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The Possible Relationships of Soil Organisms to Avocado Tree Decline and Collapse

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The purpose of this discussion is to point out the relationships of microorganisms to decline and collapse of avocado. In addition, we wish to describe some greenhouse and field experiments which may contribute toward an understanding of the trouble and possibly suggest measures for alleviating it.

While most of our work has been with citrus decline, Dr. Sokoloff and I have been interested in the similarity of the trouble in avocados and accordingly have conducted a few experiments with the latter crop. Moreover, our findings with citrus may in part be applicable to avocado.

The Associated Fungi

Regarding the citrus troubles, we have been able to isolate two species of brown rot fungi from the fibrous or feeder roots of both apparently healthy and declining trees; however, much more consistently from trees that show symptoms in their above-ground parts. These organisms become established in the soil within a few years after the orchard has been planted. Only in young orchards on virgin soils is it difficult to find the parasites.

The fibrous roots of potted one year old sweet and sour citrus seedlings, kept in the greenhouse at several soil temperatures and with the soil at a high moisture content, were readily infected by both fungi.

In a field experiment groups of 12-year-old navel trees on Ramona loam soil were respectively under-irrigated (furrow irrigation every six weeks), normally irrigated (furrow irrigation every four weeks), over-irrigated (furrow irrigation every two weeks), and flood or basin irrigated every two weeks. Although large masses of the several brown rot or Phytophthora fungi were introduced into the root zone of the sweet and sour stocks in August, 1941, and October, 1942, to date we have seen no evidence of decline symptoms in the tops of these trees. While the brown rot and gummosis fungi can be readily reisolated from the fibrous roots, the damage caused by the parasites has been insufficient to be reflected in the tops. Moreover, we have been able to reclaim sour and sweet citrus seedlings, which were heavily infected by the brown rot fungi and which were growing in badly contaminated soil, by placing them in earthen pots in the greenhouse and watering judiciously. Apparently new roots were grown faster than the fungi destroyed them under the conditions. These experiments and others suggested to us that other factors in addition to the parasites were playing a part in the decline of citrus. The story for avocados appears to be similar.

Tucker, in Puerto Rico, apparently demonstrated that two factors are necessary in the decline and collapse of avocado—namely, a waterlogged condition and the presence of the parasite **Phytophthora Cinnamomi**. Wager of South Africa repeated this with similar results. Professor Horne has repeated their pot experiments with variable results. With large vigorous seedlings in a well drained orchard soil seeded with **P. Cinnamomi** and almost continuously basin-flooded for 15 months he observed no symptoms of top injury. Then one large tree and several small seedlings suddenly collapsed. The fungus was reisolated from roots taken from that basin. As fast as avocado seedlings become available we, too, are repeating these experiments in cooperation with Professor Horne, using concentrated zoospore suspensions of the fungus in water for the inoculum. A possible criticism of Wagner's method of inoculation is that relatively large quantities of organic matter were added in the wheat on which the fungus was grown. We shall show that soluble organic matter is a necessary factor in this root injury. While Wager in his 1942 paper states that the fungus was found very seldom on the fibrous roots, Professor Horne has repeatedly isolated the parasite from these roots and has demonstrated infection of excised roots and of roots of large seedlings in the orchard with pure culture of the fungus.

Avocado Growers Meet at Vista to Discuss the "Decline" Problem.

Conditions and Chemicals Important in Decline and Their Relation to the Fungi

The results of field, greenhouse and lathhouse experiments have led us to believe, for the present at least, that toxic materials produced during the processes of denitrification or of arrested nitrification, and sulfate reduction which occur under conditions of poor aeration and drainage, low pH, low temperature and high organic matter of the soil, are responsible for much injury to plants in general, including avocados, citrus, and several vegetables. These toxic chemicals, which may be the well-known respiratory poisons, hydrogen sulfide and nitrites, or other accompanying toxic materials, may injure the

roots to such an extent that a type of decline or collapse follows. We feel that the fungi, while important, play a secondary and supplementary role. Although we have found the fungi capable of reducing nitrates under certain conditions, the magnitude of their effect is probably small compared to that of the soil bacteria. There is some evidence, however, that roots injured by these chemicals are more susceptible to the attack of the fungi.

Experiments Which Suggested the Tentative Interpretation and Indicate Possible Methods of Alleviation of the Troubles

Here we shall describe some of the experiments on which the statements are based. Several of them have already been described in the Citrograph and Citrus Leaves. Although there is not time to go into much detail, for the records I want to give the tentative conclusions:

We have studied the collapse of avocados in relation to combinations of the following factors:

1. Excessive moisture
2. Nitrates, sulphate, nitrite, ammonium
3. Organic matter, such as sugar, flour, glycerin
4. The brown root rot fungi of the Phytophthora group

It soon appeared that any single one of these factors, such as waterlogging, inoculations with the fungi, additions of inorganic nitrogen or of organic matter, is not seriously harmful to the avocado roots. Certain combinations of these factors, however, are definitely harmful and, indeed, are conducive to the collapse. For example, either sulphate or nitrate in combination with soluble organic matter and excessive water causes a rapid deterioration of the roots, followed, as a rule, by a collapse of the entire plant. A combination of nitrite and excessive water is in no apparent way different from the combination of nitrate, organic matter, and excessive water, or of sulfate, organic matter, and excessive water. It makes no difference what base is used in combination with the nitrate or sulfate, be it sodium, calcium, magnesium, potassium, or ammonium. In all three of the above combinations in certain ratios as yet not well defined, in our opinion, we are dealing with the formation of root poisons, possibly of the respiratory poisons such as hydrogen sulfide and nitrite in the root zone. The roots, under such conditions, appear to be unable to absorb as much water as the healthy roots. Accordingly in severe conditions the leaves quickly become wilted and dry.

