UNITED STATES
DEPARTMENT OF AGRICULTURE
DEPARTMENT CIRCULAR 387
Washington, D. C. August, 1926

POLLINATION OF THE AVOCADO

T. RALPH ROBINSON
Physiologist
and
E. M. SAVAGE
Assistant Plant Breeder
Office of Crop Physiology and Breeding, Bureau of Plant Industry

CONTENTS

OBSERVATIONS OF OTHER INVESTIGATORS

Within the last few years attention has been called to the flowering habits of the avocado with special reference to the influence of flower behavior on effective pollination and fruit setting.

Nirody,[1] reporting on his investigations in avocado breeding in Florida, brought to light certain time relations between pollen shedding and receptivity of avocado flowers, which he deemed might have an important bearing on fruit production. He concludes (p. 72): "Since the stigma in the majority of cases observed shows a browned and withered appearance before the anthers of the same flower have opened their valves, the chances for self-pollination seem remote." And, further (p. 73): "It is obvious that certain varieties interplanted with certain other varieties ought to give better chances for the setting of fruit." He then proceeds to give a tentative grouping of varieties to facilitate cross-pollination.

Nirody seems to have recognized that there was a closed interval between the receptive and the pollen-shedding stages of the avocado

[1] NIRODY, B. S. INVESTIGATIONS IN AVOCADO BREEDING. Calif. Avocado Assoc. Ann. Rpt. 1921-22: pp. 65-78, illus. 1922.

flower in the case of varieties having the first opening in the afternoon, but not for the varieties of the other group having flowers opening first in the morning.

Stout,[2] in the winter of 1922–23, while in California as a visiting member of the faculty of Pomona College, made careful studies of all the principal avocado varieties grown in California, covering practically the entire blooming period. The outstanding new feature clearly brought out by Stout's careful studies was that practically all varieties, under normal conditions, habitually have two distinct periods for the opening and closing of the individual flowers. It was further demonstrated that the first-period flowers have the pistil receptive, but no pollen is shed while the flower is open for the first time. At the second opening pollen is shed, but by this time the pistil is usually past the receptive stage. To increase further the difficulties of pollination, it was found that on a given tree or on trees of the same variety the flower-opening periods are so synchronized that flowers in the pollen-shedding stage are rarely open at the same time as first-period flowers having receptive pistils. In other words, except in occasional instances due to weather changes, no opportunity was given for either self or close pollination in the foothill groves where Stout's studies were carried on.

A study of variety behavior, however, revealed that under normal conditions all varieties have more or less definite periods for opening and closing their two sets of flowers. One group (class A) has only first-period flowers (receptive) in the morning, with second-period flowers (shedding pollen) in the afternoon; another group (class B) has only second-period flowers (shedding pollen) in the morning and first-period flowers (receptive) in the afternoon. It was further made apparent that this grouping by varieties may be altered or upset (even to an almost complete reversal) by sudden and violent weather changes, but that it holds good for weather conditions most favorable to pollination and fruit setting.

On the basis of this grouping of varieties it was deemed possible to make tentative recommendations for mixed variety plantings suitable to effect cross-pollination, provided always that there were bees or other insects at work to bring about the necessary transfer of pollen.

The influence of bees on fruit setting was brought out by experiments carried out by Clark [3] at Point Loma, Calif., in which normal crops of fruit were set on trees of several varieties covered with gauze tents, provided a hive of bees was placed under the tent. If bees were excluded no fruit was obtained. This might seem to indicate that there was no lack of self-fertility in the instance cited, but the intensive working of the avocado flowers by the imprisoned bees offered exceptional opportunities for the transfer of pollen during brief periods of overlapping in different sets of flowers, not likely to be duplicated under ordinary grove conditions. There is also the possibility that bees may occasionally carry pollen on their bodies long enough to bridge the gap between pollen-shedding and receptive

---

[2] STOUT, A. B. A STUDY IN CROSS-POLLINATION OF AVOCADOS IN SOUTHERN CALIFORNIA. Calif. Avocado Assoc. Ann. Rpt. 1922–23: pp. 29–45, illus. 1923.
——— THE FLOWER MECHANISM OF AVOCADOS WITH REFERENCE TO POLLINATION AND THE PRODUCTION OF FRUIT. Jour. N. Y. Bot. Gard. 25: pp. 1–7, illus. 1924.

[3] CLARK, O. I. AVOCADO POLLINATION AND BEES. Calif. Avocado Assoc Ann. Rpt.1 922–23: pp. 57–62, illus. 1923.

sets of flowers, especially with those varieties which shed pollen in the morning. The probing of unopened flowers by bees in search of nectar may result in considerable close pollination. It was Clark's opinion, based both on observations of flowers and on actual experiment, that cross-pollination should be provided for in most cases, even with such varieties as might under favorable circumstances prove self-fertile.

HYBRIDIZATION AND POLLINATION STUDIES

Investigations on the hybridization of avocados, chiefly with a view to obtaining increased hardiness, were begun in Florida in the spring of 1916 by the Bureau of Plant Industry, the work being done under the direction of Walter T. Swingle. The junior writer at that time made numerous cross-pollinations between varieties of the West Indian and Guatemalan races, the work being done at Homestead and at Miami. A few crossed fruits were obtained and seedlings grown, but the young plants were lost in a freeze occurring the following year.

In connection with this attempt at avocado hybridization the occurrence of two sets of flowers at different times of day on the same tree, one set receptive and the other shedding pollen, was noted and recorded. As in the case of Nirody's observations some years later, the full significance of this was not realized—that all flowers normally have two periods of opening, separated by a closed period often extending over a full 24 hours.

