aids in carrying pollen from tree to tree. If the wind does aid in distributing pollen, is it distributed in sufficient quantities to insure the fertilization of the ovules? Since so many of our varieties of apples are known to be self-sterile and must depend upon foreign pollen for fertilizing the ovules, this question is of serious consequence. Is it the wind or our common honey bee that does the work? From the observations made the past two years, it is evident that bees play an important part in the fertilization of the blossoms. To arrive at some definite conclusions as to how much pollen is transmitted through the air by the wind, experiments were carried on to determine this question. Waugh, of Massachusetts, demonstrated that plum pollen was not transmitted through the air in sufficient quantities to insure cross-pollination. To substantiate his statements, the authors carried on some experiments with plums, as outlined by him, and arrived at the same conclusions.

To determine whether apple pollen was carried through the air by the wind, in sufficient quantities to insure cross-pollination, experiments were conducted in the following manner. Small glass slides 1x3 inches were smeared with vaseline and placed at different distances and at different heights from certain large trees in the orchard. In this case two of the largest trees in the orchard, the Rome Beauty, and the Mammouth Black Twig, were selected. After an exposure of 24 hours the slides were taken to the laboratory and examined under the microscope. The following table indicates the results obtained:

Table 1—Showing Distribution of Pollen by Wind.

Slide Number	Distance from trunk of tree	Height of slides	Number pollen grains
1	4 feet	On ground	16
2	12 "	6 feet	9
3	15 "	4 "	11
4	15 "	6 "	8
5	20 "	9 "	6
6	30 "	6 "	7

During the experiment a strong north wind was blowing, and the trees were in the height of their blooming period. The conclusion to be drawn from this experiment is that the wind cannot be relied on as an agency to transfer pollen from tree to tree throughout the orchard.

To verify our last experiment the following work was carried on. A 7-year-old tree, containing 1,500 blossoms, was emasculated and left exposed to the wind and insect visitation. The object of this experiment was two-fold:—First, to determine if pollen was transmitted through the air in sufficient quantities to insure cross-pollination; second, to determine if removing the floral part of the blossom would affect the visits of insects. The tree operated upon was located about 20 feet from another tree that blossomed profusely. It is generally conceded by many experimenters that the honey bee is attracted to the blossom by the inflorescence. The results obtained will be a fair index as to the truth of this statement. Out of the 1,500 blossoms emasculated only 5 set fruit. During the whole period that the pistils of these blossoms remained receptive, only 8 bees visited the tree. More than twice that number was seen in one-half hour on the tree 20 feet away. Since only a small portion of the emasculated blossoms set fruit, it is manifest that pollen is not transmitted through the air in sufficient quantities to insure cross-pollination. While this experiment demonstrated the fact that bees will visit trees when the floral part of the blossom is removed, they are not attracted in sufficient numbers to insure perfect pollination. It is apparent that the showy petals of the blossoms aid materially in attracting the bees. The blossom is well supplied with nectar, and the open character of nectary makes it accessible to almost all insects. The bees, in trying to reach the nectar, brush against the anthers and carry away with them, on their hairy legs and abdomen, large quantities of pollen. The insects in visiting other blossoms transfer some of the foreign pollen to these pistils. Since the wind aids so little in cross-pollination it is evident that the various insects, especially the bees, are carriers of pollen from one variety to another.

As the assurance of a crop depends upon insects as distributers of the pollen, it is necessary that apiaries be established in the dif-

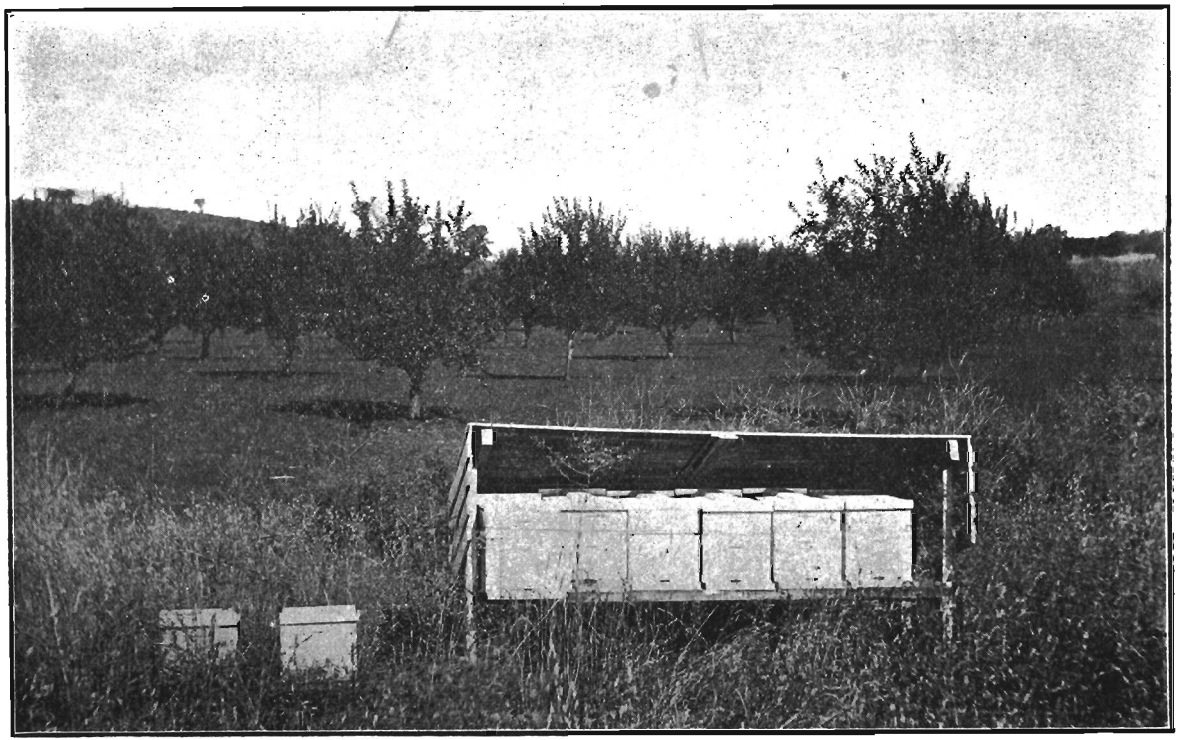


Plate 10.—Apiaries should be kept in orchards, as the bee is the best agent for cross-pollination.

ferent fruit sections. With favorable climatic conditions and proper planting of varieties the bees would insure pollination.

SELF-STERILE AND SELF-FERTILE VARIETIES.

A knowledge of the sterile and fertile varieties is essential in pollination work, before any definite investigations can be conducted. A sterile variety is one that will not fertilize its ovule with its own pollen, while a fertile variety is one that will perform this function. Since investigators have found that climatic conditions influence greatly the sterility and fertility of a variety, it is doubly important that this experiment be demonstrated in every locality, especially when a wide variance is found in the climate. Eastern conditions are hardly applicable to those found in the West.

The method usually followed to ascertain this question, was to inclose in manila or cloth bags, blossoms, before they opened, thus removing all danger from foreign pollen by insect visitation. After the blossoms open and the anthers expand the pollen is scattered on the several stigmas, and if the blossoms set fruit it is evident that the variety is self-fertile, but on the other hand if the pistil shrivels and dries up, it is sufficient evidence that the variety is self-sterile. For this experiment it is very important that the right branches be selected. Outside branches should be choosen as they are more favorably situated. In every case all the open blossoms should be removed before sacking. Too much stress cannot be placed upon this important question if accurate results are realized.

In 1907 three grades of bags were used, namely the manila paper bag, the fine and the course cheese cloth bags. Since enclosing a blossom in bags is subjecting it to unnatural conditions, these three styles were selected in order to detect if possible any differences that might arise in the setting of fruits. As the effectiveness of the three bags was the same, in 1908 we confined ourselves to the manila bags, as they were cheaper and more easily handled.

