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SUN-BLOTCH DISEASE OF AVOCADOS

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Young wedge-grafted avocado tree showing sun-blotch leaf symptoms. Note variegated and crinkled leaves. Photograph by J. M. Wallace.

HISTORY

Sun-blotch, a virus disease affecting the avocado, was observed as early as 1914 in Southern California. Carter Barrett, avocado nurseryman and specialist, reports having

seen symptoms of the disease on young avocado trees in the West Indian Gardens Nursery at Altadena that year. Barrett reports also that he observed symptoms of the disease on a budded Taft avocado tree near San Dimas some time between 1917 and 1919.

Sun-blotch was observed in Palestine in 1924 on avocado trees which had been introduced from California. These trees were known varieties such as the Fuerte and Dickinson. The fruit from these trees was described as "having sunken areas, yellow, and later turning brown. The seriously affected ones were not marketable."[2]

Sun-blotch was first adequately described in the California Avocado Association Yearbook of 1928 in an article by J. Eliot Coit, formerly Professor of Citriculture at the University of California Experiment Station at Riverside, and mentor and patron of the avocado industry. The article was entitled "Sun-blotch of the Avocado, a Serious Physiological Disease." In the article Dr. Coit named the disease "Sun-blotch" because he believed at the time that the disease was "a direct result of sunburn as affecting spindling or weak trees which suffer seriously from neglect."[3] Dr. Coit expressed his opinion as to the probable cause of the disease in the article as follows:

Recently scientists have been able to bring about marked changes in the sex cells of plants by exposing them to X-rays. Profound hereditary changes have been brought about by the X-ray applied to seeds. It appears probable that in the case of sun-blotch of the avocado, the direct rays of the sun when applied to bark in which the sap is not moving rapidly may produce similar results. In my opinion, when this occurs, a chimera is usually formed which later shows itself in the striped appearance of shoots arising from sunburned limbs. Likewise the chimeric condition extends to the fruits.[4]

Dr. Coit described the symptoms of the disease as

. . . pendulous branches or a weeping form together with a rough and scaly condition of the bark; yellowish or light colored somewhat depressed streaks or stripes of the twigs and young branches; irregular, white, yellow, reddish yellow or red sunken areas on the fruit which is usually accompanied by dwarfing or marked distortion of shape. The tree is prevented from making satisfactory growth and affected fruit is practically worthless for marketing."

Dr. Coit noted that the disease appeared more common on Guatemalan than Mexican varieties. He saw cases on such varieties as Fuerte, Puebla, Dickinson, Linda, Dorothea, Taft, Mayapan, and Mattern.

At the time of Dr. Coil's article in September, 1928, no research had been conducted on the disease to determine the nature of the causal agent. Studies were initiated at a later date that same year at the Citrus Experiment Station at Riverside, California, on the effects of the disease upon the tree and fruit and also upon the means of transmission.

By the latter part of 1932, controlled experiments at the Citrus Experiment Station at Riverside had brought to light the following information and conclusions about the disease: (1) That the disease probably was not transmitted by bacteria or fungi, or by means of tools. (2) That the disease could be transmitted by propagation of a healthy tree with an infected scion in shade as well as in direct sunlight. (3) That a rootstock would get the disease from a diseased scion budded or grafted to it. (4) That buds taken

from diseased wood and budded or grafted to disease-free trees produced sun-blotch symptoms in those trees. (5) That rate of movement of the infectious principle was about three feet a year in two year old wood. (6) That movement was faster vertically than horizontally. (7) That observation of a large number of seedling avocado trees of Guatemalan and Mexican types which had never been propagated showed no evidence of the disease. (8) Due to the repeated failure to secure inoculation by other methods than vegetative propagation, it seemed probable that the infectious agent was a virus.[6]

During the year 1932, sun-blotch was noted on a West Indian seedling avocado tree topworked *to* Carlsbad variety at Homestead, Florida.[7]

It was reported recently that the entire Fuerte avocado plantings in Israel were so heavily infected with sun-blotch that an entire replanting to this popular variety, using only registered trees from California, was contemplated in the near future.[8]

So far the exact origin of sun-blotch disease has not been ascertained. Most of the original importations of avocado trees and seeds to Southern California prior to 1911 originated in Mexico and Guatemala. The cities of Atlixco and Queretaro, Mexico, were two main sources of seed in the early days. It is possible that importations from one of these cities may have brought sun-blotch into California. In 1948, the disease was noted on some thirty year old seedling avocado trees in the Rodiles grove near Atlixco, Mexico.[9]

At the present time sun-blotch occupies a position as the second most important avocado disease in California.[10]

DISTRIBUTION

Sun-blotch is widespread in California, and likely to be found in all districts where avocados are being grown. The main counties in which the disease is found are San Diego, Ventura, Los Angeles, Orange, Riverside, and Santa Barbara.

It is important here to compare these avocado counties as to total acreages of planted avocado trees. The state-reported figures on the total acreage of avocado trees show as of February, 1949, a total of 17,000 acres planted to avocados. San Diego County has a little over one-half of this acreage. Nearly a fourth of the plantings are in Los Angeles County. One-eighth of the plantings are in Orange County. Ventura and Santa Barbara Counties have under ten per cent together. Riverside and San Bernardino have relatively minor percentages of avocado plantings.

Because of the latent character of the virus, sun-blotch could conceivably exist in any avocado orchard planting or nursery in California. No avocado orchard can be said to be entirely free from sun-blotch. Even the most carefully planted and maintained groves are not certain to be free from the disease. There are cases where sun-blotch has shown up for the first time on avocado trees over fifteen years of age.

SURVEY OF COUNTIES AFFECTED BY AVOCADO SUN-BLOTCH

This survey was made to determine approximate percentages of known sun-blotched trees found in the main avocado counties. Before a disease may be brought under control or an eradication attempted, it is necessary to know not only the areas where the disease is prevalent but the extent to which it affects the given areas. Unfortunately

there is at present no way of determining the true percentage of sun-blotched avocado trees in any one county. Only the avocado trees which exhibit true symptoms may be definitely classed as having sun-blotch.

In some trees the disease may be masked, evidently because of inactivation of the virus or because of such low incidence of the virus that the symptoms are not manifested. It would be exceedingly difficult, time consuming, and expensive to have a thorough inspection of the older, more mature avocado trees for sun-blotch symptoms. Particularly would this be true of old seedling avocado trees because of their great height, enormous spread of branches, and thick foliage. Until a positive and speedy method, applicable to all varieties, is developed to determine whether or not avocado trees have sun-blotch, it will be impossible to determine with accuracy the extent to which sun-blotch actually does exist in any of the counties in which it is found.

However, even in view of the above, as control or eradication has to do first of all with plants which are known to have a disease, this survey may prove helpful as an indicator for use in sun-blotch control or eventual eradication.

SAN DIEGO COUNTY

San Diego County, the county having the largest total acreage of avocado trees in California, appears to have the largest number of known sun-blotched avocado trees. In this county, sun-blotch occupies a position as the second most important avocado disease in the county, exceeded only by avocado root rot.