With the new viewpoint afforded by the work of Nirody and Stout, it was decided to continue pollination and hybridization studies in Florida, recognizing that the problems involved were so complex that intensive study over several seasons would doubtless be required before any general conclusions could be drawn.

The need for varieties of winter-maturing avocados better adapted to Florida conditions than the varieties introduced from high altitudes in Central America had become so evident that this work seemed imperative. Furthermore, the indications that a few varieties are apparently self-fruitful, judged both by flower behavior and by grove performance, made it desirable to breed this valuable trait into new hybrids if possible.

POLLINATION INVESTIGATIONS IN 1924 AND 1925

During February and part of April, 1924, studies were made by the writers at Homestead, Dade County, Fla., an important center of avocado culture, the extensive variety planting of W. J. Krome being utilized for the work. Less detailed observations were made at other points in Dade County between Homestead and Miami; also at Lucerne Park, typical of the sand-hill section of Polk County, and at Terra Ceia, Manatee County, representing the low hammock region of the west coast.

In Florida the month of February, 1924 (when most of the 1924 observations were made), was marked by such an unusual succession of cold waves, accompanied by rain, that the flower behavior was very erratic, rendering the data of doubtful significance for normal seasons, and attempts at hybridization for the same reason were particularly

difficult of accomplishment. A single cross-pollinated fruit was obtained (Taft × Winslowson), the seedling from which gives evidence of being a hybrid. The set of fruit for that season (1924) was correspondingly very low. Pressure of other work in 1924 prevented these studies from being extended through March. Accordingly, plans were made to repeat the observations in 1925, covering the entire blooming season, and it was arranged to work jointly with Doctor Stout, of the New York Botanical Garden.

As in the previous season, the chief center of work was in the Homestead section,[4] although numerous observations were made at other points in Dade, Polk, and Manatee Counties. Temperature records were taken in the grove at morning, noon, and evening, together with relative-humidity observations. As pointed out by Doctor Stout in his California observations and as will be shown later, weather conditions have an important relation to the flower behavior of the avocado. The weather conditions in 1925 were almost uniformly good, in striking contrast to those of the previous season.

PLAN OF OBSERVATIONS

The plan of operation was to mark with small tags flower buds opening for the first time, using different colors on alternate days, and by making hourly visits from daylight until dark (or later) to record the successive stages of the floral cycle. Observations were often carried through until 10 p. m. Usually the complete cycle with class A varieties requires observation for two full days and occasionally a part of the third day. With class B varieties the cycle requires two half days (an afternoon and the following forenoon). With a few varieties (as Trapp and Estelle) there are rare occasions in cool weather when the cycle is completed in a single day, anther valves lifting and pollen being shed during the latter part of a single opening. This may be interpreted as an omission of the normal first opening due to the inhibiting effect of low temperature, and is limited to varieties in class B.

FLOWER BEHAVIOR AND GROUPING OF VARIETIES

The fact that on the first opening of the flowers all the stamens are opened in a nearly flat plane (as in pl. 1, left) and on the second opening the inner whorl of stamens, three in number, are folded about the style (pl. 1, right) makes it easy after a few observations to distinguish between these different sets of flowers occurring during the same day (rarely simultaneously) on trees visited.

---

[4] A joint report of the Dade County work, by A. B. Stout and E. M. Savage, was made to the Florida Avocado Association and to the Florida State Horticultural Society. This report, minus charts and plates, was published in the proceedings of the latter society for 1925 (Proc. Fla. State Hort. Soc., 1925, pp. 80–91). Several of the charts appearing in that paper (charts 1, 2, and 3) were orginally prepared and used as lantern slides in the joint report above referred to, these charts having been drawn up by Doctor Stout. The presentation to the Florida Horticultural Society was made by E. M. Savage; to the Florida Avocado Association by A. B. Stout. This paper also makes use in condensed form of portions of the text of the joint report, the preface to which, quoted below, indicates the circumstances under which this joint investigation was made: "This report pertains particularly to studies made in Florida during February and March, 1925, in which Dr. A. B. Stout of the New York Botanical Garden and Mr. E. M. Savage of the United States Department of Agriculture cooperated. The expenses of Doctor Stout were met by Dade County through its Farm Bureau. The County Agent, Mr. J. S. Rainey, various officers of the Florida Avocado Association, and numerous growers of avocados cooperated very fully in the investigations. This report also draws freely on previous studies by the authors, those of Doctor Stout in California in the Spring of 1923 and those of Mr. Savage in Florida during the Spring of 1924. Certain portions of this report and especially the discussion of interplanting draws freely and to the point of exact quotation from articles previously published. The plan has been to assemble in this one article all the most important data now available on flower behavior of avocados with advice regarding interplanting."

AVOCADO FLOWERS AT THE FIRST AND THE SECOND OPENING

The flower at the right is of the Grande variety at the second opening, showing the pollen lids open and the pollen masses exposed to insect visitation, with the stigma already discolored. On the left is the first open flower of the Winslowson variety, with the stigma receptive, but no pollen shedding. The lower left flower is loosely closed with the spent anthers protruding. Magnified about 5 diameters. Photographed by David Fairchild

The outer whorl of stamens, six in number, on the second opening do not open so widely as in their first opening and do not fold inward until pollen has been discharged and the flower is about to close. The anthers at the time of discharging pollen open up tiny lids or valves, four to each anther. These are shown in Plate 1, right. It frequently happens, as shown in Plate 1, lower flower, that these pollen-laden valves protrude from loosely closed flowers. It is doubtful whether pollen at this stage would be effective for pollination purposes, and such spent flowers would have little attraction for insects seeking nectar.

