Proc. Fla. State Hort. Soc. 46:109-114. 1933.

POLLINATION AND OTHER FACTORS INFLUENCING THE PRODUCTION OF AVOCADOS

T. Ralph Robinson
Senior Physiologist,
U. S. Department of Agriculture, Terra Ceia

The discovery about ten years ago that the avocado, because of certain peculiarities in the flower mechanism normally required cross-pollination was soon accepted and grove plantings in Florida have generally been made in recent years with this fact in mind. Occasional instances, however, of good fruiting under circumstances precluding cross-pollination have made necessary further studies of the flower mechanism, and these observations have brought to light several aberrant or non-typical forms of flower mechanism in the avocado. A brief review of our knowledge as to the normal behavior of avocado flowers will give the background for our later studies.

The unique behavior of the avocado flower, exhibiting both proterogyny and synchronization of a new type, has been investigated in detail by Stout and later by others. The normal flower cycle was found to involve two openings of the flower, the closed interval between these open periods, however, differing widely for varieties in different groups, and sometimes for different varieties of the same group. By "group" is meant that aggregation of varieties having receptive flowers at the same period of the day. Class A varieties, as distinguished by Stout, comprise those having their "first-period" (receptive) flowers in the morning, with another set of open flowers in their second opening or anthesis shedding pollen in the afternoon. Class B comprises all other varieties which have a reverse flower behavior, i. e., exhibit "first period" flowers (receptive) in the afternoon, with pollen shed only at the second opening of the flowers, which usually occurs during the forenoon following.

With Class B varieties it will be readily seen that the complete cycle is completed in approximately twenty-four hours—from noon until the following noon, though with some varieties when exposed to low night temperatures, first-period flowers (after their closing at nightfall) may remain closed until the morning of the second day, thus requiring a forty-eight hour cycle.

With Class A varieties, the first-period flowers closing about noon normally remain closed until the afternoon of the following day, pollen shedding on the second opening, the full cycle requiring thirty-six hours. These rhythmic cycles are often upset or completely reversed by violent weather changes—cold weather and rain delaying flower opening and high temperatures and sunlight speeding up the process. These weather changes sometimes result in "overlap" of two sets of flowers for short intervals—long enough if insects are active to permit considerable close pollination. The fact that the stigma usually withers during the first flower opening when no pollen is available from flowers of that same tree or trees of the same variety pointed to the need for cross-

pollination, and many observations have confirmed the belief that interplanting of varieties of Class A and Class B would facilitate cross-pollination and increase crop production.

The observation, however, of instances in which isolated trees or solid plantings of a single variety (such as the Fuerte variety, widely grown in California) have produced excellent crops without the possibility of cross-pollination has led to some scepticism as to the validity of the recommendation for interplanting of reciprocating varieties. Further studies seemed desirable with especial reference to the effect of local climatic conditions on the flower mechanism. This seemed of especial importance in connection with Fuerte variety, which greatly preponderates in all recent California plantings.

During the studies made in Florida by the writer, the Fuerte variety in its flower behavior had been observed to be quite sensitive to variations in temperature. In the paper cited, an instance is recorded where a ten-acre planting of this variety in South Florida had remained practically sterile, though in good thrifty condition. The later planting of additional trees of reciprocating varieties along one side of this grove resulted in a full set of fruit in the Fuerte trees adjacent to the new planting as soon as these later planted trees began to produce flowers. The effect of cross-pollination extended, however, only to the second row of Fuerte trees, the main grove remaining practically sterile.

Some time later an isolated tree of the Fuerte variety attracted considerable attention among Florida horticulturists for its abundant crops, despite the lack of any nearby reciprocating variety to provide for cross-pollination. This tree was located near the northern limit for avocado growing in Florida (at Blanton in Pasco County) and was planted in a fairly rich soil heavily fertilized each year. A study of the flower behavior of this tree showed during the cool weather, during the first half of the bloom, abundant opportunity for both close and self-pollination, and fruits set freely during this time—late January and February. With the coming of warmer weather, the flower behavior changed so that self-pollination became impossible and no more fruit was set. The first opening of flowers during the period of cool weather occurred so late in the afternoon—often as late as 5 P. M.—that the stigma was carried overnight in good condition and apparently was still receptive when pollen shedding took place the following morning.