Root rot, the most important disease of this count)', is a physiological disease, but is associated with the fungus, *Phytophthora cinnamomi.* The disease affects avocados growing on poorly drained or water-logged soils. At first, the roots are affected by the resultant lack of oxygen; then the foliage turns yellow, the leaves begin to drop, and the tree gradually begins to die from the branch tips downward.

A letter from the Extension Service revealed the following information about sun-blotch in San Diego County:

For the county, the percentage (of sun-blotch) may now be around 5-7%*,* realizing that many diseased plants have been removed. It's difficult to appraise, since groves are either relatively free, (1-3%) or really have it, (15-35%).

In the older plantings in San Diego County, trees planted from 1927 to about 1935, the occurrence of sun-blotch was high. In some large developments of the real estate promotional subdivision type, the percentage could be roughly placed at 20%*.* In the more carefully developed plantings, 3-5% might be an average. Few, if any, even with careful selection of propagating material, get completely sun-blotch free plantings.

Plantings made during the '40's were much improved in this respect. But still the occurrence is too high. One six-year old planting of trees from a progressive nurseryman shows 12% infection today. In 1942 or '43 one grower bought 40 Fuerte trees from a nurseryman. After four years, when I first saw them, 33 were obviously sun-blotch—and if there is such a thing, due to a virulent strain of the virus.[11]

VENTURA COUNTY

Although sun-blotch apparently occupies first place on the list of diseases affecting the

avocado in Ventura County, results of this survey show it to be of minor importance here.

A letter from Extension Service revealed the following:

The sun-blotch disease is not a serious problem in Ventura County. We occasionally run across trees which are infected with this virus; usually the tree is not productive and is pulled out. I do not know the number of acres or the number of trees affected with this disease in the county but I could give as a guess not over one-half of one percent of trees growing in this county are in any way infected with this sun-blotch disease. There are approximately five hundred acres of bearing avocado trees in the county at this time. If you figure an average of about seventy trees to the acre that would mean about thirty-five thousand bearing trees. That would figure approximately one-hundred and seventy-five trees which are infected with this disease. In addition to the five hundred acres of bearing avocados there are now about five hundred acres of non-bearing trees. New plantings have been carefully inspected at both the nursery and in the field. My guess is that none of the new plantings will be found infected with sun-blotch.[12]

ORANGE COUNTY

In Orange County, neither the Extension Service, nor the Agricultural Commissioner's office had records of the number of the known trees affected with sun-blotch.

The reason for this lack of statistics is because of the nature of the disease. The trees affected are widely scattered. They are individual cases. There are no single large blocks of trees showing the trouble. Sun-blotch symptoms vary. In some trees symptoms show early; in others, the disease is masked ; and yet in others, the tree may reach 10 or 15 years before symptoms evidence themselves. Mr. Carter Barrett feels that about 2% of all the trees are infected with sun-blotch.[13]

LOS ANGELES COUNTY The opinion of the Extension Service was that an estimate of the number of known sun-blotched trees in the county would not be possible because of the peculiar nature of the disease.

RIVERSIDE COUNTY

A letter from the Extension Service revealed the following information:

As nearly as I have been able to determine, about 12% to l5% of the planted acreage in the county has the sun-blotch disease of avocados. This high percentage is due principally to one large planting which shows a high percentage of the disease.[14]

SANTA BARBARA COUNTY

In Santa Barbara County, sun-blotch is one of the most important diseases affecting avocados. However, it was the opinion of the Agricultural Commissioner that it was difficult to rank the importance of sun-blotch as compared to other troubles. However, it is extremely serious when it does affect an individual tree. Individual trees affected with sun-blotch are widely scattered in orchards in Santa Barbara County. However, the total number of trees is relatively small compared to the total number of trees planted in the county.[15]

RATE OF SPREAD

The rate of spread of sun-blotch virus appears to be extremely slow due to improved cultural practices in the nursery and field and the apparent absence of an insect vector.

In the early days of the avocado industry when nurserymen and growers were not very familiar with sun-blotch, the disease was spread at a much greater rate than at present. Knowledge of the symptoms and habits of the disease in the nursery and field have undoubtedly slowed the rate of spread of sun-blotch in recent years.

To show the effect that improved nursery practice has had in lowering the rate of spread of sun-blotch, a Vista nurseryman wrote that

In the Vista-Fallbrook-Escondido district of San Diego County older avocado orchards have a 15% to 20% infestation of sun-blotch. Newer plantings showed on the average less than 5% in this same area. This is undoubtedly due to improved nursery practice.[16]

TRANSMISSION OF THE VIRUS *TRANSMISSION BY BUDDING AND GRAFTING*

Indiscriminate selection of budwood and possibly seeds for rootstocks, added to the fact that knowledge of the habits of this strange virus disease was lacking in the early days, undoubtedly caused the major initial spread of sun-blotch throughout the avocado growing regions of Southern California.

In the early days of the avocado industry in California when there were comparatively few mature avocado trees from which budwood could he secured, buds were often taken indiscriminately from young trees which looked promising to the eye. Many of these trees were barely able to produce bud-wood, and many others were not yet in commercial production. The registration of certified avocado trees was practically unheard of early in the history of avocado culture in Southern California. One has only to look at some of the old mature avocado plantings to observe that in some instances as high as twenty per cent of the trees in a single planting are noticeably infected with sun-blotch, a condition attributed to poor propagation practices.

Budding and grafting are among the main ways sun-blotch is transmitted. Scion wood taken from an infected tree need not show symptoms in order to transmit the disease to a healthy tree. When a disease-free seedling is budded or grafted with an infected scion a diseased tree is the result. When a scion is taken from a healthy tree and budded or grafted to a seedling affected with sun-blotch the resultant tree is diseased.

The time taken for symptoms to appear after an infected scion starts to grow varies considerably. Symptoms may be apparent within a month, or they may require from two to seven years for positive identification. An explanation of this behavior is that sun-blotch belongs to that type of plant virus which requires a relatively long period of time after inoculation of the host with the infectious principle before symptoms appear. Factors causing the delay may be due to environmental conditions, vigor of the tree, or amount of inoculum in the tree, and perhaps even the scion-rootstock relationship.