During the closed period between the first and second openings of the flower the style elongates, so that when the stamens on the second opening fold about the style the stigma is usually elevated above the anthers; furthermore, the stamens are reflexed so that the anthers do not come in contact with the stigma even when of the same height. The pollen, moreover, is not of light, powdery character easily blown about by air currents, but occurs in sticky masses, evidently adapted for insect dispersal. Even in cases where there is opportunity for self-pollination, therefore, insect visitations must be considered as a factor in the setting of fruit.

The avocado produces flowers in such superabundance that most of them are destined to be fruitless even under the most favorable conditions. A full-grown tree may have a million individual blossoms, several hundred to a cluster, so that the actual fruiting of only a fraction of 1 per cent will give an abundant crop. This enormous percentage of shedding renders it difficult to hybridize successfully on a large scale and precludes the obtaining of direct evidence by ordinary methods on the need for cross-pollination or the occurrence of self-fertile varieties.

However, the indirect evidence afforded by the flower behavior is in a measure capable of being correlated with tree performance and affords a sufficient clue to justify a new plan of avocado-orchard planning, viz, the abandonment of solid variety plantings in favor of mixed plantings of reciprocating varieties, choosing desirable varieties of the A and B groups, each shedding pollen at such a time as to coincide with open flowers in a receptive stage on the other reciprocating variety. It follows that the varieties chosen should have approximately the same or at least an overlapping flowering season, early bloomers, for example, being unsuited for planting with distinctly late bloomers. Most of the midseason bloomers would serve ordinarily for planting with either early or late bloomers, since the blooming season is usually prolonged, lasting from four to six weeks.

Lack of compatibility between varieties may still interpose difficulties, but the mixed planting at least immeasurably increases the chances for effective pollination, as compared with solid plantings of one variety or of varieties all having the same periodicity of bloom.

More than 100 avocado varieties have been studied in California and Florida and classified as to flower periodicity. It is worthy of note that approximately 50 per cent fall into each of the two classes already mentioned (A and B), and similarly in any group of seedlings a like distribution takes place, a fortunate provision of Nature if indeed fruiting is mainly dependent on cross-pollination. Moreover, the flower periodicity (for example, morning opening of first-period

flowers in group A) is a fixed character of clonal varieties, and thus far no proved exceptions have been found under normal weather conditions, whether in Florida or California. In a few instances where apparent exceptions were discovered it was later demonstrated that the variety in question had been wrongly identified.

No attempt will be made here to detail all the observations on scores of varieties studied, but figures showing the typical daily behavior of a number of important varieties will reveal how the flowers go

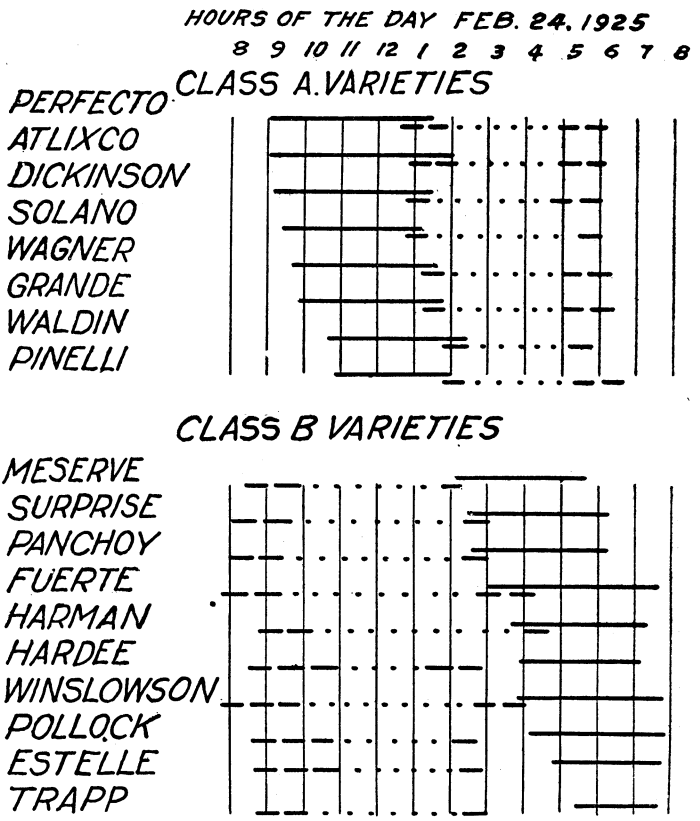

FIG. 1.—Flower behavior of avocado varieties at Homestead, Fla., in normal weather. (Solid lines indicate hours of first opening of flowers, with pistils receptive; broken lines, hours of second opening; dotted lines, period of pollen shedding.)

through their cycle with the passing hours. The solid line indicates the hours of the day during which the first-period flowers (receptive) are open; the broken line, the time during which second-period flowers remain open; the dotted portion, the period of pollen shedding. The arrangement of varieties in Figures 1 to 3 is according to the time of opening of first-period flowers in normal weather in extreme southern Florida, which results in separating the class A and class B varieties, as shown.