This same condition was noted by Clark at Point Loma, Calif., with the conclusion that pollination of the Fuerte variety in this cool coastal area must usually take place on the second opening, i. e., in the morning.

In warmer weather this first opening was advanced to two or three o'clock in the afternoon; by sundown, when the flowers closed, the stigma was withered and brown and quite unreceptive when pollen was shed on the following morning. During cool weather there was also a also short period of overlap of receptive and pollen sets of flowers, giving opportunity for close-pollination. This overlap did not occur (or to a negligible extent) when higher temperatures prevailed, temperatures ranging from 75 to 85 degrees during the middle of the day.

These contrasting instances afforded a possible clue to the apparent self-fertility of the Fuerte variety over a considerable area in Southern California, and observations were made during April and May of 1930 in several groves fairly typical of the region where

rapid expansion of avocado acreage in California is taking place. The coast region of San Diego County extending inland for ten to twenty miles has become the most active center of avocado planting, with similar but smaller developments taking place further north in Orange and Los Angeles County. This coastal region, under the influence of ocean breezes, has an equable though relatively cool climate, especially during the blooming season of the avocado, roughly from February until May.

Temperature records taken in connection with avocado bloom studies at Torrey Pines Station (La Jolla, Calif.), Escondido and Vista, showed temperatures during the height of the bloom, in late April and May, seldom in excess of 75 degrees F and dropping rapidly in the late afternoon to 65 degrees or even 60 degrees, even on sunny days. This coolness in the late afternoon is especially critical with the flower behavior of Fuerte, and goes a long way to explain its apparent self-fertility in this region.

Not only do many flowers open late and carry their stigmas overnight in good condition for pollination the following day, but the whole floral action is less definitely synchronized. Pollen shedding flowers opening in the morning do not close promptly and synchronously around the noon hours (as they do at higher temperatures), but those opening rather late in the morning continue to dehisce practically all the afternoon, providing pollen for fertilizing the receptive "first-period" flowers opening from three o'clock onward. Thus the Fuerte variety under the climatic conditions of this region shows abundant "overlap" of receptive and pollen-shedding sets of flowers during a good part of the blooming season, rendering close-pollination easy of accomplishment providing insects are present and actively working over the flowers.

This condition evidently was not found or was very rare in the foothill section around Claremont where Stout made most of his observations in 1922-23, a region where the Fuerte variety in solid plantings has proven decidedly unproductive with, however, occasional instances of good fruiting, explainable as due to seasonable differences.

An attempt to check over the behavior of the Fuerte flowers in this region in 1930 was made, but a period of rainy weather coming near the very end of the blooming season, in May, rendered reliable observations impossible.

In connection with these studies, some instances of unusual flower behavior were noted that seem worth recording. Stout has made reference to occasional aberrant behavior of flowers which omit the first opening, going through their cycle in a single opening. This appeared to be induced by weather conditions, especially subnormal temperatures, in nearly all cases. In the course of observations made in the relatively cool coastal region of San Diego County, California, several varieties were noted that regularly exhibited this flower behavior. A complete cycle is accomplished in a single opening, with pollen being shed in normal abundance and with stigmas still apparently receptive, instead of the normal or double opening of the flower, pollen shedding only after the second opening.

The Chota variety, one of the Popenoe introductions from high elevations in Ecuador, regularly showed this single cycle, both at the Matzen grove near Escondido and the "Little Rancho," near Vista, Calif. Not only did the flowers of this variety show this aberrant mechanism, but approximately fifty per cent, of the flowers examined exhibited double pistils and carpels.

Likewise the Nabal variety at both these stations shed pollen in a single opening in normal weather for the blooming season, temperatures ranging from 78 degrees at noon to 61 degrees at *5* P. M. The flowers, moreover, were normal in other respects.