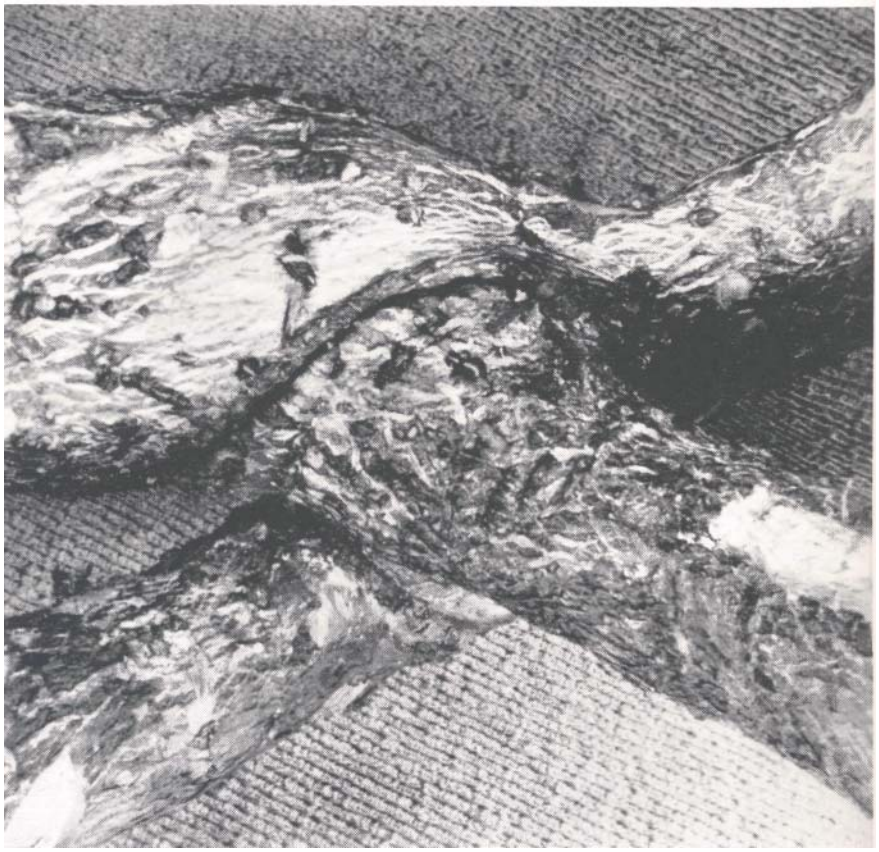
TRANSMISSION BY TOPWORKING

In past years topworking of the avocado tree in Southern California has undoubtedly been a contributing factor to the spread of sun-blotch. Many unproductive avocado trees have been topworked in an effort to increase yields or to secure a more desirable variety. Perhaps a sizeable number of these unproductive trees were grafted with

scions taken from trees which contained sun-blotch virus. Possibly in a number of instances topworking of avocado trees may have brought about masking of symptoms enabling such trees to become symptomless carriers of the disease. This condition may have made possible transmission of sun-blotch through scion and seed.

Topworking a sun-blotched infected tree to increase productivity or to secure a more desirable variety will not eliminate the disease because of the systematic character of the virus. The infectious principle carried in the sap of the tree will sometime later affect the grafted scion. Any one of several confusing or troublesome situations may occur should one attempt to eliminate sun-blotch by topworking the tree: (1) For an indefinite period of time the topworked tree may appear free of sun-blotch, only to later exhibit disease symptoms. This condition might be caused by the new growth outgrowing the virus, at first, only to succumb to it after the virus reaches the new growth. (2) The virus may fluctuate in its intensity in the topworked tree from time to time, alternately manifesting itself through symptoms, and then apparently becoming inactive through cessation of symptoms as some stimulus within or without the tree evidently causes it to do. (3) Topworking an unproductive tree may uncover the presence of a hidden carrier of sun-blotch as apparently happened in a case cited by J. Eliot Coit after topworking a budded Taft avocado tree, and in a case parallel to this concerning the same variety in Avon Park, Florida.[17] (Details of these two cases appear later under the title heading "Hidden Carriers of Sun-blotch.")

In summarizing effects of topworking a sun-blotched tree in an effort to eliminate the virus, to increase yields, or to secure a more desirable variety, the results obtained have proven most unsatisfactory.



Natural root graftage between two roots of the same avocado tree. Photograph by W. E. Averett.

NATURAL ROOT GRAFTAGE

As sun-blotch is systematic in the avocado tree, it can exist in the roots as well as the above-ground parts. Thus it might be transmitted through natural root graftage between a healthy and diseased tree.

It is known that tree roots will sometimes become forced together in some manner until finally a natural root graft has taken place. The natural grafting between roots of trees has been attributed to a number of causes, some of which are as follows: (1) Roots growing in a shallow soil underlaid by a hardpan when crowded for growing space will sometimes become grafted together. (2) Two roots growing between two rocks or other barriers when wedged together tightly may form a graft. (3) Roots from mature avocado trees which are planted close together in a grove may, if crowded for growing space, form a graft.

It is believed, through evidence existing in certain avocado orchards, that sun-blotch disease has infected healthy trees through natural root graftage.

There are places where the evidence strongly supports the con-elusion that the disease has spread through natural root graftage. These are, of course, older groves with the same owner for many years, and good grove charts and records. Early grove charts,

made when the trees were about eight years old, would show a few definitely sun-blotched trees in a grove. In subsequent years, additional cases would show up, but always adjacent to one of the original cases. In one particular orchard that showed this, numerous natural root grafts have been found in the process of digging ditches for pipeline or repairs. In a relatively close-planted grove, the incidence of this natural graftage could be quite high.[18]

The writer has visited two groves containing sun-blotched trees where, he \vas told, natural root graftage may have occurred. In one grove an entire row of eighty-four trees had been planted alternately with sun-blotched and healthy trees. "Every other tree originally had sun-blotch in that row, while every other tree was apparently free from the disease."[19] The trees now are over fifteen years old and seven of the supposedly healthy trees alternating in the planting with the diseased trees now show sun-blotch symptoms.

The other grove in question contains a sun-blotch experimental planting.

A sun-blotch avocado tree and a healthy control tree were planted side by side in March, 1932. Sometime between eight and ten years later the healthy tree exhibited its first symptoms of sun-blotch. It is suspected in the absence of a known insect vector that the healthy tree may have contracted sun-blotch through natural root graftage.[20]

These two examples do not conclusively indicate that natural root graft-age occurred; they are merely indicative of such a possibility. In the latter example, the "healthy control tree" may actually have been a sun-blotched tree in which the symptoms of the disease were slow to appear.

Opinions vary as to the percentages of avocado trees that actually transmit sun-blotch through natural root graftage. It is known that in a number of cases of natural root graftage the grafting has occurred only between roots of the same tree.

It seems evident that research is needed to determine the importance of natural root graftage as a means of sun-blotch transmission in orchards containing the disease.

TRANSMISSION THROUGH SEED

Transmission of plant viruses by means of seed occurs very rarely according to present information. Examples of transmission of plant viruses through seeds are known in the case of certain cucurbits and in bean mosaic. In transmission by cucurbits, one out of a thousand seeds from a diseased plant sometimes produces a plant showing symptoms of a virus.

Unless there is an insect carrier of sun-blotch, seed transmission definitely takes place.[21] Although experimental plantings of seeds from known sun-blotched trees have failed to produce a single diseased tree, evidence suggests that seed transmission may be one of the main ways the disease is spread.

In 1945, two cases of possible seed transmission of sun-blotch were cited in a Report of the Variety Committee on Avocados, California Avocado Association Yearbook of 1945, under the heading "Transmission of Sun-blotch through Seed."