OBSERVATIONS OF THE FLOWER CYCLE IN AVOCADO VARIETIES

Figure 1 gives a picture of a typical day's flower behavior in good weather, at Homestead, Fla., fairly early in the blooming season (February 24, 1925). As will be seen, there was in nearly all cases a distinct break between the first-period (receptive) flowers (solid

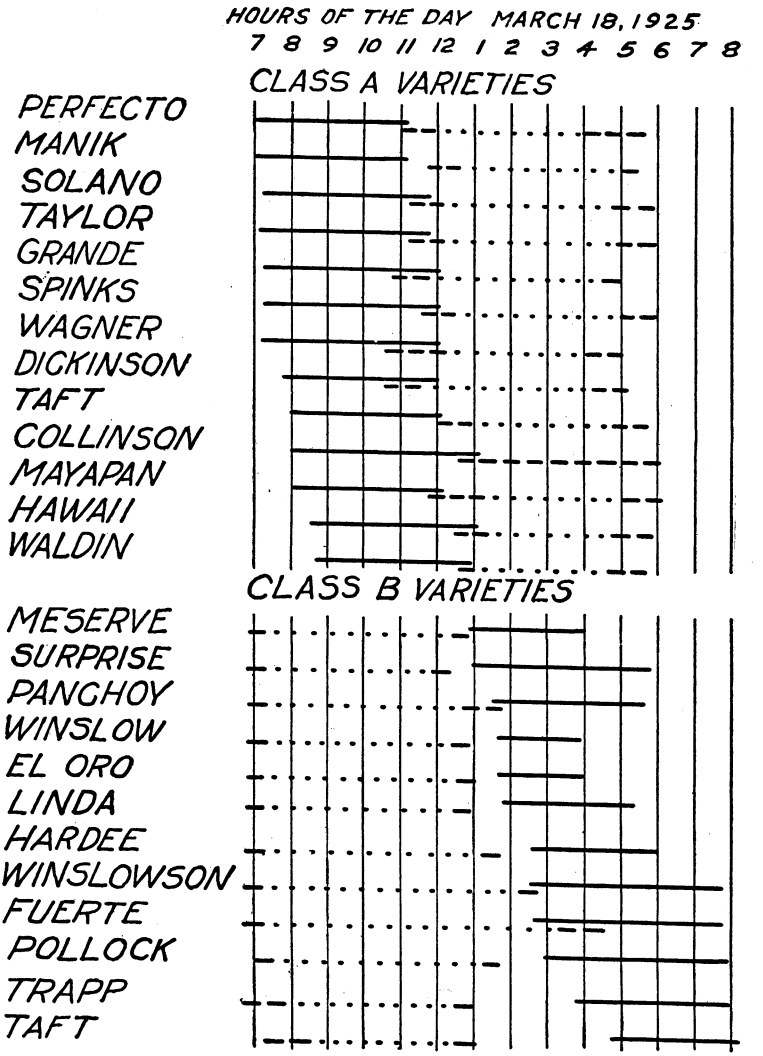

FIG. 2.—Flower behavior of avocado varieties at Homestead, Fla., showing opening earlier in the day with higher temperature of advancing spring. (For explanation of lines see legend of fig. 1)

line) and the pollen-shedding stage of the second-period flowers (dotted line). The exceptions (Atlixco, Grande, and Harman) overlapped for a brief period only.

The first-period flowers probably are not receptive during the entire period of their opening, especially when their period is such as to expose the stigma to the full sunlight for several hours. This

applies to the class A varieties generally and to class B varieties that open first-period flowers soon after midday. In the case of a few class B varieties, notably Trapp, the first-period flowers open so late in the afternoon (4 to 5 o'clock) that they suffer only short exposure to the sun, and when they reopen in the morning and begin shedding pollen many of the stigmas seem to be still in good condition, affording an opportunity for self-pollination. If this were not the case, effective pollination would be especially difficult of accomplishment, since the late afternoon when Trapp flowers are first opened coincides with the gradual cessation of insect activity, and most of the afternoon pollinizers are either closing their flowers or ceasing to shed pollen. Because of a similar situation, O. I. Clark concluded that the Fuerte variety must usually be pollinated in the morning (that is, on second opening), the first opening at Point Loma, Calif., coming so late in the day that little or no pollen is being shed by other varieties, and bees have ceased operations for the day. The apparent self-fertility on the part of the Trapp variety accords with the observation that even in solid plantings it is often abundantly productive despite the lack of opportunity for effective cross-pollination. With Fuerte in Florida a similar condition sometimes occurs, especially when flower opening is delayed by cool or cloudy weather. In warm weather, however, usually prevailing during the latter half of the blooming period, the case is quite different. In warm weather the first-period flowers of Fuerte open around 3 p. m. and are usually not in receptive condition on second opening the next forenoon. Isolated Fuerte trees therefore are liable to set most of their crop from the early bloom when there are occasional opportunities both for self and close pollination.

Figure 2 includes most of the varieties shown in Figure 1, together with several additional varieties as they were behaving in good normal weather several weeks later (March 18, 1925) in the same groves. It will be noted that with the higher temperature and longer illumination of the advancing spring, flower opening became earlier by one to three hours, affecting nearly all varieties in each class. The net result, however, is not changed, the break between receptive and pollen-shedding flowers remaining substantially as before.

An anomalous condition was discovered by Stout and Savage in the study of the Collinson avocado. This is a new variety originating in Florida as a seedling of the Collins, evidently crossed with a West Indian variety. The flowers of the Collinson appear, under casual examination, entirely normal but do not shed any pollen (fig. 2), nor do the anther lids open as in all other varieties observed.

Repeated observations of the parent tree and of widely scattered progeny trees of the Collinson avocado, both in the Homestead and Miami sections on the east coast and at Terra Ceia on the west coast, failed to show a single grain of pollen produced. In only two cases were single anther lids found partially open, but no pollen was found. The fact that this excellent variety fruits well in mixed plantings is convincing evidence that cross-pollination is the regular method of fruiting with avocados generally, and in this case it is the only possible explanation of fruitfulness. This lack of pollen further complicates the problem of interplanting when the Collinson variety is selected for planting, since it can not serve as a pollinating (or reciprocating) agent. The Winslowson variety, for example, might be used to furnish pollen for the Collinson, but a third variety, as

Taylor or Waldin, would be desirable (if not absolutely necessary) to reciprocate with Winslowson. It is to be hoped that seedlings