From the condition of the stigmas when anthers began to dehisce it seemed fairly evident that the self-pollination was easy of accomplishment for these varieties, the only requirement being insect visitation. The stigma regularly stands above the open anthers and the pollen grains cohere in such a way that they are not blown about by air currents but must be transferred by insect agency.

When the phenomenon of "single cycling" occurs, the flowers on first opening do not have their anthers spread out in a flat plane, as do normal, first-period flowers, but the inner whorl of anthers, three in number, are more or less erect, radiating from the erect pistil, and are gradually drawn inward before final closing of the flower until almost in contact with the style.

Similar observations were made on the flowers of the Nimlioh, Carlsbad, and "Banana Lyon" varieties at the Matzen grove near Escondido and on two seedlings at the Oakley grove at Brentwood Heights, near Los Angeles, California.

This "single cycling" is recognized as occurring with considerable frequency in Florida with such B Varieties as Trapp and Winslowson, which normally have their first opening quite late in the afternoon. It is commonly interpreted as simply an omission of this first flower opening under the influence of subnormal temperature with perhaps diminished sunlight contributing to the aberrant behavior. It may play an important role in the pollination of such varieties.

There is abundant evidence that the Trapp variety is entirely self-fruitful under Florida conditions, solid plantings frequently bearing so heavily as to overburden the trees, a result which might be expected from abundant single cycle flowers. This omission of a flower opening is not to be expected so frequently, if at all, with varieties of Class A, having their first flower opening in the morning hours during a period of rising temperature, and it is noteworthy all of the varieties observed, are definitely of Class B.

If varieties of Class A should be found frequently exhibiting in normal weather this single cycle habit, it would be decidedly surprising and might require some modification of the interpretation now placed on the flower mechanism of the avocado.

A striking and unique, case of aberrant flower mechanism is found in the case of the Collinson variety, a Guatemalan-West Indian hybrid and one of the favorite varieties for planting in Florida. Despite the fact that the flowers of the Collinson are completely pollen-sterile, trees of this variety in mixed plantings are normally productive, indicating that cross-pollination is a common occurrence where opportunity is afforded. A single tree of the Collinson variety was observed at the U. S. San Diego Acclimatization Garden, Torrey Pines, in California. The tree had lost its label at the time of planting and so it was not known what variety it represented. A single observation of its flowers, normal except for the failure of the anthers to open and dehisce, gave a clue to its identity. Examination of the shipping records then confirmed the identification as the Collinson variety. The tree had flowered for two seasons, but had borne only one fruit. The varieties planted nearby—Ward, Mayapan, Spinks and Puebla— were all of the

same class as the Collinson (Class A) and did not shed pollen freely at a time of the day when the Collinson flowers were in a receptive condition. A bud of the Fuerte variety was topworked by the writer into one branch of this tree to provide means of cross-pollination. Within a year the Fuerte bud bloomed and as a result the Collinson tree set and matured several fruit the following season. It would be folly, of course, under any circumstances to make a grove planting of such a variety without providing for cross-pollination. With this provision it is a valuable and fruitful variety under Florida conditions. The fact that the Collinson variety fruits fairly well in Florida has led many growers to doubt the observation that its flowers are devoid of pollen and must be cross-pollinated. The following experiment was devised to test this conclusion, the test being made in Mr. J. W. Barney's grove at Palma Sola, Florida.

On February 18, 1929, before any open bloom appeared, a framework was built over one of the Collinson trees (No, 1) which was covered with "seedbed muslin," care being taken to leave no openings that would admit insects. The end of one of the lower branches was allowed to protrude from the tent, thus exposing the flowers to insect visitation. On another tree (Tree No. 2) a single lower branch was similarly covered with muslin, leaving the main tree uncovered. Provision was made for opening these tents to permit inspection during the blooming period, but care was taken to admit no insects during inspection. On April 14, when blooming was nearly over, it was observed that, due to warping of one of the side cleats, a small, opening had been made in one upper corner of Tent No. 1. One wasp and a few flies and gnats were inside the tent at this time. As in previous experiments examination of open flowers showed a complete absence of pollen, although the flowers went through their cycle in a normal manner.