The first case occurred in a nursery five years ago. Source records were kept and segregation of seed in the beds was practiced. Out of thirty-six sources on which

records were kept one lot of seedlings showed "Sun-blotch." This occurred in about fifteen percent of the trees when they were ready for balling. This group of seedlings were budded with buds from three varieties, all from definitely identified sources. These same bud sources were used on other stock in the nursery. Only on the #11 stock did the disease appear. On checking the parent tree of these seedlings, which is a beautiful and large specimen tree, we found that there was no visual evidence of the disease, but that its history showed that it was a budded tree which froze down in 1922, and as is apparently often the case, the new tree from the Mexican type root came up clean to the eye, but able to transmit the disease.

The second case of this sort was checked upon during the last year. An East Whittier grower planted a grove with approximately four hundred nursery trees and four hundred seedlings, which were to be budded in place. The seedlings were all from one parent tree which grew near the home of the owner. Seed had been taken from this tree in other years and it had been examined by a number of competent observers for "Sun-blotch" without being suspected. The seedlings were budded at one year of age to four main varieties— Fuerte, Ryan, Encanada, and Hellen. The buds were all taken from individually identified trees. The same buds have been repeatedly used on other stocks both in nursery production and in top-working without any trouble appearing over a period of years. When the buds on these seedlings were mostly one year of age, some rebudding of missed trees was needed and on inspecting a number of specimens of the buds in working the rows, unmistakable signs of "Sun-blotch" were discovered. A careful check which took over a day and a half disclosed that one hundred and fifty-two trees out of three hundred and forty-one showed conclusive evidence of "sun-blotch" with a number of others apparently border line cases. Therefore at one year of age over half of these buds on this root showed the disease. , On close questioning, the owner remembered that the seed source had been a Sharpless or Fuerte originally and had frozen to the ground in 1922, coming up as a vigorous, apparently healthy seedling, bearing heavy, consistent crops of a black fruit which seemed very satisfactory for seed purposes. Yet the facts indicate that the disease is systemic and such an apparently clean tree is fully capable of transmitting the disease in a heavy percentage of cases. These two cases would seem to establish that for all practical purposes, the disease of Sun-blotch is transmissible through seed and that it is imperative that the greatest care be exercised in the selection of seed sources.[22]

The two foregoing cases of apparent seed transmission involved budded trees which had frozen to the ground, coming back as apparently healthy seedling trees. The cases listed below of apparent seed transmission involve a Mexican seedling tree which had not been frozen to the ground but was apparently able to transmit the disease.

The seedling was planted about 1906 and is one of the largest avocado trees in Orange County.

Seeds were taken from this tree, (approximately 250) and planted by Hugh Walker and myself, (E. T. McFadden). Seedlings were budded with Newman Fuerte buds, from Newman Tree No. 1 and with Ryans from H. C. Smith Grove, La Habra. Many thousands of buds have been cut from Newman No. 1. It is considered free from Sun-blotch. Most of the balled trees were planted on the Walker property. They showed early symptoms of Sun-blotch. Finally, at least 95% of both Fuerte and Ryans had Sun-blotch

evidence. This condition was observed by Dr. George Zentmyer and Dr. J. M. Wallace of the Citrus Experiment Station, Riverside.

I also planted about 56 Ryans from this nursery as replants on our Prospect Ranch. Practically all showed Sun-blotch and all were dug up.

Douglas Marshburn, who is generally considered as one of the most experienced and best nurserymen in this district also planted a large number of seed from this same tree in 1939. Adjoining these he had other known seed. He did not like the appearance of the seedlings which grew from these seeds. The late Dr. William Home of the Citrus Experiment Station, Riverside, examined the seedlings. Dr. Home was of the opinion that there was definite evidence of Sun-blotch. Marshburn plowed up all of the questionable seedlings.[23] It is the opinion of some avocado nurserymen that sun-blotch is transmitted quite frequently through the seed but does not show up readily or affect the tree severely unless the tree is shocked in some way such as by frost, excessive moisture, excessive heat, or dryness.

A survey of twelve avocado nurserymen when asked what percentage of avocado seedlings they thought was affected with sun-blotch in the nursery row at any one time revealed the following information:

Nurseryman No 1	Less than 1/10 of 1%.
Nurseryman No 2	Less than 1/2 of 1%.
Nurseryman No 3	As high as 1%.
Nurseryman No 4-5	Less than a fraction of 1 %.
Nurseryman No 6	The percentage of avocado seedlings affected would depend on the source of the rootstock.
Nurseryman No 7	About 1%.
Nurseryman No 8-9	Less than 1%.
Nurseryman No 10	The number affected is difficult to determine.
Nurseryman No 11	It varies considerably; often times as many as 5% may show this condition in a minor degree.
Nurseryman No 12	0-5% certain.

The results of the above survey indicate that the number of sun-blotched avocado seedlings in the nursery row varies from time to time, (from less than .5 per cent to as high as 5 per cent), but that the percentage might be higher than this depending on the source of the rootstock.

TRANSMISSION BY MECHANICAL MEANS

Transmission of a virus by mechanical means consists of introducing the virus-bearing sap from diseased plants into wounds made in healthy plants. Cultural practices in the field, such as pruning, cultivation, and transplanting, are the chief means of spread by mechanical means.

While some viruses may he transmitted easily by mechanical means others cannot be transmitted or are transmitted with difficulty by this means.

Evidence at the present time indicates that a few viruses, such as tobacco mosaic, are

transmitted by pruning knives. So far as we know, none of the viruses attacking trees are transmitted in this manner.[24]

Controlled experiments have indicated that sun-blotch virus cannot be transmitted through mechanical means.

TRANSMISSION BY INSECT VECTORS

Transmission of viruses by insect vectors is one of the chief means by which viruses may be spread. Insect vectors which transmit virus diseases usually belong to an order with sucking mouth parts, especially the order Homoptera, (aphids, leaf hoppers, plant hoppers). Other insects involved to some extent in the transmission of plant viruses include some grasshoppers, thrips, beetles, and mites.

Transmission experiments have been conducted on sun-blotch disease using insects common to the avocado such as the melon aphid and mealybug, but the results obtained were all negative.[25]

The lack of rapid spread of sun-blotch in the field indicates that insects commonly play little or no part in its spread.[26]

DISEASE SYMPTOMS

LEAF SYMPTOMS

Leaves of sun-blotched avocado trees usually appear normal, but occasionally certain types of leaf patterns do develop on diseased trees and these are said to be leaf symptoms of sun-blotch. Unfortunately, these symptoms do not appear often enough to be used as true indicators of the disease.

