Proc. of Second World Avocado Congress 1992 pp. 669-678

Workshop 3
"*Phytophthora* Root Rot Management and Trunk Injection: History and Methodologies"

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The root rot workshop was structured as a discussion with participants chosen from the major avocado-producing countries. The workshop participants were Dr. George Zentmyer, California; Dr. Joe Darvas, South Africa; Mr. Tony Whiley, Australia; Dr. Yaakov Pinkas, Israel; Dr. Daniel Teliz, Mexico; Dr. John Menge, California; and Mr. Herbert Young, Rhone-Poulenc Company.

ROOTSTOCK HISTORICAL REVIEW -DR. GEORGE A. ZENTMYER.

We began the project for testing avocado rootstocks for resistance or tolerance to Phytophthora root rot in the early 1950's with a three-phase program: (i) testing as many California varieties and trees used for rootstocks as possible; (ii) looking for trees that had been growing well in groves infected by root rot for many years, and attempting to recover and propagate the rootstock; and (iii) initiating a search in the native home of the avocado and other species of *Persea* in Latin America.

California varieties. Under this phase, seeds of many California varieties were obtained from Calavo and other packing houses and from a wide variety of trees around the state. Seedlings were tested for resistance by soil tests in the greenhouse and lathhouse, and by the nutrient solution tank test. Many Mexican and Guatemalan and *a* few West Indian varieties were tested.

From these many tests, the primary indication of resistance was found in the Duke variety, a Mexican variety originating from seeds sent from Mexico to Oroville, California, in 1912. Thousands of Duke seeds were obtained and tested from trees in many parts of California and from packing houses. In extensive tests in beds of infested soil in our lathhouses, two Duke seedlings showed significant resistance and good growth in soil heavily infested with *Phytophthora cinnamomi.* These I designated as Duke 6 and Duke 7. Clonal propagations were made by Ted Frolich (UCLA) and later by Fred Guillemet in the Department of Plant Pathology at the University of California, Riverside. Duke 7 produced a more vigorous tree, so that was the local variety that has been propagated widely.

California resistant trees. Several individual trees that appeared to have resistance were located in the first 20 years of the program. One of these, the Huntalas from San Diego county, showed promise but had sunblotch viroid which could not be eliminated. A number of other trees were tested with no outstanding results until the Thomas variety was brought to our attention in the 1970's by Frank Koch in Escondido and was propagated by Fred Guillemet.

Latin American collections. To begin this phase of the program, I visited 11 herbaria in botanical gardens or universities in the United States and several other countries where there were collections of Latin American plants. There I found locations where native avocados or other related species of *Persea* (avocado is *Persea americana)* grew. Then, in 1952, I made my first trip to native avocado areas in Mexico, Guatemala, El Salvador, Honduras, and Costa Rica. This was the beginning of our extensive 40-year search for the best possible root rot-resistant rootstocks.

Many other collecting trips were made over the next 20 years, with thousands of seed and budwood collections, and collections of native avocado material, 14 other species of *Persea,* and other plants in the family Lauraceae. In the early years, very high resistance was found in several non-edible, small fruited species of *Persea,* including *P. borbonia, P. caerula, P. chrysophylla, P. donnell-smithii, P. alba, and P. skutchii.* Unfortunately none of these were graft-compatible with the avocado, but these, and other later collections serve as an excellent source of germplasm for many types of research with the avocado.

In 1971, Dr. Eugenio Schieber from Guatemala joined our rootstock collecting program. He has collected many thousands of additional seed and bud wood specimens, and several additional species of *Persea,* including one of particular interest that we had been searching for earlier, *P. steyermarkii.* This, then is a brief summary of the first 20 years of our rootstock program.

CHEMICAL CONTROL REVIEW AND ROOT ROT MANAGEMENT IN SOUTH AFRICA - DR. JOE DARVAS.

The control of *Phytophthora* root rot of avocados by chemical means has been explored for nearly four decades. The earliest published control methods and chemicals gave mixed field results and presented little commercial value to growers.

The first significant field-control of root rot was achieved with the introduction of modern systemic fungicides, such as metalaxyl (Ridomil^{R}) and fosetyl-Al (Aliette^{R}), both field-tested since 1976 for root rot control in South Africa. Recommended commercial application for metalaxyl was to spread a granular form under the canopy of avocado trees 2 or 3 times a year and for fosetyl-Al was application to the foliage 6 times a year.

Metalaxyl was widely used in South Africa on producing trees for a few years with good results, but soon problems developed due to resistance by the root rot organism against

the chemical and rapid biodegradation in the soil. Three years after the South African launch of metalaxyl, the commercial use of the product in the field had virtually been discontinued, but it dominated the avocado nursery fungicide scene for many years. Fosetyl-Al (Aliette WP) showed a very slow initial reaction and because it was expensive the chemical has never really been used for root rot control commercially in the foliar spray form.

