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AVOCADO ROOT ROT

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Avocado root rot (formerly known as decline) has been present in California for a number of years, but has become increasingly important during the past 8 or 10 years coincident with increased avocado acreage and increased age of plantings. It is a disease in which a soil fungus *(Phytophthora cinnamomi)* known as the cinnamon fungus attacks and rots the roots of the trees, primarily under conditions of impeded soil drainage, with consequent deterioration of the top.

The rotting condition of the roots is reflected in poor growth of the top, small leaves, poor color of leaves, dieback of branches, and a gradual decline of the entire tree. The disease is important on two general soil types: heavy soils, and soils with an impervious layer underlying a relatively light surface layer. In either case drainage is impeded and water conditions favorable for fungus attack may occur. Under conditions of poor drainage, the roots may be weakened because of low oxygen content of the soil, or because of the formation of toxic substances, such as nitrites, in the soil. The roots may then be more susceptible to fungus attack.

Much of this presentation will concern our work with a root-rotting fungus, so perhaps the word fungus should be defined. Fungi are low forms of plant life which contain no green coloring matter (chlorophyll); thus they are unable to make food for themselves as do the higher, green plants. Fungi in a general sense break down what the higher plants build up. Many fungi are beneficial; they break down dead and decaying plant and animal tissue, or are sources of medicine, dyes, and various chemicals. Some fungi are parasitic on insects and various weeds. Others are definitely harmful to plants, attacking the leaves, stems, roots or fruit of various plants, and causing disease.

As a result of the work at Berkeley last spring we now have considerable information on the life cycle of *P. cinnamomi.* The fungus reproduces itself by means of two different types of spores, analogous to seeds in the higher plants. These spore types, produced readily under the proper environmental and nutritional conditions, are known as sporangia and oospores. Sporangia are formed in great numbers when the fungus, or roots infected by the fungus, or soil infested with the fungus, is placed in water. These sporangia are formed only between temperatures of about 70° and 88° F. A small drop in temperature induces the discharge of swimming spores from these sporangia. These spores swim through water in the soil and attack the avocado roots. The oospores are presumably resistant spores, which have previously been reported only rarely with the cinnamon fungus. We found that oospores are produced readily in the presence of

avocado roots, at temperatures between 60° and 77° F. It is not certain yet just what role these oospores play in avocado root rot; in other similar fungi they are usually quite resistant to various unfavorable conditions, such as drought, chemicals, and heat. The cinnamon fungus is also restricted as to the temperature range for its normal vegetative growth, making no growth below about 50° F., nor above 95° F.

Temperature would seem to be particularly important with respect to production of sporangia. Most of the infection in the field probably results from the swimming zoospores. If these are not formed below 70° F. this would mean that the main infection period is after soils warm up in late spring and early summer, and that irrigation water is more important than winter rainfall in providing water for these spores.

P. cinnamomi causes root or crown rots of a number of hosts in addition to the avocado, including such plants as chestnut, pine, camellia, heather, rhododendron, pineapple, cinchona, cinnamon, and tung. In addition to its occurrence in the United States the fungus has been found in a number of tropical countries in this hemisphere as well as in Asia, South Africa, and Puerto Rico.

FUMIGATION WORK

As reported previously we have established a number of field plots during the past 3 to 4 years to study the effect of soil fumigants on the cinnamon fungus and avocado root rot. These involve over 600 trees in 24 experimental plots,[1] and a number of different materials have been tried. For the first two years at least, fumigation with the chlorinated hydrocarbon materials (Dow-fume N, Shell D-D) particularly in the San Diego County plots gave very good results. As an example, 42 of 58 trees replanted in areas fumigated with these materials made good growth for the first two years, while only 8 of 66 trees in comparable untreated areas made good growth.

Now, however, the fungus has re-invaded many of the treated areas, and many of the young trees are showing symptoms of root rot. As an example, on one plot in Vista where five trees in areas fumigated with Dowfume N made excellent growth for the first two years after replanting, the picture has radically changed during the past year. Now four of the five trees are showing symptoms of root rot and the cinnamon fungus has been recovered from the roots of all five trees, where it was recovered from none of them a year ago. The trees on all of our fumigation plots are re-sampled every six months to determine presence or absence of the cinnamon fungus; it is present on a much higher percentage of the replants now than a year ago.

SOIL FUNGICIDES

A number of fungicidal chemicals have been tested in the laboratory in an attempt to find one that would kill *P. cinnamomi* in the soil and still not damage avocado roots. A material that met these qualifications could conceivably be applied in the irrigation water with the possibility of at least retarding the disease development.

A number of chemicals will kill the cinnamon fungus in the laboratory at quite low concentrations when tested by standard methods for screening fungicides. Very few of

these will kill the fungus when they are applied to the soil, however. Many of the materials that do an excellent job of controlling fungi on leaves or fruit are practically useless when applied to soil, as they are rendered inactive very rapidly. One or two materials have shown some promise in soil, however, and these are being tested in the field, by applying in the irrigation system.

SOIL AMENDMENTS

Several years ago some of our work showed that applications of organic matter, particularly in the form of alfalfa meal, gave indications of beneficial effects against avocado root rot. This approach has worked well in several trials in our greenhouse, and a number of field plots have been established to investigate the possibilities further.[2] In the greenhouse most of our trials have involved mixing soil from diseased trees with alfalfa meal. Seedlings replanted in such treated soil made excellent growth, while seedlings in untreated naturally infested soil showed severe root rot symptoms.