Most plant viruses induce characteristic leaf symptoms on susceptible host plants but such is not true of the sun-blotch disease. Many different inoculation techniques have been used in an attempt to induce young avocado seedlings to show a consistent, dependable leaf symptom that could be used as an index of infection. Up to the present no such symptom has been found.[27]

Leaf symptoms of sun-blotch may appear as follows: (1) Leaves show white, yellow, or grey-green variegation, the mottled condition varying from faint light spotting, scarcely discernible, to large spotted areas. When the mottling favors one side of the leaf more than the other, the leaf becomes unevenly developed, resulting in a ruffled or distorted appearance. The pale areas of the leaf may be "somewhat imperfectly developed so that such leaves may be asymmetrical at the petiole, or less often they are distorted throughout, some even having two midribs."[28] *(2)* Crinkled leaves. The leaves have a warped or curled appearance somewhat suggestive of the leaf symptoms of Crinkly Leaf Psorosis, a disease affecting lemons.

Crinkly Leaf Psorosis disease of lemons causes no apparent injury to the bark or wood of the lemon tree. The only symptoms of the disease are the flecking of the young leaves and a warping and pocketing of the leaves and distortion of the fruit on some branches.[29]

Not all deformed or variegated leaves appearing on avocado trees are symptoms of sun-blotch.

Occasionally a shoot is found on a healthy tree which bears variegated leaves; these shoots are true chimeras like many of the variegated-leaved plants grown as ornamentals. These variegations, though infrequent, might be mistaken for sun-blotch.[30]

Some deformed leaves on avocado trees may be the result of certain mechanical injuries or insect injuries.

GREEN STEM SYMPTOMS

"The only consistent symptoms of sun-blotch are the yellow or lighter-colored streaks that develop on the bark chiefly of the younger green limbs and shoots."[31]

On young seedlings the disease usually shows by a yellow or red streaking on the green bark of the trunks. Sometimes small brown splotches show up that go well into the wood. The streaking may be depressed in the wood, but not always. Some nursery trees get the tell-tale streaks directly under the leaf stem. This can be noticed after six months or so growth. Seedling trunks which have the disease are usually quite flexible.

The streaks seen on the young green bark of the limbs and shoots are either flush with the surface of the bark or may be at variance in depth in the wood. A rapid growing sucker will sometimes show almost fluted depressions.

The depressed light-yellowish streaks are usually most prominent in the areas on the stem marked by numerous small buds which are the early parts of a flush of growth. In these areas the light streak may be broadened to entirely surround the stem. From those areas the light portion extends upward and narrows to the typical light streak. The light streak usually does not continue to the end of the flush of growth. In some stems the streaks may be broken up into light spots which are irregular in shape, more or less vague in color, and not always clearly distinct from the condition of some pale stems which are not affected with sun-blotch. Very succulent, vigorous stems such as arise from severe cutting back or below stem girdles may have the streaks much depressed and the stems weak so they bend over. Normal shoots, under similar conditions, may also be angular when young so that they might be mistaken for diseased stems. The light color in the streaks is the significant, distinguishing feature in this case.[32]

BARK SYMPTOMS

The use of bark symptoms as a positive indication of sun-blotch is not recommended as there is not always a correlation between bark and branch symptoms.

Bark symptoms are usually noticeable on the more mature avocado trees affected with sun-blotch. Symptoms may appear in the form of a necrosis pattern. Small patches of brown or grey may appear on the trunk or main branches of affected trees. These patches are usually rough to the touch as compared to the wood surrounding them.

Usually the bark of the affected tree shows a rectangular checking or cracking, particularly on the trunk and some of the main and smaller branches. These symptoms present a contrast to the much smoother appearance of the bark on the trunk, main, or smaller branches of a healthy, mature avocado tree.

Twigs, stems and trunks of severely, sun-blotched trees appear to age more rapidly than corresponding parts of normal trees. The corky surface tissues of the bark become dry, brown and cracked at an earlier age than surfaces of normal trees. When the rough

bark is cut into, brown streaks are found in the living part and usually to some extent in the wood.

This symptom suggests the condition found in citrus psorosis but the wood streaks are usually less abundant. Other conditions may also cause rough bark.[33]

The bark of certain large avocado trees having thick trunks sometimes shows bark cracking or shedding and such conditions may be confused with sun-blotch symptoms.

DECUMBENT HABIT

Some sun-blotched avocado trees are recognized by their bushy or stunted appearance as compared to normal sized trees of the same age and variety. On trees of this sort the streaking symptoms on the small branches are usually quite pronounced. Such trees are usually too weak to make a normal upright type of growth.

Heavily affected sun-blotch twigs have a deficient development of their woody tissues. They are frequently weak and bend down easily. This often gives rise to a striking change in habit or aspect of the tree so that it becomes sprawling, bushy and decumbent.[34]

Although this decumbent habit of severely affected sun-blotched trees may be one of the indicators of the presence of the disease, it is a secondary symptom, as is rough bark, and does not necessarily indicate the presence of sun-blotch.

Both the rough bark and the bushy habit furnish symptoms which are easily seen, but these conditions may have other causes also, so that until other symptoms are found the affected trees should be considered as suspicious cases only.[35]

FRUIT SYMPTOMS

Fruit symptoms of sun-blotch are not always present on sun-blotched trees. When present they are seen as yellow, reddish, or purplish longitudinal streaks or broad spots sunken in the outer skin of the fruit.

The streaks are most pronounced from the stem end to the middle and are often so depressed that the fruit is much distorted. At and below the middle the streaks often occur as rather broad spots. In round or short fruits the streaks may take the form of broad depressed areas. When fruits of dark varieties attain color, the sun-blotch streaks remain lighter than the background color and show up strikingly as a rich red or royal purple.

Below the surface of the streak there is also a light streak in the flesh which apparently softens with other parts of the flesh.[36]

Fruit from sun-blotched avocado trees may from time to time show dwarfing. A severely streaked or spotted fruit may grow only to walnut size or slightly larger.

Some sun-blotched fruits which have long or severe longitudinal streaks or spots may crack open leaving the seed exposed to view.

When Fuerte avocado fruits with external symptoms of sun-blotch are cut open "the vascular bundles of the fruit have a water-soaked appearance and the pulp darkens considerably when exposed to air."[37] Although the appearance of the affected fruit may

be somewhat unsightly when cut open, the flavor and food value of the affected fruit is not impaired.

Some fruits from sun-blotched trees are perfectly clean and free from any blemish. They evidently show no trace of the disease and cannot be distinguished from fruits from normal healthy trees.

The percentage of affected fruits on sun-blotched trees is variable. Whether this varies from year to year has not been determined. On small trees with a few fruits, cases have been observed where all were streaked, but this is exceedingly rare. Sometimes no marked fruits are found on a tree which shows distinct symptoms on the twigs.[38]

VARIETY RESISTANCE

All varieties of avocados appear to be subject more or less to infection by sun-blotch virus.

In an effort to determine which varieties of rootstocks were the most visibly affected *by* sun-blotch and which were the least affected, the following questionnaire was sent to seven avocado nurserymen:

> 1. What variety or varieties of rootstock seedlings do you find show(s) symptoms of sun-blotch in the most cases?
>
> 2. Have you had any variety of rootstock growing in your nursery row on which you have never noticed a case of sun-blotch?