To determine if there was any difference in the temperature within a wet and dry bag, and the temperature on the outside, a record was kept of the temperature at different intervals throughout a certain period. The following table indicates the results obtained:

Table 2.—Temperature Tests.

Nature of sacks	Time	Temperature	Time	Temperature
Dry	11 o'clock	72° F.	12 o'clock	89° F.
Wet	11 "	79° F.	12 "	90° F.
Temp. in open	11 "	70° F.	12 "	83° F.

Thus it is seen that the differences in temperature were very slight. A rainy period followed closely by extreme heat would probably cause

Plate 11.—Emasculating and bagging blossoms.

a greater difference in temperature than is recorded in the table above.

Whenever it was possible from 50 to 100 bags were placed on each variety. To many investigators, the bagging process has been seriously questioned as to its effectiveness in determining the sterility or fertility of a variety. In order to demonstrate the effectiveness, bagging experiments were conducted in the following manner. Fifty bags were placed upon the variety in hand and were not molested in any way until after the petals fell from the blossoms. Then the bags were removed. Another 50 bags were placed on at the same time and when the blossoms opened and the anthers became ruptured, each of the 50 bags was removed and the pollen found in that cluster was actually transfered by hand to the pistils. The pollen was placed on the stigmas by a camel's hair brush, each variety having its own brush. In this way we have a check on "hand" verus "bag pollination." The table is explained as follows. The first column contains the variety operated upon. The second column represents the number of bags placed on each variety. The third shows the number of fruits that set when the pollen was transfered to the pistils by hand, while the fourth indicates the number that set when the bags were not molested in any way. The following table demonstrates the value of this check:

Table 3—Self-sterile and Self-fertile Varieties.

Variety	No. bags	No. set Hand poll.	No. set Bag poll.	Total fruits set	Pollen bearers
Arkansas Black	100	none	none	none	Medium
Autumn Sweet	50	none	none	none	"
Baldwin	200	5	9	14	"
Bailey's Sweet	100	17	6	23	"
Beu Davis	100	2	1	3	"
Bethlehemite	50	4	6	10	Abundant
Bietigheimer	50	none	none	none	Shy
Bellflower [Yellow]	50	"	"	"	Medium
Bottle Greeuing	50	"	"	"	"
Canada Sweet	50	"	"	"	"
Canada Reinette	50	"	"	"	Abundaut
Colvert	100	5	2	7	Shy
Canada Red	50	1	none	1	Medium
Delaware	100	none	none	none	"
Domine	100	"	"	"	"
Dutch Miguonne	50	"	"	"	"
Ewalt	100	"	"	"	Abundant
Early Strawberry	50	"	"	"	"
Fallwine	100	9	14	23	Shy
Fallawater	100	none	none	none	Medium
Fall Jenneting	100	2	1	3	Shy
Great Bearer	100	none	none	none	Abundant
Grimes Golden	100	11	3	14	Shy
Gravenstein	50	none	none	none	Shy
Golden Sweet	100	"	"	"	Medium
Gano	50	"	"	"	Abundant
Green Sweet	100	"	"	"	"
Hoover's Red	50	"	"	"	Medium
Haas	100	"	"	"	Abundant
Holland Beauty	50	"	"	"	"
Holland Pippin	100	"	"	"	"
Hydes Keeper	50	"	"	"	Medium

Table 3—Self-sterile and Self-fertile Varieties (*Continued*).

Variety	No. bags	No. set Hand poll.	No. set Bag poll.	Total fruits set	Pollen bearers
Hauwell Souring	50	"	"	"	Abundant
Jonathan	200	"	"	"	Medium
Jewett's Red	50	1	2	8	"
King of Tompkins Co	100	none	none	none	Abundant
Keswick Codlin	50	24	16	40	Shy
Longfellow	100	13	14	27	Abundant
Limbertwig	100	none	none	none	Medium
May	100	"	"	"	Abundant
Melon	50	"	"	"	Medium
McMahon White	100	"	"	"	Shy
Melou Sweet	50	"	"	"	Medium
Munson Sweet	50	"	"	"	Shy
Maideu's Blush	100	"	"	"	Medium
Missouri Pippin	50	"	"	"	"
Mammoth Black Twig	100	"	"	"	Abundant
Mann	100	2	none	2	"
Montreal Beauty [crab]	100	none	none	none	Medium
Newtown	100	41	25	66	"
Ortley	100	none	none	none	"
Oldenburg	100	3	2	5	"
Paradise Sweet	100	none	none	none	"
Pumpkin Russet	100	8	8	16	"
Pryor's Red	50	2	none	2	Abundant
Pewaukee	50	none	none	none	Medium
Red Golden Pippin	50	"	"	"	"
Rambo	100	1	1	2	Shy
Romanite	100	none	none	none	Abundant
Rome Beauty	100	"	"	"	"
Red Cheek Pippin	100	"	"	"	Medium
Ralls	100	"	"	"	"
Rhode Island Greening	100	"	"	"	"
Sweet Bough	50	"	"	"	"
St. Lawrence	100	"	"	"	"
Stark	100	1	none	1	"
Salome	100	none	none	none	"
Scott's Winter	100	20	17	39	"
Summer Queen	100	none	none	none	Abundant
Shiawassee	100	11	12	23	Shy
Summer Permain	50	none	none	none	Shy
Steel's Red	50	"	"	"	Medium
Spitzenburg	100	3	4	7	"
Tolman Sweet	100	none	none	none	Abundant
Transcendent Crab	100	"	"	"	Shy
Trumbull Sweet	100	"	"	"	Abundant
Twenty Ounce	100	"	"	"	"
Wagener	50	2	1	3	"
Western Beauty	50	none	none	none	Shy
Washington	50	5	2	7	Medium
White Pippin	100	11	15	26	Shy
Willow Twig	50	1	1	2	Medium
Wealthy	50	none	none	none	"
Whitney's Crab	100	1	3	4	"
Winesap	100	none	none	none	Shy
York Imperial	100	"	"	"	Abundant
Yellow Transparent	25	1	1	2	Shy

The results show very conclusively that varieties naturally self-fertile are abundantly able to fertilize their pistils without artificial aid. In some instances only 2 to 3 blossoms set fruit out of the 100 clusters enclosed. With these varieties it indicates that their capability for self-pollination is slight. In all cases where there were more than one blossom that set in a cluster, they were thinned to one fruit. This was done in order to give the self-fertile fruits an equal show with the crossed. Certain conditions, such as the

general health of the tree, or the defective viability of the pollen of these varieties, may have caused such a low percent to set fruit.

Other varieties, however, were very prolific, and set an abundance of fruit with their own pollen. In many cases the pollen apparently caused the fruit to develop without the formation of seeds. The following, (Plate 12, Figs. 2 and 3) shows the Keswick Codlin, a self-fertile variety that developed full sized fruit without fecundation of the overy, being absolutely seedless. Plate 12, Fig. 1, shows the same variety crossed with foreign pollen, having many plump, large seeds. A few of the self-fertile Keswick Codlin apples, Fig. 2, obtained a large size, but the majority of them were small as seen in Fig. 3. While there are some self-fertile varieties such as the Longfellow and Scott's Winter, that produced a large number of seeds, a majority of fertile and partially fertile varieties were seedless or produced only a few seeds. The apples crossed with foreign pollen, had large plump seeds, and none of the apples compared, were nearly so deficient in seeds as those self-pollinated.

In all there were 87 varieties of apples tested for their sterility and fertility and of these 59 varieties were found to be self-sterile, that is unable to set fruit when self-pollinated. This experiment has shown that a large majority of our apples depend upon cross-pollination. Fifteen varieties were found to be self-fertile and able to produce fruit when relying upon their own pollen, but when crossed with other varieties better results were obtained. Thirteen varieties can be classed as partially self-fertile. However, it is not advisable to plant them alone as greater yields of larger and more uniform fruits are obtained by crossing.