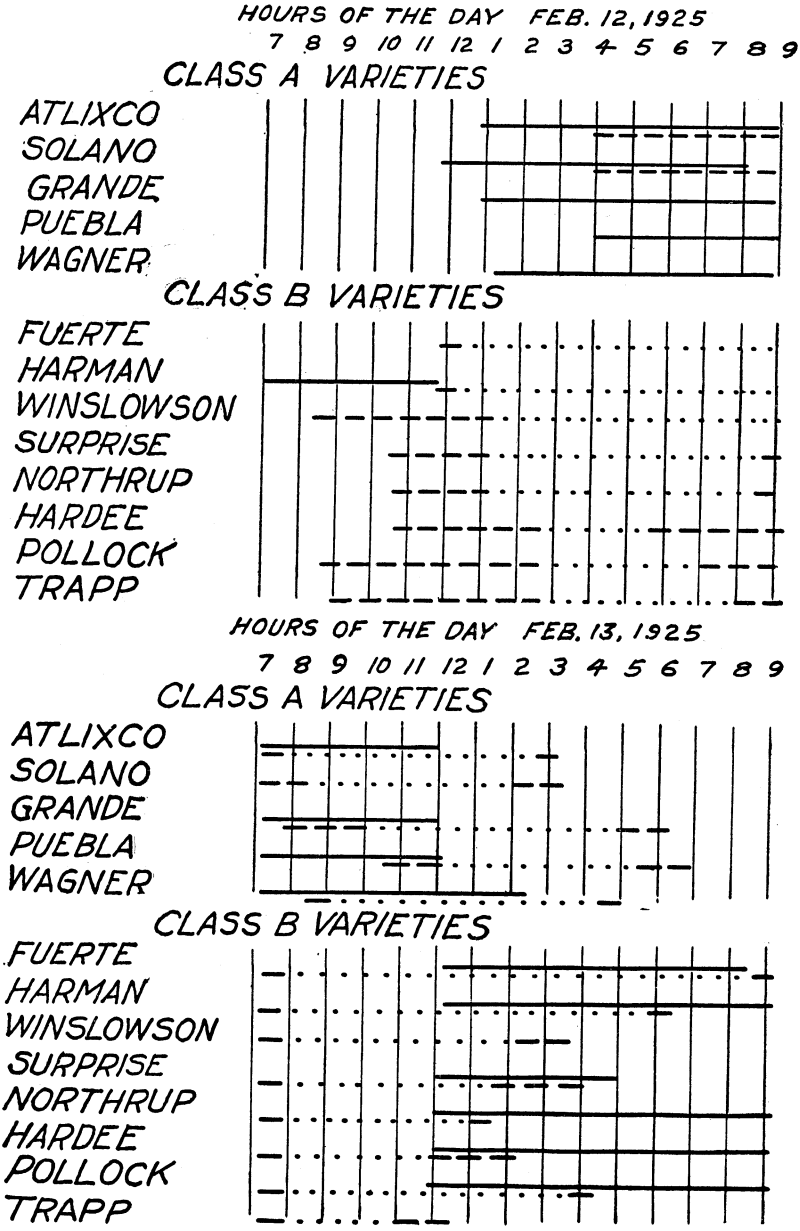

FIG. 3.—Flower behavior of avocado varieties at Homestead, Fla., showing effect of a cold spell. (For explanation of lines see legend of fig. 1)

resulting from cross-pollinated fruits of this variety may give rise to a new strain preserving the excellent qualities of this variety—scab resistance, thrifty habit, and hardiness—and at the same time re-

storing the pollen-shedding function to its flowers. Meanwhile, it would be folly to make solid plantings of such a variety, lacking any means for pollination beyond that afforded by chance insect visitations from neighboring groves.

FLOWER CYCLE UPSET BY WEATHER CHANGES

Figure 3 shows how a sudden change of weather may upset the floral cycle, deferring flower opening and partially inhibiting the regular action of the floral parts. The flower behavior on February 10 was substantially as shown in Figure 1 (February 24). A cold wave during the night of February 11, following a rain the day before, resulted in the conditions shown. The drop in temperature during February 12 and 13 was not excessive (about 20° below the daily mean as compared with the three days previous) but was sufficient to give a light frost on the night of February 12, the only such occurrence of the season. The delayed opening and irregular closing of the flowers resulted, as shown, in considerable overlap of receptive and pollen-shedding flowers on the same tree (Atlixco, Grande, Wagner, Fuerte, Harman, and Pollock); but the scanty pollen production and diminished insect activity, together with unfavorable temperature, render it doubtful whether close pollinations occurring at such periods would be of material effect in setting fruit. The low temperatures resulted in many flowers failing to close at night and continuing in open condition during pollen shedding and until final closing.

EFFECTS OF MIXED PLANTING

Figure 4 [5] shows the flower behavior observed in a collection of avocado varieties at Lucerne Park, Fla., on two dates about a year apart (April 18, 1924, and April 20, 1925) when the weather conditions were normal for the season—warm and dry. It will be noted how nearly the 1925 showing reproduces that of the year previous, indicating a very fixed habit in the flower behavior. The arrangement of varieties is not by classes but as the trees occurred in the rows. This arrangement was not especially conducive to facilitating cross-pollination, and fruit setting was generally very scanty. Bees were not seen visiting the flowers except in rare instances. Figure 4 shows how very slight is the opportunity afforded for any close pollinations, there often being a gap of a full hour between the closing of first-period (receptive) flowers and the opening of the second-period (pollen-shedding) flowers. An exception must be noted in the case of the last variety, Val di Flor, a small-fruited Mexican variety of no commercial importance. In this case there was a pronounced overlap between the two sets of flowers, affording approximately a two-hour period in the afternoon when close pollinations might take place. It is not surprising, therefore, that the set of fruit on trees of this variety was very heavy in both seasons, much more than the trees could possibly hold to maturity.