The following answers were received to the above questions:

Nurseryman No. 1

> 1. Northrup, Fuerte, and Henry's Select in the order named show most symptoms of sun-blotch. However, there are several old Mexican seedlings that don't show sun-blotch, but the seed taken from them may show sun-blotch after they are budded.
>
> 2. Yes, Ganter, Topa-Topa and Gerkin Mexican.

Nurseryman No. 2

> 1. Ganter, Miscellaneous Mexican, and Northrup.
>
> 2. Not certain—Topa Topa seems free.

Nurseryman No. 3

> 1. I don't think any one variety over another, all are susceptible but few seem to have it.
>
> 2. No.

Nurseryman No. 4

> 1. Budded varieties show sun-blotch more so than plain seedlings and Mexican strains show up more than Guatemalan even though the Guatemalans probably have it in a dormant stage. We have seen Guatemalan varieties that have sun-blotch but apparently aren't hurt too much by it and sometimes it never shows up

in the fruit.

2. We have some seed off certain trees that we have never found to have any sun-blotch at all to our knowledge.

Nurseryman No. 5

1. When seeds are purchased from unknown, unnamed, mixed seedlings, the visible infestation of budded trees may be about 5-8% provided healthy buds were used. Seeds purchased from known and disease free trees generally do not show infestation in the nursery, which of course is no guaranty that they are disease free.

2. Our observation is that the Guatemalan *(Persea Americana)* seedling rootstock is relatively free of the disease. It occurs on budded varieties, such as Nabal, Anaheim, Dickinson, but the percentage is less than with Fuerte. We have grown Guatemalan rootstock in the past, all from seedlings; and with careful bud selection out of 3,000 trees none had the symptoms of sun-blotch. Seeds from budded Guatemalan varieties may be infected through their Mexican root.

Nurseryman No. 6

1. I have not observed that any variety or varieties show more symptoms of sun-blotch than any other.

2. No, not to my knowledge.

Nurseryman No. 7

1. We have only used Mexican seeds such as Topa Topa, Harmon, Blake, etc. I have only seen it appear on the rootstock of miscellaneous seed of unknown origin.

2. There are a good many sources of seeds that have never shown evidence of sun-blotch and when the supply of seed is ample we use only those sources.

The above questionnaire would' seem to indicate that Guatemalan variety rootstocks are less visibly affected by sun-blotch than are Mexican variety rootstocks.

The Anaheim, which is a Guatemalan variety, is said to be able to retard the effects of sun-blotch on the fruit when it is top-worked to a sun-blotched avocado tree.[39] The Puebla, which is a Mexican variety, when affected by sun-blotch shows fruit symptoms which are usually quite pronounced.[40] Sun-blotch symptoms are seldom seen on fruit of the Nabal variety, a Guatemalan variety, but the symptoms are seen on the branches.[41]

HIDDEN CARRIERS OF SUN-BLOTCH

The topworking of several apparently healthy budded Taft avocado trees to other varieties has uncovered symptoms of sun-blotch. This has given rise to the belief that the Taft variety may be a hidden carrier of sun-blotch.

Dr. Coit discussed several cases involving sun-blotch infection of the Taft variety in an article in the California Avocado Society Yearbook of 1949 entitled "Is the Taft Variety a Hidden Carrier of Sun-Blotch?"

Some years ago the writer planted a Taft avocado tree in his variety collection at Vista.

There is no record of the source of the bud from which this tree was propagated. The tree grew well and came into bearing as a beautifully shaped tree. At that location the fruit had a tendency to drop before full maturity, but there was nothing abnormal in the appearance of the fruit, and at no time were any sun-blotch symptoms seen.

It was decided to topwork the tree to Fuerte. The writer personally cut scions from a selected "mother" Fuerte tree in the same orchard which was noted to be a healthy and an excellent bearer. Buds and scions from this tree had been used for several years without any signs of sun-blotch. The writer personally top-grafted this tree. All three scions grew and all were so severely ; sun-blotched that they soon hung down by the trunk.[42]

In Avon Park, Florida, cases parallel to the above occurred, again involving the Taft variety:

West Indian seedlings were grafted (1925) with tip buds from a Taft tree growing near Lake Wales, Florida. The young trees, about 30 in number, were budded by the owner, grown under nursery conditions, and later planted in two rows across the grove. The trees did not prove to be satisfactory producers, and all of the Taft trees were later (1932) topworked to Taylor and Nabal varieties. The Taylor budwood came from Taylor trees on the place, but the Nabal budwood was obtained from 2 sources in California and it was stated to have come from trees free from sun-blotch. At the time the Taft trees were worked over, seedling trees on either side of the two rows were also topworked, with some of the same budwood from California. All of the Taft trunks that had been budded to Taylor and Nabal developed more or less Sun-blotch this season (1938), and none of the adjacent trees or other trees in the grove that had been grafted with the same Nabal and Taylor budwood showed any indication of the disease.[43]

PRESENT METHODS OF CONTROL

The basic objectives in the study of sun-blotch disease are its eradication or control. Because of the apparent absence of an insect vector it is felt that eradication of the disease may be eventually accomplished. However, it is not the writer's purpose to discuss eradication of the disease as additional information about sun-blotch is still being provided through research.

The most important means of controlling sun-blotch lies in prevention of the disease. Prevention of sun-blotch may be accomplished through repression of the disease in the nursery and orchard.

PREVENTION IN THE NURSERY

One of the most important means of preventing sun-blotch from becoming established is to check the disease in the nursery.

The first consideration in the nursery toward prevention of sun-blotch is the selection of disease-free seed. To do this it is highly important that knowledge be had of the results obtained by previous users of seed from the source tree(s), that the history of the tree(s) be known, and that the source tree(s) be previously checked for symptoms of sun-blotch by competent specialists in the identification of the disease for at least a five year period. As instances are known where certain well-known seedling avocado trees have yielded seed which have apparently produced high percentages of sun-blotched trees,

the need for careful selection of seeds for rootstocks cannot be stressed enough.

The second consideration in the nursery lies in checking the young seedling trees for symptoms of sun-blotch. Weak and off-type seedlings should be viewed with suspicion. Those seedlings with sun-blotch symptoms should be spotted and rogued out immediately. If a diseased seedling is not seen and rogued out immediately, there is a chance that the virus may become temporarily inactivated and the symptoms may disappear for months or possibly even years.

The third consideration lies in the selection of disease-free budwood. To do this it is also important that knowledge be had of the results obtained by previous users of buds from the source tree(s), that the history of the tree(s) be known, and that the source tree(s) be previously checked for symptoms of sun-blotch by competent specialists in the identification of the disease for at least a five year period. In the past certain budded avocado trees have exhibited symptoms of sun-blotch (apparently for the first time) when over fifteen years of age, during which time they were considered disease-free. A close check on even those budded avocado trees which are certified to be disease-free is desirable for sun-blotch prevention, because a budded tree has been derived in most cases from two sources: (1) a rootstock source, and (2) a bud source, either of which may have carried sun-blotch in a hidden form.