The varieties of apples can be classified as follows:—

Self-Sterile.—Autumn Sweet, Arkansas Black, Bietigheimer, Bellflower (Yellow), Bottle Greening, Canada Sweet, Canada Reinette, Delaware, Domine, Dutch Mignonne, Ewalt, Early Strawberry, Fallawater, Great Bearer, Gravenstein, Golden Sweet, Gano, Green Sweet, Hoover's Red, Haas, Holland Pippin, Holland Beauty, Hydes Keeper, Hanwell Souring, Jonathan, King of Tompkin's Co., Limbertwig, May, Melon, McMahon White, Mammouth Black Twig, Melon Sweet, Munson's Sweet, Montreal Beauty, Maiden's Blush, Missouri Pippin, Ortley, Paradise Sweet, Pewaukee, Red Golden Pippin, Red Cheek Pippin (Monmouth Pippin), Romanite, Rome Beauty, Ralls, Rhode Island Greening, Sweet Bough, St. Lawrence, Salome, Summer Queen, Summer Permain, Steele's Red, Tolman Sweet, Transcendent Crab, Trumbull Sweet, Twenty Ounce, Western Beauty, Wealthy, Winesap, York Imperial.

Self-Fertile.—Baldwin, Bailey's Sweet, Bethlehemite, Colvert, Fallwine, Grimes Golden, Keswick Codlin, Longfellow, Oldenburg (Dutchess of), Pumpkin Russett, Scott's Winter, Shiawassee, Washington, White Pippin, Yellow Newtown.

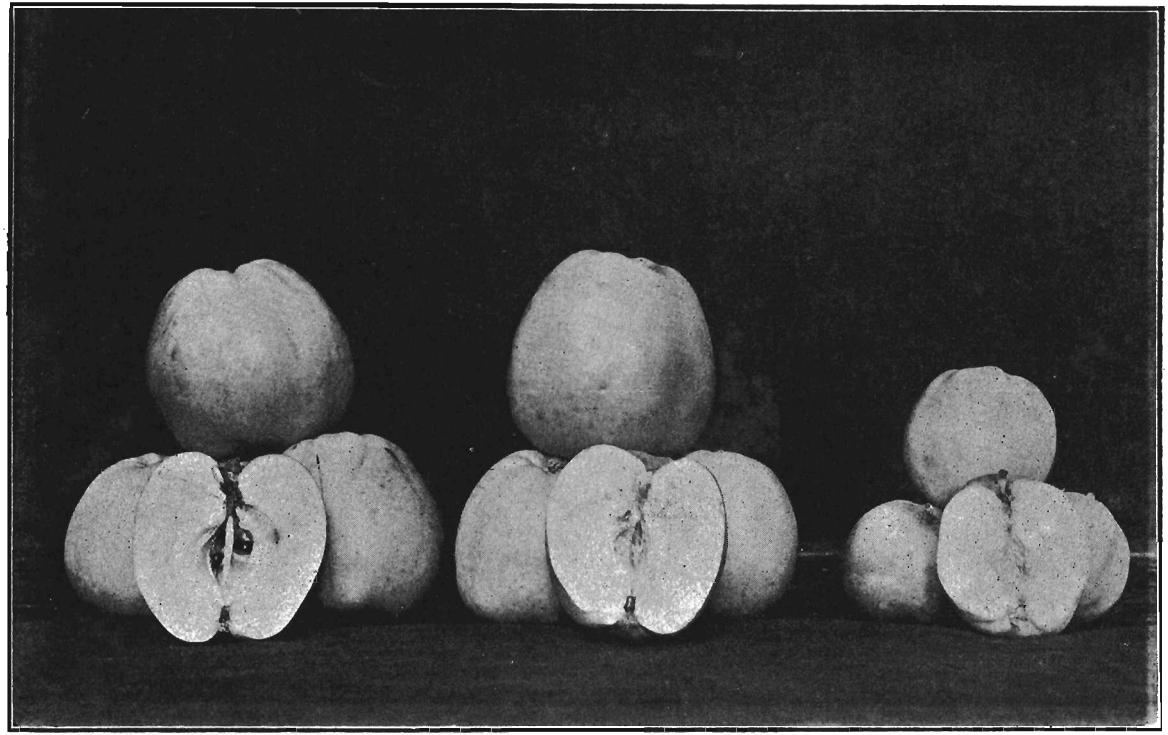


Plate 12.—Figs. 1, 2 and 3. Fig. 1. Keswick Codlin cross-pollinated. Figs. 2 and 3. Self-pollinated. Note the absence of seeds in self-pollinated apples.

Partially Self-Fertile.—Ben Davis, Canada Red, Fall Jenneting, Jewett's Red, Mann, Pryor's Red, Rambo, Stark, Spitzenburg, Wagener, Willow Twig, Whitney's Crab, Yellow Transparent.

POLLENIZERS FOR SPITZENBURG.

While it has been demonstrated by the experiments carried on, that the Spitzenburg is partially self-fertile, nevertheless the percentage setting fruit, only 3 per cent, was so small that this variety can almost be classed among the self-sterile varieties, and for commercial purposes should be cross-pollinated.

The results obtained in these several experiments fully emphasize the fact that cross-pollination is the rule while self-pollination is the exception. This principle is sufficiently emphasized in the tables showing the sterility and fertility of the different varieties. In every case when a variety appeared to be self-fertile an improvement could be made in crossing with some other variety.

Realizing the value of determining some of the best pollenizers for the Spitzenburg, one of the leading varieties grown in this State cross-pollenizing experiments were carried on in several orchards in the Hood River Valley. In 1907, work was conducted in orchards belonging to Messrs. Carter, Paasch, Mason and Marshall. A continuation of these experiments was carried on in 1908. The following tables explaining the work, show the variety crossed, the pollen used, the number of blossoms emasculated, the time of emasculating, the date of applying the pollen, and the number of fruits set.

Table 4.—Cross-pollination Experiments with Spitzenburg in A. I. Mason's Orchard.

Variety crossed	Kind of pollen	No. Emas.	Time Emas.	Time Poll.	No. Set
Spitzenburg A	Baldwin	100	4-27	4-30	56
" B	Ortley	100	4-27	4-30	67
" C	Arkansas Black	100	4-27	4-30	70
" D	Red Cheek Pippin	200	4-28	5-1	117
" E	Newtown	100	4-29	5-1	37
" F	Jonathan	100	4-29	5-1	62

Each different tree worked upon is designated by the letters of the alphabet. In the table it can be readily seen that fewer fruits set when Newton pollen was used, than with the other varieties.

Table 5.—Cross-pollination Experiments with Spitzenburg in M. Dragseth's Orchard.

Variety crossed	Kind of Pollen	No. Emas.	Time Emas.	Time Poll.	No. Set
Spitzenburg A	Newtown	100	4-30	5-2	40
" B	Arkansas Black	100	4-28	5-1	52

The preceding table table shows the results obtained.

In Mr. Sproat's orchard a series of experiments were started, but through some unavoidable cause the blossoms did not develop and the trees failed to set a crop of fruit. In the several places where these experiments were conducted the orchards were in a high state of cultivation.