If either soluble organic matter or sulfate or nitrate was absent, waterlogging alone for a considerable period apparently did not impair the roots in our experiments in the greenhouse. We have kept citrus, e.g., in waterlogged soil cultures for six weeks and avocados for four weeks without visible signs of distress during or after the exposure.

If the exposure of the roots to the combination of either sulfate or nitrate, organic matter and excessive water was of a brief duration in our experiments and if the soil was washed free from the chemicals or was aerated, following the exposure, the plants tended to recover. New roots grew to replace the dead ones and new flushes of leaf

growth appeared. If the proportion of the injured roots in reference to the total was not great, the recovery was quite rapid.

It is at this point that the root rot fungi appear to be factors of prime importance, because the roots, following their exposure to either sulfate or nitrate in combination with organic matter and excessive water, are particularly easily attacked by the fungi. To repeat, the roots exposed to any one of the above factors alone are not readily and severely attacked by the fungi.

Exposure to small quantities of nitrites which caused no visible injury of the roots caused seedlings to succumb more quickly to the stresses of high temperature and winds than those not treated with nitrites.

Tests for nitrites in leaves do not always give reliable indications of the previously sustained decline or collapse because the chemicals do not always reach the leaves. The small roots and the soil in contact with them are more reliable indicators.

In pot experiments with avocados and with tomatoes, high chloride or high sulfate minimized the injury from nitrites added as such or generated from nitrates and sugar; high nitrate minimized the injury from sulfates with sugar.

In a field experiment on Ramona loam given basin irrigation, vigorous avocado seedlings collapsed 10 months after the addition of nitrate and organic matter (wheat flour). The nitrate check also collapsed, but the soil showed 2.5 to 5.0 ppm. of nitrogen as nitrites. The tree given only organic matter was uninjured and the soil around it had 0.5 ppm. of nitrite. Ferrous sulfate added with the nitrate and organic matter did not protect the tree, possibly because of poor mechanical distribution and contact with the nitrite formed. The application of ferrous sulfate or chlorinated lime to potted plants prior to the addition of nitrates, organics, and water protected the seedlings. This is due to a direct chemical reaction with the nitrite. We believe that this lead should be investigated thoroughly. The new compound called Gesarol, which is relatively insoluble and which slowly liberates its chlorine, will be tried. The soil sterilant called D-D, a nematocide and fungicide, is also being tested.

The absorbents, carbon and diatomaceous earth, which when incorporated into the soil in concentrations as low as 0.5 per cent, protected seedlings from the effects of waterlogging and induced a vigorous root growth, suggest another possibility for protection of trees against decline and collapse. Such suggestions are being taken to the field for experimentation as we secure materials.

We do not wish to leave the impression that we think we have solved the problem. It seems evident from what has been said that good drainage and the careful control of irrigation practices are very important. In spite of the best irrigation practices, however, it is possible to damage trees by certain combination of fertilizers, particularly during the rainy season. We have merely meant to point out the results of some of these preliminary experiments in reproducing and alleviating the trouble. The purpose of these tests is to guide our further trials under field conditions.

Summary

We believe, and we have some experimental evidence to support the view, that nitrites and hydrogen sulfide, or accompanying toxic materials, are important factors in root injury of avocado trees, especially under waterlogged conditions. If present in sufficient concentration they will kill the fibrous or feeder roots of avocados and citrus, even in the absence of Phytophthora fungi. If the concentration is not great enough to be lethal but in varying degrees only injurious to these feeder roots, the fungi can and do successfully parasitize and kill them.

The third but probably minor factor in the relationship mentioned at the Vista meeting of September 29, 1943, was that the fungus itself can reduce nitrates to nitrites. The evidence so far indicates that the effect of adverse soil factors, whether they be nitrites, hydrogen sulfide, or other substances, precedes any extensive parasitism by the fungus. This does not mean that roots are never infected in the absence of some predisposing factors; it means that, operating alone, this fungus parasitism is probably of minor importance.

Professor Horne, with excised roots on agar, and even in the field on roots of large seedlings, and I with citrus seedlings in moss, peat, and in water cultures have demonstrated that it is possible to infect the small roots. If the trees are being grown under good conditions, the rate of production of new roots greatly exceeds the rate a which roots are killed by the fungi, and the tree maintains itself in apparently good health. If, on the other hand, poor cultural conditions permit the fungi to kill at a rate that exceeds regeneration, decline or collapse may follow. It should also be mentioned here that roots of citrus and possibly of avocado are more resistant to attacks of Phytophthora species than is the trunk.