EXCLUSION IN THE FIELD

It is important in the control of sun-blotch in the orchard that the avocado grower know as much as possible about the original sources of the trees which are to grow or are growing in his orchard. He may through these means be able to prevent the introduction of the disease through young diseased budded trees, or be able to recognize and exclude any diseased trees which are already in his orchard.

It is important that a sun-blotched tree be recognized in an orchard before it reaches maturity, as such tree may become a source of infection to healthy trees through natural root graftage, or by unknown means. Such a tree may also be a source of infection through its own budwood and possibly its seed. Finally, the virus may become inactivated in the infected tree for a time. The tree may then be classed as a hidden carrier. Later on symptoms of sun-blotch may become intensified. This may lower the value of the crop and to a certain extent, the value of the orchard.

The best way to control the disease once it is established in the orchard is to pull the infected tree. (A healthy replant avocado tree may be successfully grown in a spot previously occupied by a sun-blotched tree, except in a spot where there has been avocado root rot.[44])

THE WEDGE BUD METHOD OF TESTING FOR SUN-BLOTCH

The wedge bud or side graft was developed as a means of hastening the development of the stem-streaking symptoms of sun-blotch, the only consistent symptoms of the disease. A tree suspected of having sun-blotch may be tested for the disease by the insertion of a bud from the suspected Tree into a young avocado seedling in the following manner:

> As soon as the seedlings have attained a height of 4 to 6 inches a wedge-shaped piece of tissue bearing a bud at the upper end is removed from a sun-blotch tree,

or a tree to be tested for virus, and is placed in a diagonal cut in the stem of the test seedling. The inoculum tissue is then wrapped with bud eye exposed. At the time of inoculation the top of the seedling is removed, leaving only one or two axillary buds above the place of inoculation. If the seedling becomes infected from virus carried by the inoculation bud, the new shoots that develop on the seedling after it is topped will begin to show the typical sun-blotch streaks sometime later. The time required for the symptoms to appear varies considerably but some of the inoculated seedlings have shown stem streaks within two months. In one experiment in which either 3 or 4 seedlings each of 22 different varieties were inoculated, sun-blotch symptoms had appeared on 60 out of a total of 86 trees after 330 days. Symptoms had not appeared on any of the inoculated trees of 3 varieties. Apparently these particular varieties are slow to develop sun-blotch symptoms and would, therefore, not be satisfactory indicators of sun-blotch. If the 12 trees of the 3 resistant varieties are not considered, the results show that 60 out of 68 seedlings developed sun-blotch symptoms within 330 days after inoculation. This shows that the inoculation technique resulted in a high percentage of infection. More than half of the number of inoculated seedlings showed symptoms in less than 4 months. In these tests the Guatemalan and West Indian varieties as a group developed sun-blotch symptoms earlier and more consistently than the Mexican varieties.[45]

REGISTRATION OF SEEDLINGS

Probably one of the most effective means of checking the spread of sun-blotch is through registration of seedling avocado trees. This in turn enables certification of seeds for rootstock purposes.

AVOCADO VARIETY COMMITTEE

Between 1928 and 1932, a committee of the California Avocado Association known as the Avocado Variety Committee was formed. The chief purpose of the Variety Committee has been to foster the search for new varieties found usually as seedlings—to study them, both the original and progeny trees, giving consideration to propagation of the trees, their yield and the marketability of the fruit in addition to other characteristics. Among other studies important to the Variety Committee has been sun-blotch disease. The Committee has helped to promote study and research on the disease through its activities.

THE SUBCOMMITTEE ON ROOTSTOCKS OF THE VARIETY COMMITTEE

In 1945 the Board of Directors of the California Avocado Society (formerly the California Avocado Association) appointed a Subcommittee for the particular study of avocado root-stocks and their relationship to the welfare of the avocado industry. Perhaps one of the main reasons for the establishment of the Subcommittee on Rootstocks was the problem of sun-blotch. In 1946, after one year of work during which time investigations were made about sun-blotch, a report by the chairman of the Subcommittee disclosed the following:

During the past five years particularly, certain well-defined instances of apparent carriage of sun-blotch through seeds have come to the attention of members of the

Subcommittee; and within the last year, at least five of these instances, where heavy percentages of infection have occurred, have been tabulated and studied with the conclusion that this is one of the serious problems meriting intensive study which confronts the industry.

In this connection the work of this Subcommittee on Root-stocks will go hand in hand with the sun-blotch investigations being conducted by Drs. J. M. Wallace and George A. Zentmyer of the Experiment Station. This is only one, but perhaps the most important phase of the study and work of this Subcommittee.[46] Other items on the program of the Subcommittee indicated that efforts of the Subcommittee were being largely directed toward sun-blotch control:

> 1. The need of gathering and coordinating all existing know ledge on the relative values of seed stocks from growers and nurserymen, encouraging systematic records of segregated seed bed plantings to be followed through to matured trees in order that intelligent studies may be made, registration of parent trees for seed purposes—a fee for this service to be charged. This service will in no wise in the beginning be inferred to be a guarantee against sun-blotch but will give the means of identification of the source of seed which will form the foundation of the industry.
>
> 2. Other studies of the Subcommittee will have to do with stock and scion compatibility; to encourage and cooperate with all the basic rootstock studies of the University; to study blocks and gather information which may be correlated in regard to resistance to decline, to dwarfing effects and as to the relative merits of Mexican and Guatemalan type rootstocks; the dissemination of information which will educate the public to the vital need of better root-stocks and particularly to the desirability of freedom from sun-blotch.[47]

The Subcommittee urged that nurserymen and growers keep exact records of the source, behavior and production of their trees as a step towards raising the general level of quality and production in avocado orchards.

SUMMARY AND RECOMMENDATIONS

Sun-blotch disease, a virus disease affecting only the avocado, has been observed in Southern California for over thirty years. The disease was named "sun-blotch" because it was thought to be the direct result of sunburn as affecting weak or spindly trees or trees which suffered from neglect.

Before much experimental study had been made of sun-blotch to determine the causal agent, the disease had already spread through nursery stock and other means to infect avocado plantings throughout Southern California. In some instances entire plantings had as high as *20%* of their trees infected with sun-blotch.

The economic importance of this disease is seen in the low producing habit of affected trees and large number of low grade cull fruit they produce.

The disease is transmitted artificially by budding and grafting, possibly by natural root grafting, through the seed, or by some insect vector. There is at present no definite indication of spread of the disease by the latter.

Although symptoms of sun-blotch are seen on the leaves, twigs, branches, bark, and fruit of avocado trees, the only consistent symptoms of sun-blotch are the yellow or lighter colored streaks that develop on the bark, chiefly of the younger green limbs and shoots. Leaf symptoms appear as light variegations varying in their intensity. One side of the leaf is usually more developed than the other side and a ruffled or distorted appearance is the result. In some cases the entire leaf presents a ruffled appearance without any striking variegation.

