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PROSPECTS FOR INTEGRATED AND BIOLOGICAL CONTROL OF AVOCADO ROOT ROT - SOME OVERSEAS IMPRESSIONS

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OPSOMMING

Die jongste oorsese ontwikkelinge ivm biologiese en gei'ntegreerde beheer van avokadowortelvrot is bespreek. In Suid-Afrika is die klimaaten grondtoestande in huidige avokadogeblede meestal vir wortelvmt baie gunstig, en ons pmbleem is gevolglik relatief ernstig. Die sistemiese swamdoder ®Ridomilis 'n baie effektiewe bestrydingsmiddel, maar ander aanvullende metodes van wortelvrotbeheer bly nog belangrik. Deeglike grondseleksie, siektevrye kwekeryboompies, en siektebestande onderstamme word nogtans aanbeveel. In gebiede met 'n besondere hoé wortelvrotrisiko kan die kweker organiese bemesting en kalktoedienings fvolgens aanbevelings) ook oorweeg.

SUMMARY

Latest overseas developments with a bearing on biological and integrated control of avocado root rot are discussed. It is concluded that climate and soil in current South African production areas make for a comparatively severe root rot problem. Although the systemic fungicide ®Ridomil is a powerful new tool, other aspects must not be forgotten. Careful soil selection, production of disease-free nursery trees, and increasing use of tolerant rootstocks remain high priorities. In high risk areas, there is considerable evidence of the beneficial effects of organic amendments and a high soil calcium content. Integration of all these control measures is recommended.

INTRODUCTION

Biological control of avocado root rot, caused by *Phytophthora cinnamomi (P.c.),* was placed on *a* scientific footing by the classical paper of Broadbent & Baker (1974). Their concept of suppressive soils has been popularized by Pegg (1976) and successfully applied by Australian avocado growers. The writer has commended the broad principles of what he calls the "Pegg wheel" to South African growers, subject to local research findings (Wolstenholme, BN, 1977 (ed.)). Recently, he had the opportunity to visit Australia, the USA, and Israel, and impressions of Australian research on this topic have been published (Wolstenholme, BN, 1979).

This paper is an assessment of prospects for a holistic, ecologically-oriented strategy for "living with" avocado root rot. With the current flush of optimism generated by the new systemic fungicide ®Ridomil, the emphasis has shifted from purely biological to integrated control. Nevertheless, it is stressed that the holistic approach remains as important as ever, especially in high risk root rot situations.

VARYING ROOT ROT SEVERITY IN DIFFERENT COUNTRIES

Of the commercially important avocado growing countries, root rot is potentially most devastating in Australia, with South Africa close behind. California's *P.c.* problem is of lesser magnitude, while Florida and Cuba are only slightly affected. Israel is widely quoted as being free of *P.c.* root rot. It is probable that these facts have an ecological explanation.

In Eastern Australia and in the South African avocado growing areas, high summer rainfall coincides with high soil temperature. Soil conditions are therefore very favourable for *P.c.,* especially in Australia. Furthermore, soils used for avocados are relatively heavy textured, low in organic matter and calcium, non-calcareous and highly leached, i.e. mostly conducive rather than suppressive to *P.c.* (Broadbent, P & KF Baker, 1974; Pegg, KG, 1976).

California's avocados are grown in low-rainfall, relatively cool climates. Since this is a winter-rainfall zone, conditions are less favourable for sporangial production when soil temperatures exceed the critical 15°C level (Zentmyer, GH, H Ohr, FB Guillemet, SD Campbell & G King, 1977). Although summer irrigation is practiced, it is much easier to avoid wetting the entire root zone. Greater emphasis is placed on soil series selection, and according to Borst (1978a) there are also a few naturally suppressive soils in California.

In Florida and Cuba, avocados are grown in a hot, semi-tropical, humid climate with a summer rainfall maximum, seemingly ideal for *P.c.* spread. However, the soils are exceptionally well-drained, typically calcareous and mostly derived from a very porous limestone bedrock. *P.c.* is widely distributed in these soils, but root rot occurs only in small low-lying areas after heavy rain and prolonged root submergence (Borst, G, 1978a). The minor importance of root rot in Florida has been attributed to the exceptional soil drainage (Sauls, JW, 1979) and to an apparent natural suppressive ness of the soils (Borst, G, 1978a).

The presumed absence of root rot in Israel has been attributed to strictly enforced quarantine. Borst (1978a) however points out that this has been in effect only since the establishment of the modern state. Avocados and many of the over 800 *P.c.* susceptible species (Zentmyer, G, 1978) were planted long before this, and it is almost certain that *P.c.* was inadvertently introduced. Borst believes that the pathogen is suppressed in the high calcium soils of that country (Borst, 1979b). Furthermore, as in California, this is a winter rainfall less favourable to the pathogen during the hot dry summer.