Not only will such varieties as Baldwin, Yellow Newton, Ortley, Arkansas Black, Red Cheek Pippin (Monmouth Pippin), Jonathan,

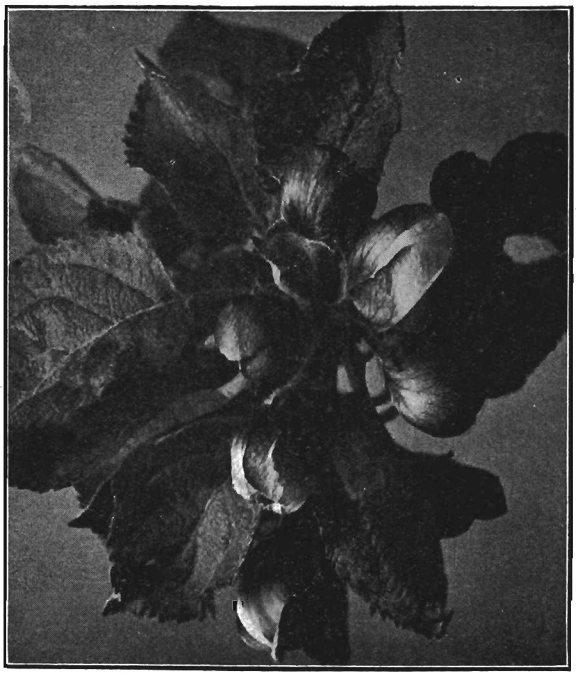


Plate 13.—Blossoms ready for emasculation. This should always be done before the petals unfold, however, when possible emasculation should be delayed until the petals are nearly ready to open.

cross satisfactorily with the Spitzenburg, but it has been demonstrated by experiments carried on by this Department, that the following varieties, Gravenstein, Stark, Mammoth Black Twig, Hanwell Souring, Washington, Bottle Greening, Hydes Keeper, Wagener, King of Tompkin's County, York Imperial and Delicious, will also successfully pollenize this variety The serious objection in using the Gravenstein as a pollenizer for the Spitzenburg is that it is almost through blooming before the Spitzenburg comes into blossom.

In making a study of the self-pollinated Spitzenburg apples it was

found that they were objectionable in that they were inferior in size, ill-shapen, as compared with the crossed apples. As far as quality was concerned there appeared to be no difference between the self-fertile and cross-pollinated apples. The blooming period of the varieties used as pollenizers as indicated in the tables, is nearly identical with that of the Spitzenburg. The Spitzenburg crosses made by Jonathan pollen resembled the Jonathan in color, with the Arkansas Black crosses took on a darker color. Crosses made by Newton pollen were not as deeply colored as those produced by either Jonathan or Arkansas Black. Before coming to a final conclusion on such an important question as the color of the Spitzenburg we wish to conduct more extensive experiments this coming season.

To illustrate graphically the differences in the fruits and seeds of the fertile Spitzenburg as compared with the crossed, the following figure is presented for consideration. The black lines in the diagram represent the average weight in grams of five different crosses on a scale of one-sixtieth of an inch per gram. Under each of the black lines the average weight of the plump seed of each cross is given, and is represented on a scale of one-twentieth of an inch per one one-hundredth gram. (1-100 gram.)

The table shows the difference in the average weight of the crossed fruits, also the weight of the seeds from these fruits. This experiment shows that where there is an increase in the size of the crossed fruit there is also a proportional increase in the weight of the seeds. The self-fertile Spitzenburgs were practically devoid of plump seeds.

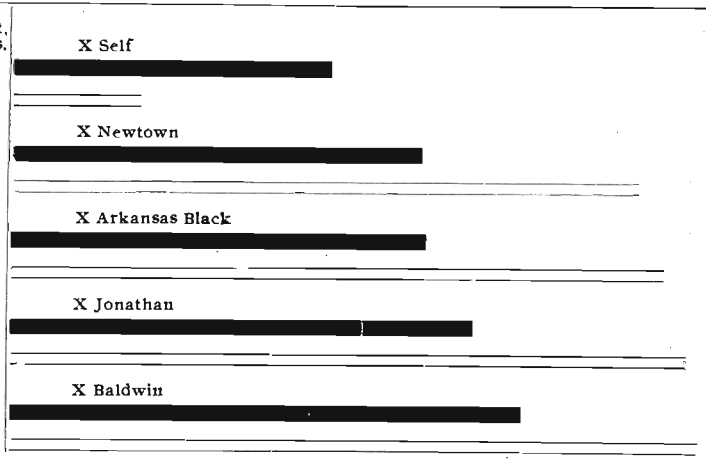
The experiments carried on the past two years demonstrate beyond a question that cross-pollination is essential in the majority of cases if a crop is insured. While these different varieties given above have been found to cross successfully with the Spitzenberg it is probable that some of them will be more desirable to others as pollenizers. The graphic table shows that some varieties tend to give better results than others. However other experiments are needed to demonstrate thoroughly which one of these is the best pollenizer for the Spitzenburg. In almost every case, when a cross was made a larger and better fruit was produced. In determining the pollenizers for any variety it is essential that they come into blossom at about the same time or extend over a part of the period, if cross-pollination is insured. (Tables 9 and 10 show blooming periods.) In selecting a good pollenizer, its pollen producing qualities should be taken into consideration, as well as its commercial value. A good pollenizer should produce an abundance of pollen. There are however exceptions to this rule, for in our experiments we have found that certain varieties known to be shy pollen bearers, have given excellent results when used as pollenizers. By consulting Table 3, the pollen producing powers of each variety can be had.

Since the intercrossing of varieties is necessary, the placing of the

Table 6

SPITZENBURG.

	Average weight, grams.
X Self	
Fruits	100
Seeds	13
X Newtown	
Fruits	126
Seeds	65
X Arkansas Black	
Fruits	128
Seeds	68
X Jonathan	
Fruits	144
Seeds	70
X Baldwin	
Fruits	157
Seeds	71



pollenizers throughout the orchard is an important question. From investigations made during the past summer in the fruit sections of Oregon it was found that the growers were placing their pollenizers in this proportion:—When three varieties were being planted, they would alternate, that is, two rows of Spitzenburg, two rows of selected pollenizer, two rows of another variety, and so on throughout the orchard. This system is giving good satisfaction and is very convenient, especially during the spraying and harvesting of the fruit.

CROSSING OF THE YELLOW NEWTOWN, A SELF-FERTILE VARIETY.

In this experiment our efforts were confined wholly to the Yellow Newton, a self-fertile variety that will set fruit without the aid of cross-pollination. The object of this experiment was to determine if possible whether any improvement could be made in the size, quality, flavor and color of the fruit, by crossing with different varieties. In every case where a cross was made, a much larger and finer apple was obtained. By consulting Plate 14, Figs. 1 and 2 the difference is readily perceptible, as to the size and shape of the two apples, the self-fertile apple, versus the cross-pollinated apple. The smaller apples in the picture, Fig. 1, represent the self-fertile Newton, while the larger ones, Fig. 2, have been crossed with Grimes Golden pollen. A few of the self-pollinated Newton apples were normal in size, but the largest per cent of them were small. In checking up the results, out of 40 self-fertile Newton apples, 30 of them were inferior in size, when compared with the crossed apples, and contained many undeveloped seeds. Examining these apples in the laboratory only 13 plump seeds were found.

In the College Orchard as well as in many of the orchards in the Rogue River and Hood River Valleys, a large number of small malformed apples were found. In some cases whole clusters of such apples existed. Some orchardists have claimed that aphis are responsible for such malformations, and that may be true. However we know that in our work the aphis were not responsible, furthermore we obtained a considerable number of such apples when self-pollenizing the Newton, while on the other hand none were noticed when cross-pollination was practiced.

This experiment would tend to show that some of our so-called self-fertile varieties could be improved by crossing, and to get the best results these varieties should not be planted in large blocks.

At this time no perceptible difference was detected in the quality, flavor and color of the self-fertile Newtown apples as compared with the cross-pollinated apples.

By studying the following table, conclusions can be drawn as to what varieties will cross successfully with the Yellow Newtown.