The South African avocado industry with the failed metalaxyl and the too expensive fosetyl-Al was in a desperate position in 1980. Then large scale control experiments, including new methods (trunk injection, trunk paint) and new chemicals commenced at Westfalia Estate, the biggest avocado growing concern in South Africa. Results soon indicated that trunk injection and trunk paint are superior to all previously tested methods both in terms of biological efficacy and in economics.

Trunk injection: the long-term control method for root rot. From 1980, fosetyl-Al wettable powder (Aliette 80 WP) water solution was used in commercial trunk injection, but in 1984 a liquid formulation (Aliette CA) was introduced for this purpose. The first phosphorous acid trunk injections were carried out at Westfalia Estate beginning in 1981 with very encouraging results. Micronutrient additives (zinc and boron) to root rot control mixtures were also first tested in South Africa. No resistance by the fungus against the alkyl phosphonates has been detected in our work in the past eleven years in South Africa.

In the field of biological control, a suspension mixture of antagonistic bacteria was injected with good results over a three year period in South Africa. But since injection with alkyl phosphonates appeared to be a long-term solution, the research with injected biological agents for root rot control has been halted.

Today, the chemical part of root rot control in the South African avocado industry is based totally on trunk injection. The method is now employed in all major avocado growing regions of the world where root rot is a problem.

In spite of all our successes with trunk injection, other components of root rot management should not be neglected and suitable soil selection, resistant rootstocks, proper water management and fertilization will always have to be maintained for optimum results in the fight against *Phytophthora* root rot.

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Darvas, J.M. 1982. Chemical control of *Phytophthora* root rot on fully-grown avocado trees. S. A. Avocado Growers' Assn. Yrbk. 5:96-97.
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After Dr. Darvas completed his summary he addressed seven questions regarding the use of alkyl phosphonates as follows:

1. The resistance threat -does it exist? There is a 14-year history of alkyl phosphonate use in South Africa, first as foliar sprays and later as injections, to this date there is no indication of any resistance to the chemical. This is reflected by experience in other parts of the world. No instances of resistance have been reported as of yet.

2. Application techniques. Of the techniques explored which include foliar, soil, trunk paint, and trunk injection; the trunk injection is the method of choice. Reasons include efficacy and cost.

3. Physical effects of injection on tree health. In South Africa, the injected trees heal rapidly with no lasting adverse effects on tree health. This experience is reflected by the Australian experience.

4. Mode of action and translocation in the tree. The consensus is that the compounds act both directly against the pathogen and also by stimulating the tree's natural defense mechanisms. Translocation is via sink strength. Whatever part of the tree is the strongest sink will pull the compound towards it.

5. Degradation in the tree. Dilution of tissue concentration occurs over time, probably by tree growth, loss through leaf fall, root turnover and fruit removal. Possibly some is metabolized.

6. Safety. The compounds are viewed as environmentally-friendly materials.

7. Continued protection program after tree health is restored. A continuing program is required to maintain tree health.

BIOLOGICAL CONTROL REVIEW AND ROOT ROT MANAGEMENT IN AUSTRALIA - A.W. WHILEY AND K.G. PEGG.

Biological control of *Phytophthora* root rot of avocado is only one of several management strategies which are recommended in the integrated approach to the control of this destructive disease of avocado orchards in the humid subtropics of Australia.

On the red basaltic soils which previously supported rainforest, growers use ecological methods to assist in control. Broadbent and Baker (1974) first demonstrated that the red basaltic soils under natural rainforest communities were suppressive to the development of *Phytophthora* root rot. These soils have a large population of resident antagonists which are attracted to and lyse the zoosporangia of *Phytophthora cinnamomi.* When these soils are flooded or waterlogged, their suppressing ability may be temporarily lost, probably due to a change in the biological balance between antagonists and the pathogen. Also if organic matter is depleted in these soils, they become conducive to root rot development. The most suppressive zone in the soil is the interface between the litter layer and the mineral soil so it is likely that a turnover of organic material is supporting the antagonist's activities. These results have been extended to avocado orchards on similar soils where management strategies were developed to enhance the organic content (Pegg *et al.,* 1982). With intensive cover cropping programs carried out until trees become self-mulching from leaf litter, it is possible to increase organic content in the top 15 cm from the degraded levels of 3 to 5% to close to the rain forest levels of 15 to 18%. With careful management, these soil organic levels are sustainable and the development of *Phytophthora* root rot is under some degree of biological control.; More recently. *Bacillus* species have been identified as one of the complex of microorganisms controlling the *Phytophthora cinnamomi* population and purified cultures have given spectacular control of root rot on young potted trees of *Persea indica* (Sterling and Pegg, unpublished data). Similarly Coffey (1986) and Maas and Kotzé (1989) have found *Phytophthora*-suppressing microorganisms in avocado soils of California and South Africa, respectively. The development of a "seeding" technique in orchards, using these *Phytophthora*-aggressive organisms may extend control measures in the future.