On April 22 blooming was completed and the tent covers removed. The foliage underneath the muslin cover was in good, healthy condition and no defoliation or other apparent injury took place as a result of partial shade during bloom.

Inspection on April 14 showed no fruits set on tree No. 1 under the tent. On the single small branch exposed to insect visitation 38 fruits had set, from one-fourth to one-eighth inches in diameter. On tree No. 2 the main tree had set fruit in abundance, with *no* fruit setting on the tented branch. A single branch comparable in size and position to the tented branch had set 21 fruits.

On April 22 (when the tents were removed and blooming was at an end) the exposed branch of tree. No. 1 had seven fruits holding one-fourth to one-half inches in diameter, with none on the main tree. Tree No. 2 continued to carry a fairly heavy crop of fruit on the main tree, with no fruit showing on the covered branch.

At the writer's suggestion, a similar tenting experiment on a tree of the Collinson avocado was made by the late W. J. Krome at Homestead, Florida. This tree was tented March 16, 1929, and tent removed May 27, 1929; Mr. Krome's notes reported to the writer read as follows: "We caged a Collinson tree under double wire netting, about the time bloom began to open and today removed this barrier to outside pollination (May 27). The shading due to the cage has left the tree in wonderful condition, but it is the only one in the entire row of Collinsons which is carrying no fruit at all."

Besides the field studies on the avocado and its flowering habits, laboratory studies have been made that confirm the conclusions pointing toward the need of cross-

pollination in most cases. Cytological work on the floral parts of the avocado carried out in California in which thousands of sections have been critically examined under high power magnification has shown that, at the first opening of the avocado flower, the embryo sack is in proper condition for fertilization, but that by the time the second opening takes place fertilization has already occurred or the embryo sack is past the receptive stage. This can only mean that the pollen for fertilizing the embryo must come from some other flower, and usually from a tree of some other variety which has a different period of pollen shedding, i. e., from a reciprocating variety. With varieties like the Fuerte in the Coastal Zone of California, the pollen may come from a flower on the same tree, since it has been shown that there is much overlap of the first and second period flowers under the climatic conditions of this region.

GIRDLING TO INDUCE FRUIT SETTING

The question is sometimes raised as to the effect of girdling on avocados that fail year after year to bloom or set fruit. In some of the foothill sections of California where fruiting of the avocado is very uncertain, girdling has become a regular practice, despite the fact that it is recognized that the tree is weakened, sometimes seriously, by girdling. The results are not at all uniform, but there is often a response that is so positive as to leave no doubt that girdling under the right set of conditions does prove effective. Investigations in California on the storage of starch in the avocado have shown that the avocado, like the citrus tree, does not store up in the limbs and fruiting twigs any considerable reserve of this material, so essential to fruit bud differentiation and to the nourishment of the developing embryo which forms the fruit. Girdling has the effect of temporarily cutting off the transfer of starch from branch and trunk to the roots and in this manner increases the reserve food in branches and enables the tree to flower and set fruit. A few experiments on a small scale have been made by the writer with positive results, others with negative results.

On Mr. Barney's place near Bradenton an old seedling; having two main branches was used in an experiment, one branch being girdled by removing a narrow ring of bark near the base of the branch. This tree had year after year borne no fruit. Girdling was done in the winter just before time for new growth and bloom to appear. The girdled branch bloomed, and set a fair crop of fruit, maturing 35 fruits as against none on the other ungirdled branch. In subsequent seasons, however, the tree has not responded as it did on this occasion.

Girdling cannot be recommended as a standard grove practice. With varieties that are uncertain in fruiting or nearly sterile despite favorable conditions as to pollination and culture it will generally be much the better plan to topwork the trees with varieties which have proven fruitful without resort to such drastic treatment. The avocado forms callous tissue at a rapid rate where the girdling takes place and apparently heals the wound in a short time, but the branch is nevertheless weakened at that point and may break off under the strain of a strong wind or a heavy load of fruit. Where girdling is done year after year the damage is likely to be especially marked.