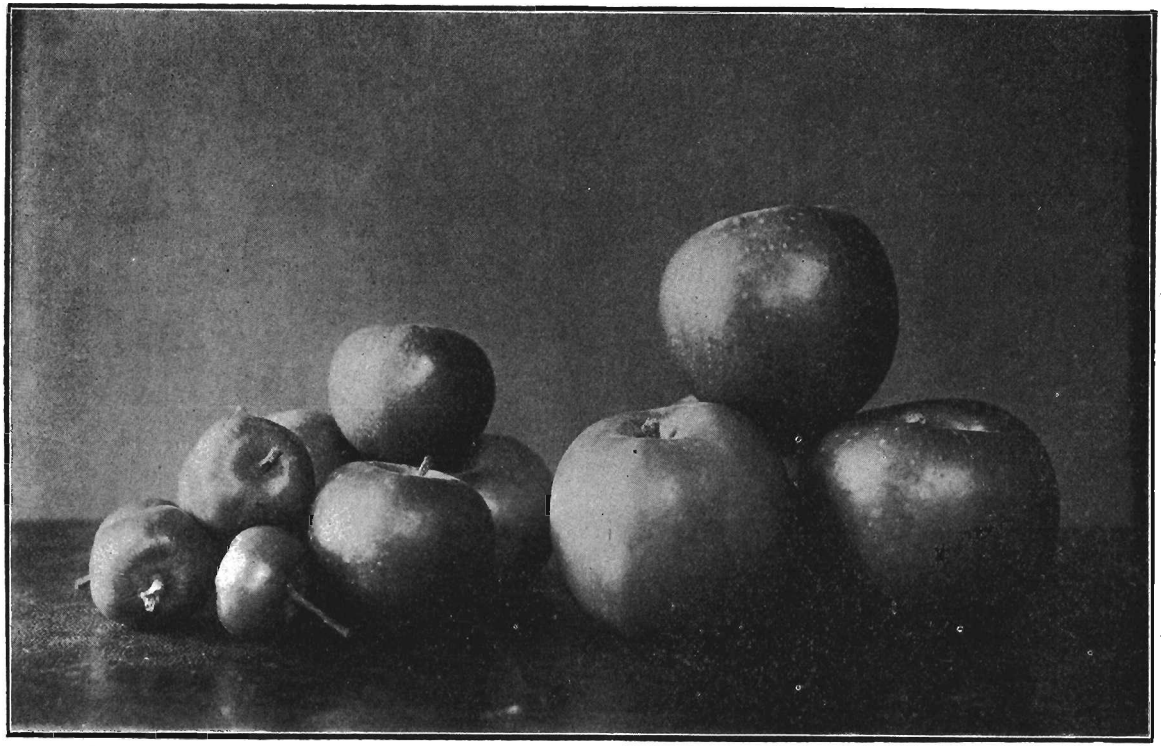


Plate 14.—Figs. 1 and 2. Fig. 1. Self-pollinated Newtowns, producing at least one-third of the apples under sized. Fig. 2. Yellow Newtown pollinated with Grimes Golden. No small apples.

Table 7.—Cross-pollination Experiments with Yellow Newtown.

Variety crossed	Kind of pollen	No. Emas.	Time Emas.	Time Poll.	No. Set	Percent Set
Newtown A	White Pippin	20	4-25	4-25	15	75
" B	Grimes Golden	57	4-25	4-25	32	56
" C	Jonathan	14	4-30	4-30	11	78
" D	Ben Davis	22	4-30	4-30	19	86
" E	Spitzenburg	32	4-30	4-30	15	46
" F	White Bellflower	14	4-30	4-30	13	93

In 1907 it was found that the Yellow Newtown would cross when the following varieties were used as pollenizers: Hoover's Red, Arkansas Black, Tolman Sweet, Maiden's Blush, Hanwell Souring, Pewaukee, York Imperial, Bailey's Sweet, Pumpkin Russet, Hydes Keeper, Twenty Ounce. While it has been demonstrated that all these varieties will cross with the Newtown, a series of experiments will have to be conducted, in order to determine what one or two varieties will produce the best results when used as Newtown pollenizers.

In determining the best pollenizers for any variety it is essential that a close study be made of their mutual affinites before definite results are assured. The potency of the pollen of the pollenizer on the pistillate plant must be ascertained. The action of the pollen of the pistillate plant on the pollenizer should also be known, before deciding which variety is the best pollenizer for some of our commercial varieties.

The salient points, such as the blooming period, placing of pollenizers in the orchard, commercial value of pollenizer, etc., are the same as those outlined in the discussion:—"Best pollenizers for the Spitzenburg."

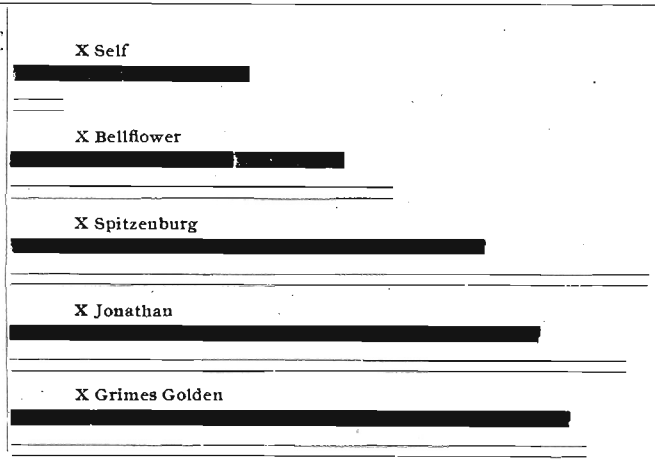
To show graphically the difference between the fruits and seeds of the several crosses made the following table is presented. The table is similar to the one found under the discussion of the Spitzenburg. From the results it can be readily seen that the self-fertile Newtowns produced decidedly fewer seeds than the crossed fruits. An increase in the weight of the crossed apples show also a proportional increase in the weight of the seeds.

RECORD OF APPLE CROSS-POLLINATION.

The experiments conducted the past two years, emphasize the need of a study of the mutual affinities of apples, that are likely to be planted together. Not all varieties will cross with each other. For the purpose of throwing some light on this important question, a list of some of the successful crosses that can be made with different varieties will be given in the following pages.

Table 8 NEWTOWN

	Average weight, grams.
X Self	
Fruits	73
Seeds	.05
X Bellflower	
Fruits	104
Seeds	.40
X Spitzenburg	
Fruits	147
Seeds	.66
X Jonathan	
Fruits	162
Seeds	.65
X Grimes Golden	
Fruits	173
Seeds	.60



Variety Crossed.	Variety Pollen.
Black Ben Davis	Hydes Keeper.
	Willow Twig.
Bottle Greening	Pewaukee.
	Charlottenthaler.
Blenheim Orange	Hanwell Souring.
	Arkansas Black.
	Jonathan.
Grimes Golden	Twenty Ounce.
Hydes Keeper	Tolman Sweet.
Hanwell Souring	Montreal Beauty.
	Charlottenthaler.
Hoover's Red	Fallwine.
	Pewaukee.
	Maiden's Blush.
Jonathan	Ben Davis.
	Yellow Newtown.
	Spitzenburg.
Keswick Codlin	Bottle Greening.
	Lady Apple.
Limbertwig	Hoover's Red.
	Arkansas Black.
Maiden's Blush	York Imperial.
Mammouth Black Twig	Mann.
	Red Astrachan.
	Charlottenthaler.
	Hanwell Souring.
Mann	Shiawassee.
	Haas.
	Pumpkin Russet.
Ortley	Haas.
Pewaukee	Hoover's Red.
	Arkansas Black.
	Fallwine.
	Hanwell Souring.
Steele's Red	Pumpkin Russet.
	Hoover's Red.
	Yellow Newtown.
Summer Permain	Salome.
	Hanwell Souring.
Tetofsky	Mann.
	Haas.
Winesap	Arkansas Black.
Shiawassee	Early Strawberry.
	Sweet Bough.
	Tetofsky.

Variety Crossed.	Variety Pollen.
Washington	Oldenburg.
	Hydes Keeper.
	Charlottenthaler.

BLOOMING PERIOD.

A point of vital importance to every fruit grower who contemplates growing varieties for commercial purposes is a knowledge of the relative blooming periods of the different varieties planted for cross-pollination. If they do not blossom at the same time, pollination cannot take place, and as varieties tend to be self-sterile with their own pollen this question needs considering. In every locality where fruit growing has become a specialty, the blooming periods of the different kinds of fruits should be known. Study this question and plant only varieties that blossom at about the same time.