Biocontrol of root rot is generally not effective in a commercial setting unless it is closely integrated with other cultural strategies. The most important of these are sound nutritional and irrigation practices which avoid the development of stress in the trees. Timely removal of fruit, a strong photoassimilate sink, also allows replacement and extension to root systems which may have had some damage from the pathogen.

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THE CONTROL OF AVOCADO ROOT ROT DISPERSAL IN ISRAEL -DR. YAAKOV PINKAS.

Avocado root rot was detected for the first time in Israel in September, 1982. During the following two years another 18 infected groves were identified. One nursery which had ceased operation in 1980 was the source of trees in 15 of the infected groves. A nationwide nursery survey revealed that seven out of 35 presently operating nurseries were contaminated. All *Phytophthora cinnamomi* isolates (from avocado trees and nursery plants) were identified as A_2 mating type, however, they could be separated into two distinct groups based on their virulence to avocado and other host plants tested. The low-virulent isolates produced confined necrotic lesions on the infected root, while with the high-virulent isolates the entire infected root died. The two groups could also be distinguished by their chlamydospore dimensions. During the last five years only two infected groves were detected.

The strategy that combined research to develop recommendations for the nursery, packing house and grove, along with the relevance of the abundance of the low-virulent isolate to the arrest of disease dispersal was discussed.

INTEGRATED CONTROL OF AVOCADO ROOT ROT IN CALIFORNIA - DR. JOHN A. MENGE.

Control of avocado root rot in California has not yet been achieved. There appears to be no single, simple answer to root rot control. However, the integrated use of several different control measures appears to provide us with some hope of managing this disease.

Resistant rootstocks. Resistant rootstocks provide our best hope for controlling avocado root rot. Currently in use in California are a number of *Phytophthora*-tolerant, clonal root-stocks including Thomas, G755, Duke 7, Barr Duke, Toro Canyon, and G6. All of these rootstocks provide field tolerance to avocado root rot. All appear to be tolerant of the disease and do not exhibit a high degree of tolerance. Currently, research is underway to determine the nature of the resistance in these rootstocks. Efforts are continuing to select resistance from horticultural collections in South America as well as from root rot survivors in California. An extensive breeding program coordinated by Dr. Bob Bergh is producing abundant, promising rootstock selections.

Systemic fungicides. Both metalaxyl (Ridomil^{R}) and fosetyl-AI (Aliette^{R}) have been shown to have some effectiveness against avocado root rot and both are being used to some extent in California. These fungicides are more efficacious when used in conjunction with tolerant rootstocks. Trunk injections with fosetyl-CA are being used in the state with some success, but are not as effective here as in South Africa and Australia.

Cultural practices. Cultural practices have always been a part of root rot management in California. Practices such as planting tolerant rootstocks on mounds in heavy soils helps to suppress the effects of root rot. Identifying high-risk soils and suppressive soils are important to this program. Other areas of investigation include maximizing the nutrition of the tree in conjunction with cytokinins, resistant rootstocks and fungicides.

Irrigation management is not practiced in diseased avocado groves as it is in citrus, but as control improves using other methods, irrigation management will become more important.

Biological control. While biological control has not yet proven effective in California avocado groves, several bacteria and fungi have been selected which provide control of avocado root rot in the greenhouse. Upcoming field tests will combine these organisms with other control methods in an effort to achieve success in controlling avocado root rot.

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Conclusion

At the end of the workshop several devices for the injection of chemicals into trees were demonstrated. All devices worked with the major differences being in the speed of delivery and the cost of the equipment. It was also pointed out that the devices are not limited to the injection of fungicides but that possibilities exist for their use for the injection of nutrients into the trees.

The consensus of the workshop participants was that despite the recent advances in chemical control techniques, root rot remains a severe problem. The success of the injection of alkyl phosphonates must not divert us away from the other methods of

control. We must integrate all methods available including resistance, cultural practices, mulches, biological controls and chemicals to achieve and maintain successful control of avocado root rot.

The workshop participants also stated the satisfaction with the exchange of information during the Congress and expressed the desire for more exchange of information and cooperation among avocado-producing countries.