Figure 5 with the varieties arranged as the rows occurred in an orchard at Terra Ceia, Fla., will serve to show the importance of careful planning of the variety orchard. The situation shown on

[5] The observations for this figure and Figure 5 were made by the senior writer.

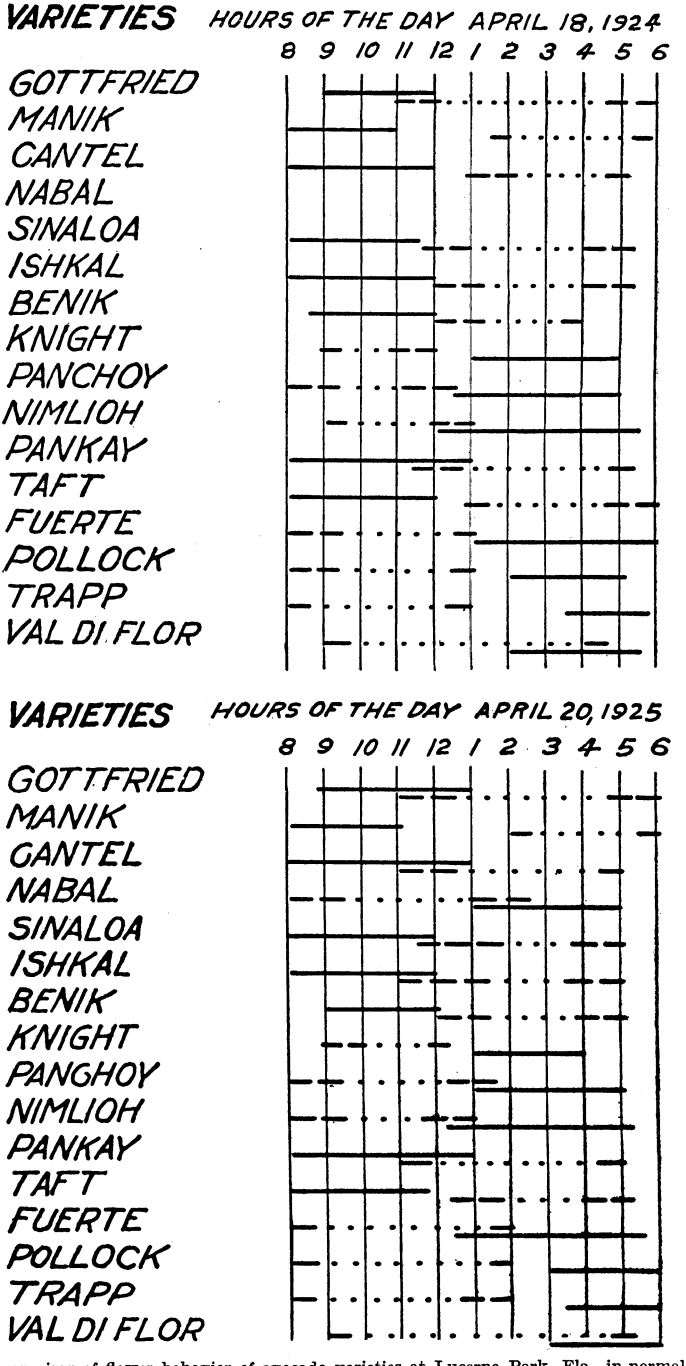

FIG. 4.—Comparison of flower behavior of avocado varieties at Lucerne Park, Fla., in normal weather on two dates approximately a year apart. (For explanation of lines see legend of fig. 1)

the dates given (April 1 and 2, 1925) is typical of several sets of observations made at this season of the year. At the time this planting was made no attention had been paid to the need for pollina-