The constancy of the relative blooming periods should receive careful study. This phase of the subject is influenced very materially by the climatic conditions. Rain, snow, cold winds, during the early part of Spring will retard the blooming period very much, while warm weather during the early Spring months has a tendency to hasten the blooming period, thus shortening it materially. Such problems as these must be met each year by the orchardist.

Whether or not varieties blossom at approximately the same period in the different localities of the State is a question that needs investigating In the Eighth Biennial Report of the Oregon Board of Horticulture for 1905, Professor Lake says:—"Records kept at other places within and without the State show that the periods of blooming of certain varieties do not remain invariable." This difference in the blooming periods of certain varieties may be attributed to several causes. The location, site, exposure of the orchards containing these varieties could very easily have caused this variation.

The past two years, in co-operation with the United States Department of Agriculture, a record of the blooming periods of the different varieties grown in the College Orchard has been kept, to ascertain what varieties blossom at about the same time. In the following tables the blooming period of 95 varieties of apples; 31 varieties of pears, and 17 varieties of cherries are given. From the observations made it was found that apples remain in blossom 13 days, pears 11 days, and cherries 10 days. In different localities these dates would vary.

The varieties given in these tables are grouped as early and late bloomers. This classification is made according to the appearance of the first blossom. By studying the table it can be readily observed that there is a variation of several days in the appearance of the first blossom of the several varieties. In localities subject to frosts, this fact is very important to growers selecting varieties for planting.

Table 9.

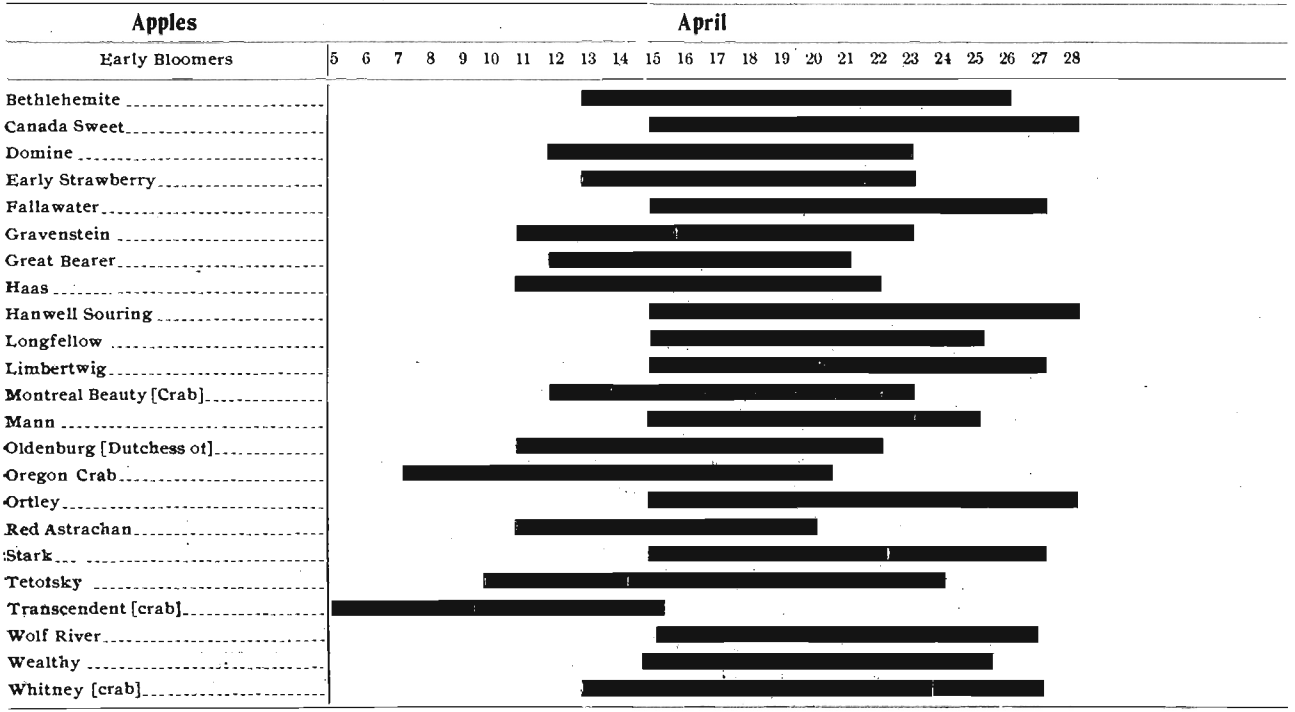

Apples
April
Early Bloomers
5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28
Bethlehemite
Canada Sweet
Domine
Early Strawberry
Fallawater
Gravenstein
Great Bearer
Haas
Hanwell Souring
Longfellow
Limbertwig
Montreal Beauty [Crab]
Mann
Oldenburg [Dutchess of]
Oregon Crab
Ortley
Red Astrachan
Stark
Tetofsky
Transcendent [crab]
Wolf River
Wealthy
Whitney [crab]

Table 10.

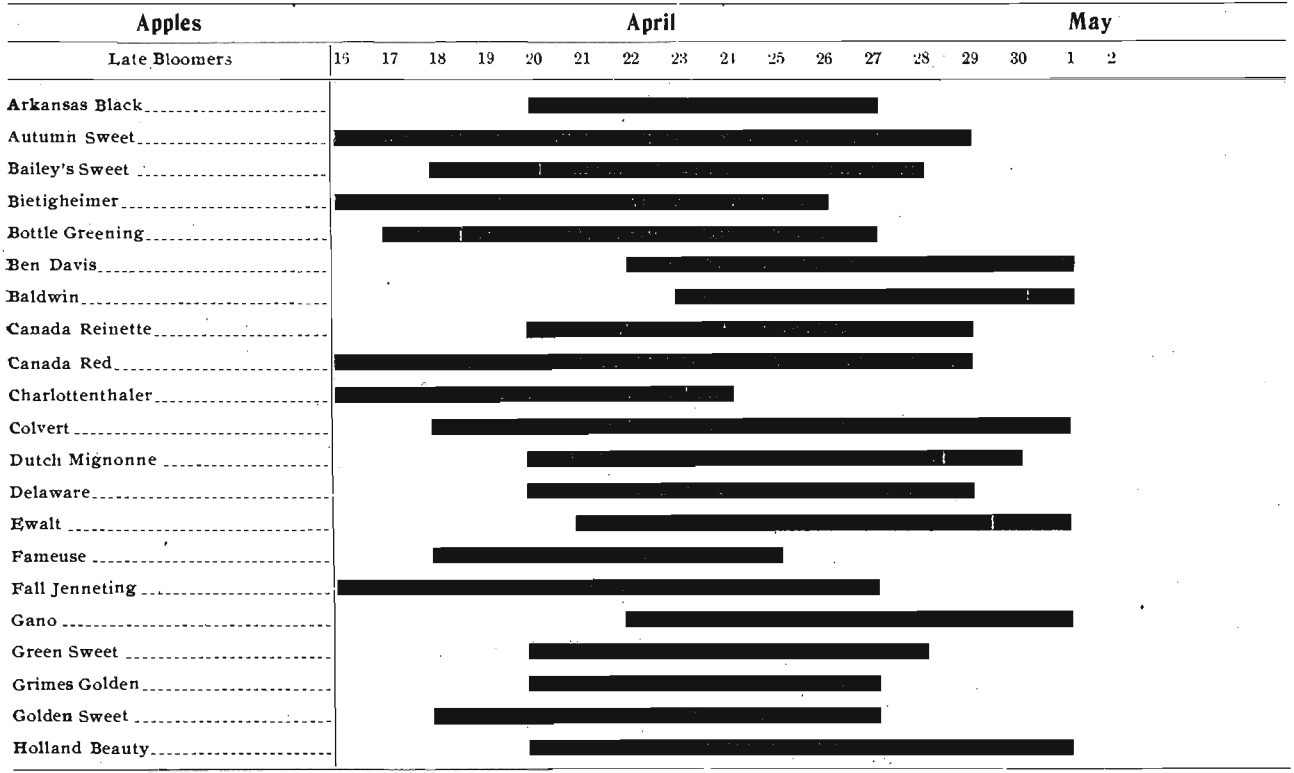

Apples
April
May
Late Bloomers
15 17 18 19 20 21 22 23 24 25 26 27 28 29 30 1 2
Arkansas Black
Autumn Sweet
Bailey's Sweet
Bietigheimer
Bottle Greening
Ben Davis
Baldwin
Canada Reinette
Canada Red
Charlottenthaler
Colvert
Dutch Mignonne
Delaware
Ewalt
Fameuse
Fall Jenneting
Gano
Green Sweet
Grimes Golden
Golden Sweet
Holland Beauty