It should hardly be necessary to add that setting of the fruit is only one step, although a vital one, in securing a crop of avocados. Without good drainage, adequate water and

plant food, grove sanitation, and good judgment in grove management one cannot hope to raise profitable crops of avocados.

Member: I wonder if Mr. Robinson would tell us about the time of girdling in relation to the time of blossoming.

Mr. Robinson: We do not have enough experiments to make a very definite reply to this question, but I think any time before new growth starts, if done at least a month or two before, you would be apt to get some response. I prefer as a rule to make it in the Fall, October or November, before the growth has ceased to get the most benefit of extra-stored starch.

Member: How wide is the girdle?

Mr. Robinson: Cut down to the hardwood, just through the bark. It doesn't need to be wide —a sixteenth or eighth of an inch is plenty. You don't really need to remove any bark. It callouses over so quickly that a narrow ring will do no special damage.

Member: If removing a ring as much as five eighths of an inch wide, on a limb two and one-half inches in diameter, what would be the result?

Mr. Robinson: I have seen such rings heal over so quickly that I don't think it would make much difference whether it were five-eighths or one-eighth; it probably would weaken the limb more, that's all.

Dr. Camp: Wouldn't the spiral cut be less weakening?

Mr. Robinson: Theoretically, that might be so. The spiral girdle would stop transportation of starch just the same.

Mr. Ward, Avon Park: To what extent do you find the Lula self-fertile?

Mr. Robinson: I would hardly expect it to be so unless some kink in the flower behavior shows up which we haven't observed. With sudden changes in weather conditions there is always a chance for self-pollination.

Member: What sort of fertilizer would be of advantage in the storage of starch?

Mr. Robinson: That's a new problem; that's one of the things that needs to be worked out. That's what this Subtropical station and this Institute is established for. I really couldn't say now, except that what would prove an effective application in rock pine soil might not be so effective on sand land, and vice versa.

Member: In your opinion, what per cent, of the light bearing avocados could be traceable to lack of starch storage, do you think?

Mr. Robinson: I couldn't answer that.

Member: What would be the possibility for the occurrence of fogs in maintaining the stigma in receptive condition over night? I live in West Palm Beach, and I know also on the East Coast section there is an area where the fog is very rare; wouldn't exceed half a dozen times a year. I have noticed avocados in that section, on the ridge even; have observed the fog variations and there is a tendency to light fruit. However, that condition seems to be ideal for mangos, as far as fruits and flowers are concerned. There are two

or three plantings there, right on top of the ridge, where they would get the benefit of a clear atmosphere all the time, and there are others on the slope where there is probably some fog accumulation, from the low rising backwoods. There are different varieties. One planting of Lulas shows a very good crop on the slope of the ridge. Other crops, on the ridge, have light production. The thought occurred to me that it might be that the occurrence of fogs would be a factor in keeping the stigma receptive to pollen.

Mr. Robinson: Undoubtedly fogs and humid conditions generally will prolong the period when the stigma will remain receptive. Brilliant illumination with strong sunlight will shorten that period, but I know of no detailed observations that will enable me to answer your question very definitely.

Mr. F. A. Rundle, Lockhart: I have several trees of the Fuerte variety but have had very poor success with them. The fruit itself is very scabby.

Mr. Robinson: The Fuerte has behaved exactly in this way for many years in Florida, and that's the reason it has been dropped from all recommended lists. It's not suited to Florida; even where the fruit holds to maturity it develops black spots and hard spots in the flesh. There are instances where they have been sprayed with Bordeaux once a month where I have seen a fine crop produced, and the fruit is very fine indeed when it grows properly, but commercially it is just not suited to Florida. As a door-yard tree, however, its hardiness recommends it; if one wishes to go to a lot of trouble in spraying and keeping it coated with Boardeaux he may be able to bring through a fairly good crop.