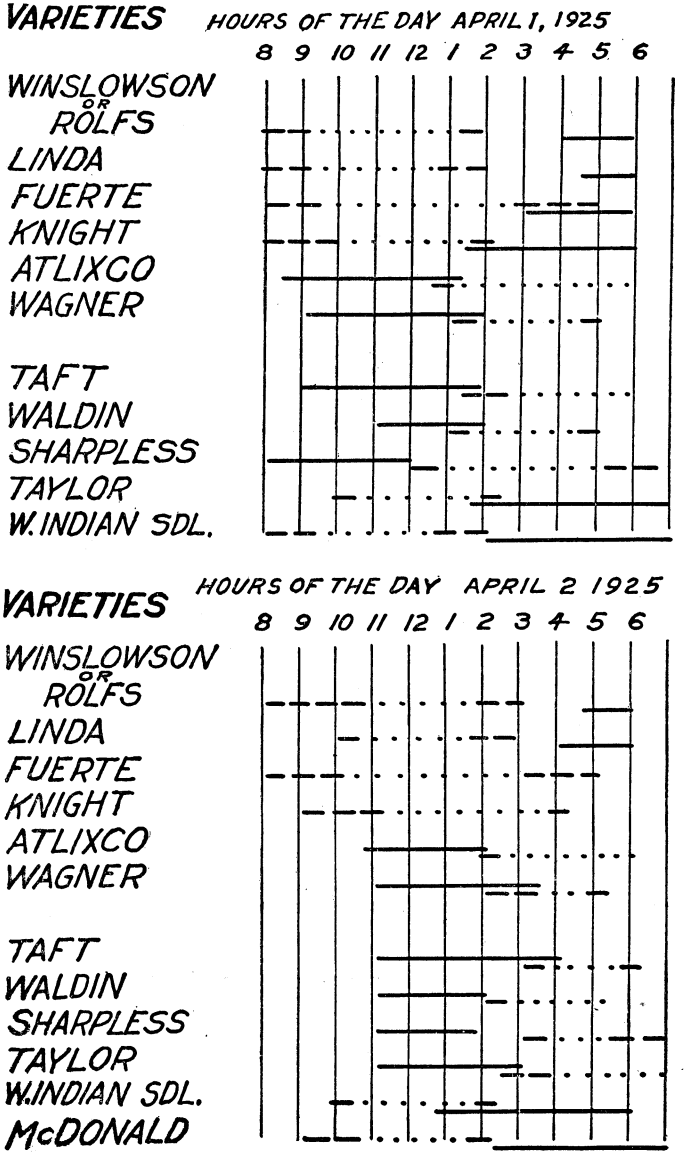

FIG. 5.—Flower behavior of avocado varieties at Terra Ceia, Fla. (For explanation of lines see legend of fig. 1)

tion, and the varieties were selected on the basis of their probable value for supplying a succession of fruit maturing during the late fall and winter months. It happened that five of the selected varieties were of class A and six of class B, which might be regarded as fortu-

nate, but in planting them the four rows on the north side were planted to class B varieties (Winslowson, Linda, Fuerte, and Knight) and the next six rows to class A varieties (Atlixco, Wagner, Taft, Waldin, Sharpless, and Taylor). Two West Indian seedlings, both of class B, stood at either end of the last row of Taylor trees, and some distance away there was a single tree of McDonald, also of class B.

This unfortunate grouping of varieties, as Figure 5 shows, greatly restricts the opportunity for cross-pollinations, but has been in a measure overcome by placing numerous hives of bees in the orchard at blooming time, about one hive to six trees. The bees have worked the flowers very thoroughly, and fruit setting, while spotted, has been fairly good for the age of the trees. The trees of the Taylor variety with the reciprocating seedlings close by have fruited very heavily, and they justify the expectation that a better arrangement of reciprocating varieties in the orchard would increase fruit production. It is expected that some trees of each class will be top-worked in the near future to increase the chances for effective cross-pollination.

Another striking instance of the effect of mixed planting on fruit setting came to the writers' attention at Lake Eloise, Fla. A 10-acre planting of Fuerte avocado trees, 10 to 12 years of age, of thrifty appearance and well fertilized, failed season after season to produce any fruit. Adjoining this grove several rows of recently planted avocados of different varieties came into flower for the first time during the spring of 1924 while Fuerte was still in bloom. The Perfecto and Spinks varieties immediately adjoined the older Fuerte grove. The first row of Fuerte trees next to the new planting for the first time set a full crop of fruit; in the second row there was only a fair set of fruit, in the third row only one tree (out of 12) had set any fruit, whereas in the fourth and succeeding rows no fruit set could be found. In the spring of 1925 examinations were made again, but the results, though indicating similar effects, were much less striking, apparently because the Fuerte trees were practically through blooming before the trees of the adjoining rows came into bloom. This tendency to early blooming in response to a period of warm weather is very pronounced in the Fuerte variety and may restrict its opportunity to be benefited by cross-pollination.

In another instance two trees of the San Sebastian variety were found growing on adjoining properties near Oneco. One tree standing alone, a fine, thrifty specimen, had never been known to bear a single fruit. The other, a younger and smaller tree, for the last three years has borne good crops, one of these crops in 1923–24 being practically the full capacity of the tree. Growing close by this bearing tree are avocados of two other varieties (Lula and Eagle Rock), and the first crop of San Sebastian fruit was borne during the season when these near-by trees became large enough to bloom. The San Sebastian in its blooming habit has the same weakness as the Fuerte, usually having its heaviest bloom before most other varieties are in flower, which may account for the fact that this variety is generally classed as exceedingly nonfruitful in Florida. Progeny trees from the fruitful San Sebastian at Oneco are to be observed in future seasons, to learn whether there is a possibility of locating fruitful strains of such varieties. At present, however, it appears most likely that the Lula

variety, serving as a pollinating agent for the San Sebastian, is responsible for fruit setting in the case cited. Bees were kept on the place, no doubt facilitating the transfer of pollen at the critical period of bloom.

TENTING EXPERIMENTS

Tenting experiments (using cheesecloth stretched over wooden frames) were made at Homestead during the spring of 1925. The tents were completed on February 28 and remained in place until a violent windstorm on May 5 blew them down. This storm injured the trees somewhat and no doubt broke off part of the recently set fruit. A hive of bees was placed under each tent, and single trees of four varieties—Linda, Panchoy, Taft, and Trapp—were thus inclosed. The bees were observed to work the flowers very thoroughly and were kept in good condition by supplying them with honey as needed. The hives were removed on April 9 when blooming was practically over. Observations on fruit setting made June 1 on trees inside and outside the tents, although not entirely decisive, indicated that fruit setting, where there was no opportunity for cross-pollination, was greatly diminished despite the long-continued and intensive working of the flowers by the imprisoned colony of bees. On Linda, under a tent, 22 fruits had set, as contrasted with an average of 67 fruits on 9 trees of this variety near by; on Panchoy 2 fruits were set as compared with 12 on an untented tree; Taft, under a tent, set 7 fruits as against 68 and 44 on 2 trees of the same variety untented. In the case of Trapp there was no such contrast, fruit setting on the trees in this grove being generally low during the season. On the tented Trapp 18 fruits were set, as compared with an average of 17⅔ for 9 untented trees close by in the same grove. This result, although indecisive, is in line with the observation previously noted that the Trapp variety is not entirely dependent on cross-pollination, but may be and probably often is self-fruitful. It is desirable to check these results further in another season, using tents both with and without bees. The grove trees generally in this region seemed to be very little visited by honeybees, but attracted a large number of flies [6] during the blooming season.