Table 10—*Continued.*

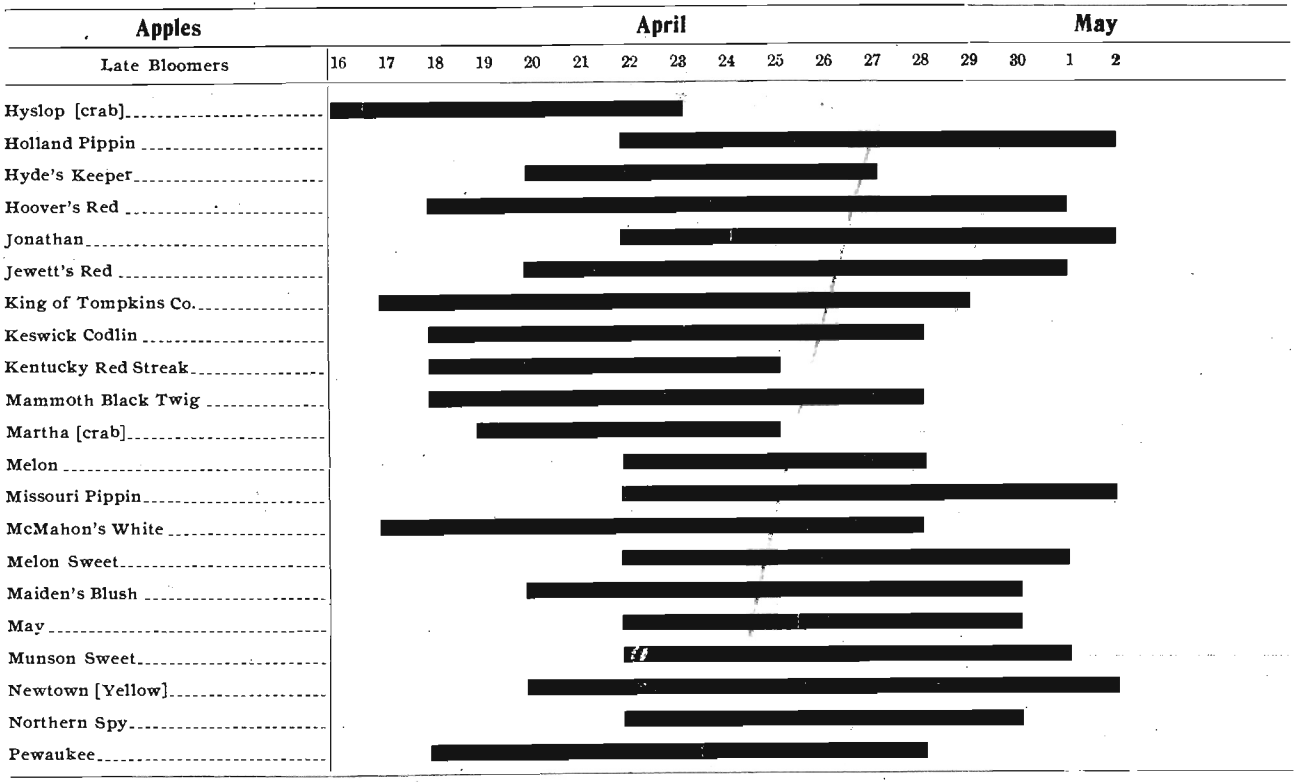


Table 10—*Continued.*

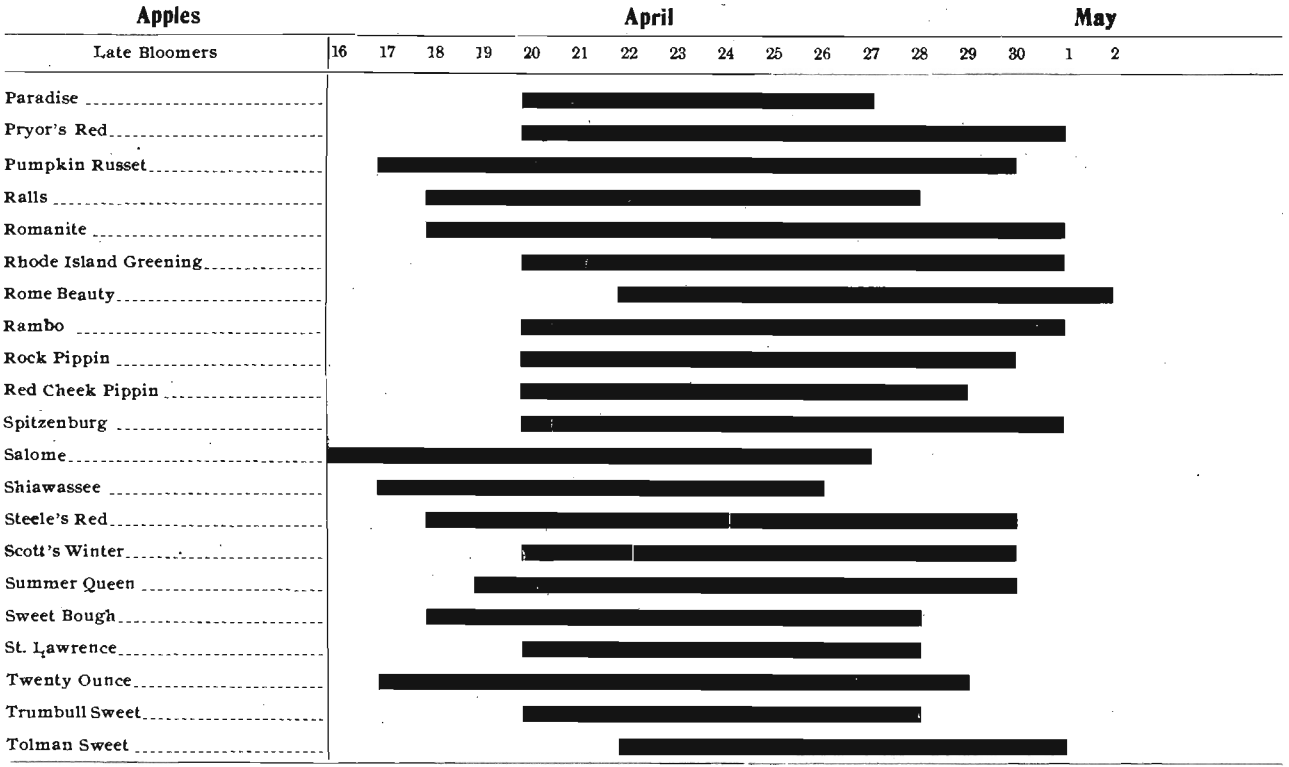


Table 10—*Concluded.*

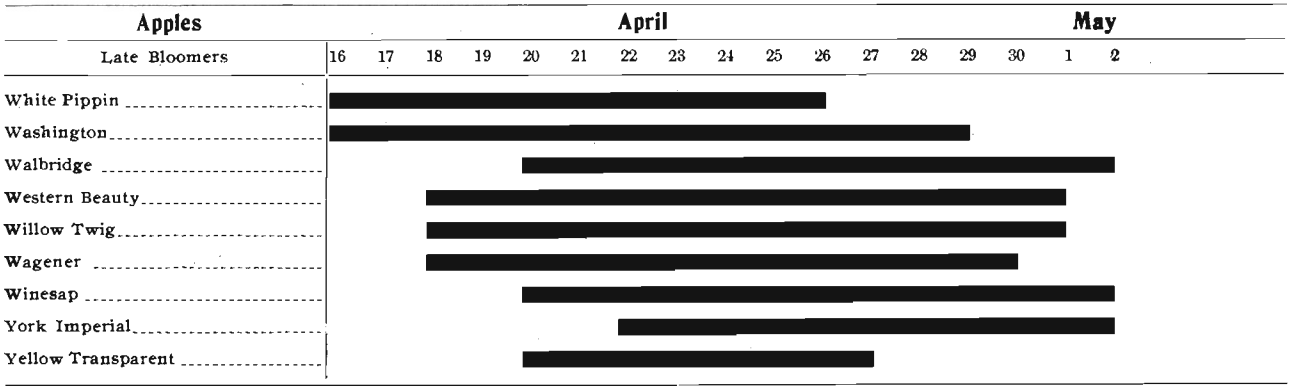


Table 11.