There has been considerable variation, as would be expected, in the field plots, but in general there has been some benefit from alfalfa meal applications at rates of 100 to 150 pounds per tree. On one plot in Vista for example, nine trees were treated with alfalfa meal in March, 1948; five of these have improved, two are in the same condition, and two are worse. Nine similar trees received no treatment other than comparable amounts of nitrogen to that provided by the alfalfa meal, in the form of ammonium nitrate; two of these have improved, three are the same, and four are in worse condition than in March, 1948.

Our idea as to the action of alfalfa meal in the soil has been that it may stimulate the development of other soil fungi and bacteria which are antagonistic to *P. cinnamomi.* The numbers of saprophytic fungi and bacteria are greatly increased in soil treated with this material; the same thing is true with other types of organic matter as regards *numbers* of other organisms, but the other types that we have tested do not give the same effect on reduction of root rot. The factors involved are being investigated further.

Some work is also being done in greenhouse and field on the effect of fertilization on development of root rot, in cooperation with Dr. D. G. Aldrich of the Division of Soils and Plant Nutrition at Riverside.

SOIL DRYING

A number of experiments indicate that the cinnamon fungus is sensitive to low moisture content of the soil. Drying a sandy loam soil heavily infested with the fungus to one per cent moisture by weight kills the fungus, and in our greenhouse tests has permitted successful replanting of such soil with no recurrence of root rot. We have not been able to recover the fungus from such air-dried soil; some of the experiments were established over a year ago and seedlings are still making excellent growth in the dried soil while seedlings in non-treated naturally infested soil have severe root rot.

Further work is underway on the minimum moisture level for survival of *P. cinnamomi* in various soil types.

IRRIGATION

Considerable work has been done on the influence of irrigation on development of root rot, in cooperation with Dr. Sterling Richards of the Division of Irrigation. A number of experiments, in the greenhouse and in the field, have shown that the disease progresses more rapidly in the wetter soils, but damage to the root system from the fungus was evident even in the drier soils later in the progress of the experiments.

RESISTANT ROOTSTOCKS

We have tested a number of different varieties of avocados by planting seedlings in naturally infested soil, in the hope of finding a variety that would be resistant to *P. cinnamomi* and wet soil conditions. Of 22 varieties tested last year only one or two showed any possibilities at all and these are being retested to see if they merely escaped the disease. Dr. F. F. Halma of U.C.L.A. has aided us in this approach to the problem. Also, with the cooperation of Dr. C. A. Schroeder of U.C.L.A., we are testing the resistance to root rot of a number of relatives of the avocado from Mexico and Central America.

OTHER SUBTROPICALS

Several other subtropical trees have been tested for resistance to the cinnamon fungus, with the possibility that they might be used as replants in areas where avocado trees have been removed because of root rot. Macadamia nut, cherimoya and persimmon seedlings have been tested in naturally and artificially diseased soils, with and without the added factor of waterlogging of the soil. To date none of these has shown any signs of disease and it looks as though these plants are resistant. Further field plots are planned to test this more thoroughly.

SURVEY

Several thousand root and soil samples to detect presence of *P. cinnamomi* have been run in our laboratory during the past few years, primarily in connection with the experimental work, but also in response to various requests. This fall we have started a more extensive general survey in an attempt to determine just how widely distributed the cinnamon fungus is, in healthy as well as diseased avocado groves, and in other types of cultivated land, and in native vegetation.

CONCLUSIONS

Fungi attacking the above-ground parts of plants (leaves, fruit, etc.) can be controlled readily as a rule by spraying the plants with any one of a number of fungicides. Unfortunately controlling pathogenic fungi in the soil is not so simple; treating a mass of soil in an attempt to eliminate a harmful fungus presents a complicated and difficult problem.

On the basis of our experimental work to date there are four phases of the work on rootstocks, soil amendments, soil drying, irrigation. The most promising approach for this type of trouble, on the problem soils on which it occurs, would appear to be the discovery or development of a resistant rootstock. Considerable work is being done and more is projected on this important phase of the problem. Soil amendments, such as alfalfa meal, and possibly also some soil fungicides show promise for prolonging the life of affected trees or for retarding the progress of the disease into healthy trees. This type of approach, however, cannot be expected to eliminate the fungus completely from the soil.

Soil drying has possibilities for retarding the spread of the disease, and also, where combined with a cover crop which would help to remove the moisture from the soil, for replanting disease areas. Limited trials with seedlings in the greenhouse have indicated that it may be possible to dry the soil down sufficiently to kill the cinnamon fungus and still not kill an avocado tree growing in that soil; further work is needed on the application of this principle to diseased trees in the field.

Many cases of root rot are connected with some history of excess moisture in the grove—a leak in the irrigation line, an irrigation followed by an unexpected rain. Careful watering can do much to prolong the life of a grove on the problem soils. Irrigation seems particularly important when it is considered that most root attack probably takes place during the warmer seasons of the year when irrigation water rather than rainfall is supplying the water needs of the trees.

[1] *The cooperation of Farm Advisors J. J. Coony, R. Puffer, K. Smoyer, and F. A. White in San Diego, Orange, Los Angeles, and Santa Barbara Counties, in establishing these field plots is greatly appreciated.*

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