On green twigs and branches the symptoms seen are generally a few light-yellowish, and often depressed, longitudinal streaks.

Bark of infected trees generally has an aged appearance and is generally rough to the touch. When the rough bark is cut into, brown streaks are found in the living part and usually to some extent in the wood.

On the fruit streaks similar to those on the young green branches are seen. They are more pronounced from the stem end to the middle, and are often so depressed that the fruit is much distorted. The fruit is sometimes much dwarfed in size. At and below the middle the streaks often occur as broad spots. When fruits of dark varieties attain color, the sun-blotch streaks show up as red, reddish brown, or purple.

The best method at present of controlling sun-blotch is through prevention of the disease in the nursery and orchard. Highly important in the prevention of sun-blotch is the selection of disease-free seed for root-stocks, and disease-free scion wood, and the speedy removal of sun-blotched trees from the orchard before the disease is allowed to spread to healthy trees through natural root graftage or unknown means such as insects.

Due to improved cultural practices in the nursery and orchard and the apparent absence of an insect vector, sun-blotch disease may be eventually eradicated.

Before eradication of sun-blotch can be attempted it seems logical that a certain necessary amount of research on the disease must be conducted in the future. The following are a few suggestions for future research on sun-blotch that have come to the attention of the writer: (1) The need for a speedy method of determining whether a given avocado tree contains sun-blotch virus. (2) Research to determine the importance of of natural root graftage as a means of transmitting sun-blotch to healthy trees. (3) Various experiments might be conducted such as treatments with chemicals, juices from other plants, high temperatures, enzymes, oxidation and aging in an effort to find some means of inactivating the virus completely in the infected tree. (4) Experiments on treating seeds in an effort to kill or inactivate the virus and remove the chance of transmission through the seed.

[1] *Robert Whitsell was a candidate for the degree of Bachelor of Science at the California Polytechnic College, San Dimas (1951). This thesis was prepared in partial fulfillment of the requirements therefore.*

[2] *Carter Barrett, Avocado Nurseryman and Specialist, in an interview with the writer, February 14, 1951.*

[3] *J. Eliot Coit, "Sun-blotch of the Avocado,"* California Avocado Association Yearbook, 1928, *p. 28.*

[4] Ibid., *p. 27.*

[5] Ibid., *p. 28.*

[6] *E. R. Parker and W. T. Home, "The Transmission of Avocado Sun-blotch,"* California Avocado Association Yearbook, 1932, *pp. 50, 51, 53, 54, 56.*

[7] *H. E. Stevens, "Avocado Sun-blotch in Florida,"* California Avocado Society Yearbook, 1942, *p. 40.*

[8] *Carter Barrett, in an interview with the writer, February 14, 1951.*

[9] *Elwood E. Trask, "Observations on the Avocado Industry in Mexico,"* California Avocado Society Yearbook, 1948, *p. 52.*

[10] *Carter Barrett, in an interview with the writer, November 28, 1950.*

[11] *J. J. Cottny, County Farm Advisor, San Dieao County, San Diet/o, California, in a letter to the writer, December 20, 1950.*

[12] *Calvin C. Delphey, County Director and Farm Advisor, J eulttra County, Ventura, California, in a letter to the writer, November 14, 1950,*

[13] *Carl D. Gustafson, Farm Advisor, Orange County, Santa Ana, California, in a letter to the writer, November 17, 1950.*

[14] *Marvin Miller, Farm Advisor, Riverside County, Riverside, California, in a letter to the writer, November 26, 1950.*

[15] *Walter Cummings, Agricultural Commissioner, Santa Barbara County, Santa Barbara, California, in a letter to the writer, January 15, 1951.*

[16] *P. L. Kovach, Toinko Nursery, Fista, California, in a letter in the writer. December 13, 1950.*

[17] *J. Eliot Coit, "Is the Taft Variety a Hidden Carrier of Sun-Blotch?",* California Avocado Society Yearbook, 1949, *pp. 55, 56.*

[18] *J. J. Coony, County Farm Advisor, San Diego County, San Diet/o, California, in a letter to the writer, December 20, 1950.*

[19] *Marvin Rounds, Horticultural Consultant, in an interview with the writer, October 4, 1950.*

[20] *Cecil Knowlton, Nurseryman, Whittier, California, in an interview with the writer, January 15, 1951.*

[21] *George A. Zentmyer, "Diseases of the Avocado,"* California Avocado Society Yearbook, 1946, *p. 79.*

[22] *Carter Barrett, "Report of the Variety Committee on Avocados, California Avocado Society, 1945,"* California Avocado Society Yearbook, 1945.

[23] *E. T. McFadden, Rancher, Santa Ana, California, in a letter to the writer, March 19, 1951.*

[24] *Melville T. Cook,* Viruses and Virus Diseases of Plants, *p. 147.*

[25] *J. M. Wallace, Plant Pathologist, University of California Citrus Experiment Station, Riverside, California, in an interview with the writer, November 23, 1950.*

[26] *George A. Zentmyer.*

[27] *J. M. Wallace, Unpublished Material, November, 1950.*

[28] *W. T. Home,* Avocado Diseases in California, *University of California Agricultural Experiment Station Bulletin 585, November 1934, p. 6.*

[29] *L. J. Klotz,* Gum Diseases of Citrus in California, *University of California Agricultural Experiment Station Circular 396, June, 1950, p. 16.*

[30] *W. T. Horne.*

[31] *J. M. Wallace, Unpublished Material, November, 1950.*

[32] *W. T. Horne, E. R. Parker, and M. B. Rounds,* "The Nature of Sun-blotch and Its Practical Control," *California Avocado Society Yearbook, 1941, p. 36.*

[33] *Ibid., p. 37.*

[34] *Ibid.*

[35] *Ibid.*

[36] *Ibid.*

[37] *A. R. C. Haas, "Some Effects of Sun-blotch on, Fuerte Avocado Fruit,"* California Avocado Association Yearbook, 1938, *p. 105.*

[38] *W. T. Home, E. R. Parker, and M. B. Rounds.*

[39] *Everett Pratt, Calavo Field Man, in an interview with the writer, December 12, 1950.*

[40] *Ibid.*

[41] *Nat Gay, Calavo Field Representative, in an interview with the writer, December 18, 1950.*

[42] *J. Eliot Coit, "Is the Taft Variety a Hidden Carrier of Sun-Blotch?",* California Avocado Society Yearbook, 1949, *p. 55.*

[43] *Ibid.*

[44] *F. F. Halma, "Replacing Declined and Sun-Blotched Trees,"* California Avocado Society Yearbook, 1948, *p. 90.*

[45] *J. M. Wallace, Unpublished Material, November, 1950.*

[46] *Report of the Subcommittee on Rootstocks of the Variety Committee,* California Avocado Society Yearbook, 1946, *p. 16.*

[47] *Ibid, p. 16, 17.*