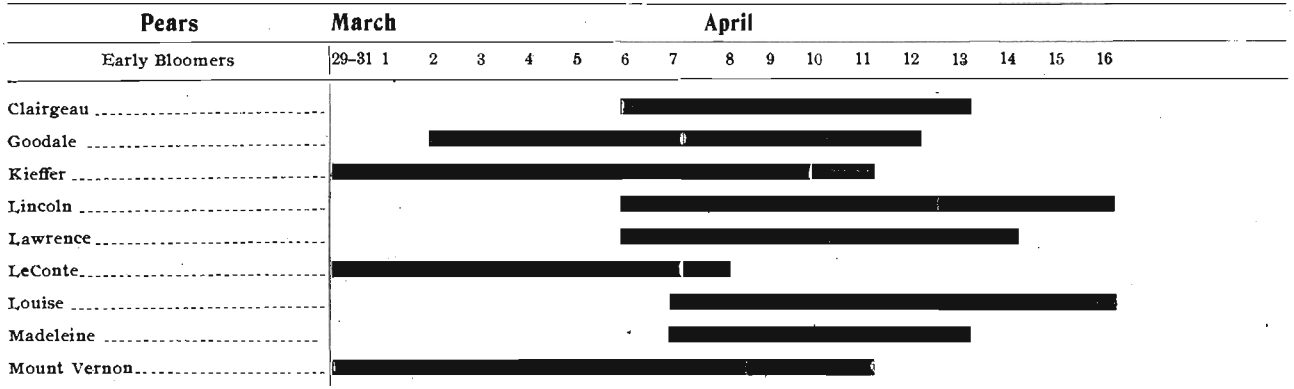

Pears
March
April
Early Bloomers
29–31
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
Clairgeau
Goodale
Kieffer
Lincoln
Lawrence
LeConte
Louise
Madeleine
Mount Vernon

Table 12.

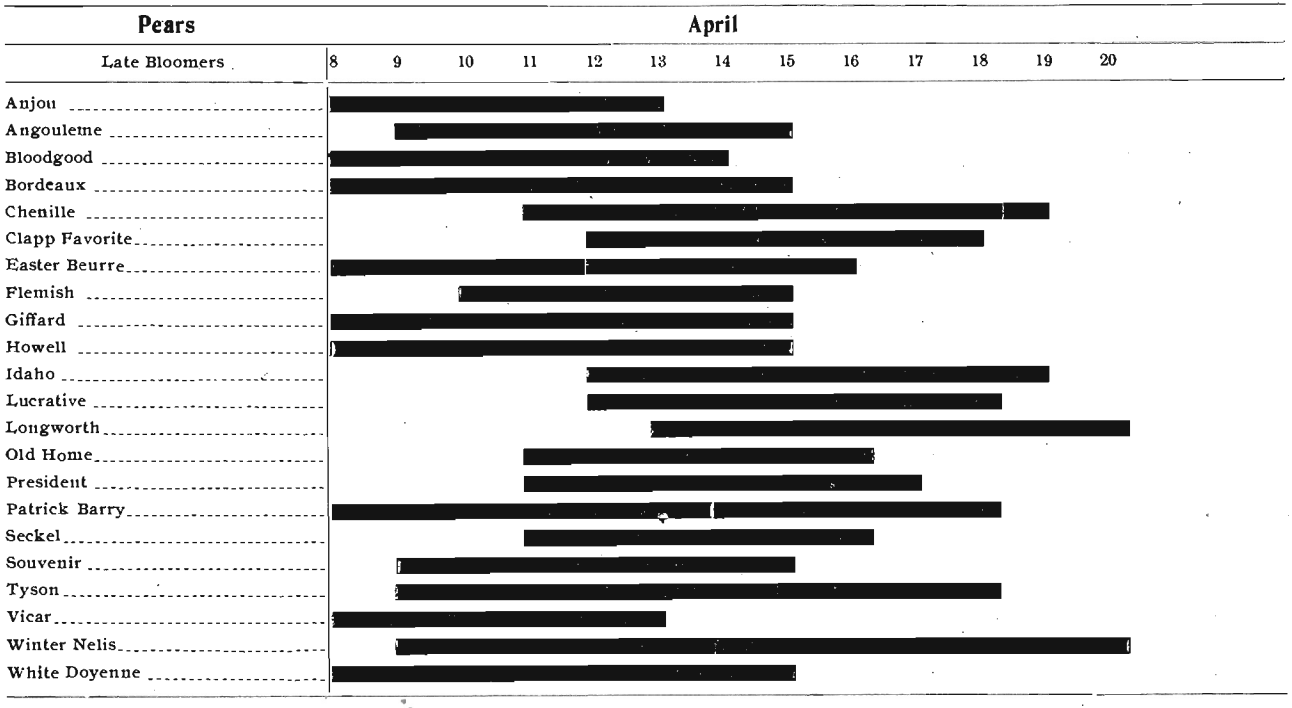

Pears
April
Late Bloomers
8
9
10
11
12
13
14
15
16
17
18
19
20
Anjou
Angouleme
Bloodgood
Bordeaux
Chenille
Clapp Favorite
Easter Beurre
Flemish
Giffard
Howell
Idaho
Lucrative
Longworth
Old Home
President
Patrick Barry
Seckel
Souvenir
Tyson
Vicar
Winter Nelis
White Doyenne

Table 13.

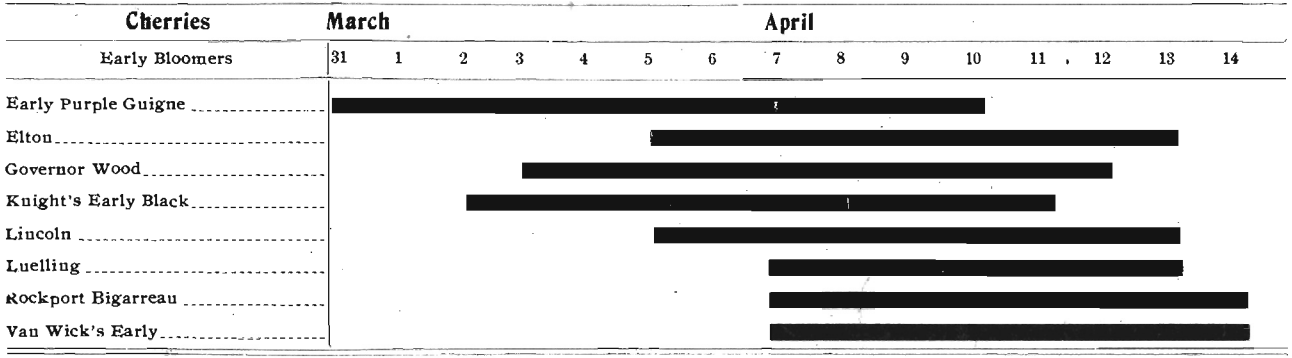


Table 14.