SUGGESTIONS FOR INTERPLANTING

There is still much to be learned about the best grouping of varieties to bring about satisfactory conditions for fruiting; but the selected lists of class A and class B varieties here given will serve to guard against making solid plantings of varieties that have the same flower behavior and therefore are not capable of benefiting each other through cross-pollination. A variety very early or very late in blooming is indicated by the symbol E or L following the name. The others may be classed as midseason.

---

[6] A collection of the more conspicuous insects (chiefly flies) found visiting avocado blooms at Homestead, Fla., was made by the junior writer in the spring of 1924. These were determined by specialists of the Bureau of Entomology, U. S. Department of Agriculture (J. M. Aldrich, C. T. Green, and W. L. McAtee), and the following names were assigned: Chloropidae.—*Oscinella* sp.; *Hippelates* sp. Muscidae.—*Musca domestica* L., *Fannia femorata* Lw. Eupidae.—*Eupid* sp. Trypetidae.—*Aciura phoenicura* Lw., *Ensina humilis* Lw. Tabanidae.—*Tabanus americanus* Forst., *Tabanus exul* O. S. Syrphidae.—*Mesogramma polita* Say, *Volucella mexicana* Mcq. Reduviidae.—*Zelus bilobus* Say. Phymatidae.—*Phymata erosa* var. *guerini*, L. and S. Miridae.—*Ceratocapsus* sp.

Class A varieties [7]

Name	Race
Atlixco	Guatemalan.
Barker	West Indian.
Benik	Guatemalan.
Blakeman	Do.
Butler	West Indian.
Challenge, E	Guatemalan.
Collinson, L	Hybrid.
Dickey, L	Guatemalan.
Dickinson	Do.
Family	West Indian.
Gottfried, E	Mexican.
Lula	Hybrid.
McCann	West Indian.
Perfecto	Mexican.
Pinelli	Hybrid.
Puebla, E	Mexican.
Sharpless, L	Guatemalan.
Simmonds	West Indian.
Sinaloa	Guatemalan.
Solano	Do.
Spinks	Do.
Taft	Do.
Taylor	Do.
Wagner	Do.
Waldin	West Indian.

Class B varieties [8]

Name	Race
Colla, L	Guatemalan.
Collins, L	Do.
Cook, L	Do.
Eagle Rock	Do.
El Oro, L	Do.
Fuerte, E	Hybrid.
Harman, E	Guatemalan.
Itzamma	Do.
Knight, L	Do.
Lamat	Do.
Linda	Do.
Lyon	Do.
McDonald, L	Do.
Meserve	Do.
Nimlioh	Do.
Panchoy	Do.
Pollock, E	West Indian.
Queen	Guatemalan.
Rey, L	Do.
San Sebastian, E	Mexican.
Schmidt	Guatemalan.
Surprise	Do.
Trapp	West Indian.
Verde	Guatemalan.
Winslowson (or Rolfs)	Hybrid.

New plantings should include varieties selected from both of the above classes for interplanting. Where solid plantings of one variety (or varieties all of one class) have been made, it may be necessary to top-work a portion of the trees to one or more reciprocating varieties before fruiting will be satisfactory. Seedling avocados growing near by may serve to effect cross-pollination in such plantings, since in any group of seedlings approximately 50 per cent is found to fall in each class. Wherever available, hives of bees placed in the groves at blooming time should increase the chances for cross-pollination and fruit setting.

Rather close planting is preferable to wide spacing in the rows, to induce free insect visitation from tree to tree of reciprocating varieties. The working of two reciprocating varieties on the same stock may prove in some cases to be feasible and effective, provided the chosen varieties grow with approximately equal vigor and bloom during the same period.

In view of the existence of occasional isolated seedlings regularly bearing full crops and of some few varieties at least partially self-fertile, there is reason to hope that controlled cross-pollinations may lead to procuring new varieties not entirely dependent on cross-pollination for fruiting.

SUMMARY AND CONCLUSIONS

An understanding of the pollination mechanism of the avocado is necessary as a prerequisite to successful breeding work with this unique subtropical fruit. Studies of the flower behavior of the avo-

[7] Class A, having only first-period flowers (receptive) in the forenoon and second-period flowers (shedding pollen) in the afternoon.

[8] Class B, having only second-period flowers (shedding pollen) in the forenoon and first-period flowers (receptive) in the afternoon. This classification may be altered or upset by sudden and violent weather changes, but holds good for weather favorable to pollination and fruit setting.

cado have revealed that the flowers really have two periods of opening and closing, as a result of which there is seldom a case where flowers that are both open and receptive are found on individual trees while pollen is being shed. Pollen is shed only on the second opening of the flower, at which time the stigma is usually past the receptive stage. All trees of the same variety behave substantially alike. This decided proterogyny is clearly an adaptation calling for cross-fertilization.

The avocado varieties investigated fall into two groups or classes shedding pollen at different hours of the day. Varieties selected from these two groups and interplanted should increase greatly the chances for fruit setting, provided they bloom at the same time and nectar-seeking insects are active in the bloom.

Little is yet known as to intervarietal compatibilities; but solid plantings of a single variety or of varieties all of one class are decidedly unwise, in the light of the data here presented.

It should hardly be necessary to add that setting of the fruit is only one step in raising a crop. Without good drainage, adequate water and plant food, grove sanitation, and good judgment in grove management one can not hope to raise profitable crops of avocados.

ADDITIONAL COPIES
OF THIS PUBLICATION MAY BE PROCURED FROM
THE SUPERINTENDENT OF DOCUMENTS
GOVERNMENT PRINTING OFFICE
WASHINGTON, D. C.
AT
5 CENTS PER COPY

▽