CONCEPTS OF BIOLOGICAL CONTROL OF *PHYTOPHTHORA CINNAMOMI*

The "Pegg wheel" concept of suppressive soils was developed specifically for the red basalt clays, which previously supported subtropical rainforest and a large and diverse

P.c. antagonistic micro flora. After clearing for agriculture, these soils gradually became conducive to *P.c.* as the resident antagonists declined. The original biological control concept was to restore their suppressive nature by liming and organic amendments, and to integrate this with other management factors.

An unusual biological control method, involving citrus trees, is being tested in California. It is well known that citrus roots suppress *P.c.* populations, and some growers are experimenting with citrus as a root rot barrier. Citrus is not a complete antidote to *P.c.,* but it is one way of slowing it down (Myers, AE, 1978b).

With the assumption that the reader is familiar with earlier publications on the subject (Pegg, KG, 1976; Wolstenholme, BN, 1979; Zentmyer, G, H Ohr, FB Guillemet, SD Campbell & G King, 1977), latest developments for each component "spoke" of the Pegg wheel will now be discussed. A modified diagram is given in Fig. 1.

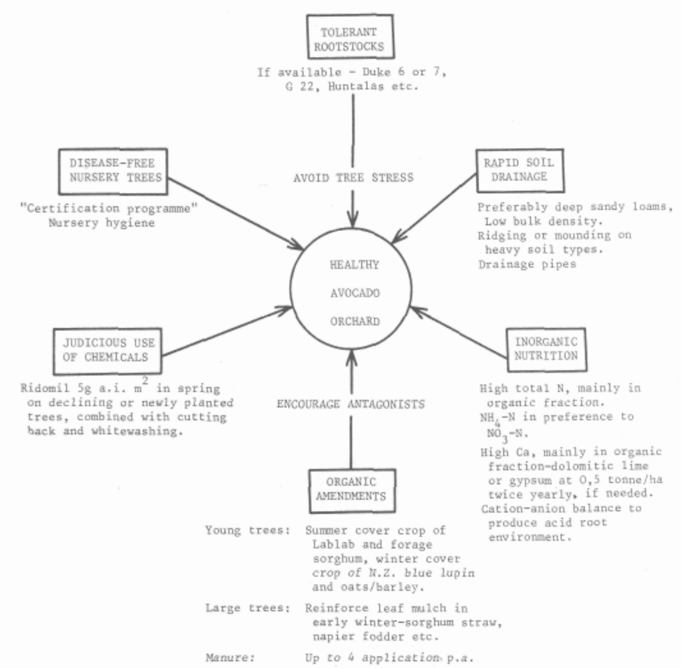

FIG. 1: The "Pegg Wheel" concept of biological control of *Phytophthora cinnamomi* in high rainfall areas

1. Tolerant Rootstocks

The screening programme for *P.c.* tolerant resistant rootstocks has high priority at the University of California, Riverside. New accessions of *Persea americana, P. schiedeana* and *P. steyermarkii* from Central America are being tested. Rootstocks from old "survival" trees are being evaluated, as well as irradiated Duke selections. Seedlings of Duke 6 and Duke 7 controlled crosses, supplied from Bergh's breeding programme, will shortly be included. The search continues for a compatible inters tock, so that the strong resistance of *P. borbonia* and *P. caerulea* in the subgenus *Eriodaphne* can be utilized (Zentmyer, G, 1979).

The origin and properties of the most widely propagated tolerant rootstocks (Duke 6 and 7, G 6, G 22) have been summarized (Zentmyer, G, 1978). Of these, Duke 7 and G 6 are currently most popular. Hunt alas is still infected with sunblotch, but attempts are being made to eliminate the disease through shoot tip grafting. Field trials with trees on various types of tolerant stocks (cuttings and seedlings) are promising. The oldest trials are now 8 to 10 years old. Zentmyer believes that resistant rootstocks are the ultimate and long-term answer to *P.c.*

Brokaw Nursery has patented an improved version of the original Frolich etiolation technique (Frolich, EF & RG Platt, 1972) for rooting avocado cuttings. It hopes to produce 80 000 trees on clonal tolerant rootstocks in 1979 (50 000 were produced in 1978 and 25 000 in 1977). Getzler Nurseries in Israel have been licensed since 1977 to use the Brokaw method. Royalties of up to $1 per tree are paid to Brokaw. This nursery aims to produce 20 000 trees on clonal rootstocks this year, although the objectives are salinity tolerance, production of "copy" trees etc. rather than *P.c.* control. The first experimental orchard of such "copy" trees (clonal stock and scion duplicates of selected outstanding orchard trees), has been planted under the supervision of Dr Ben Ya'acov at Kibbutz Horshim.

2. Rapid Soil Drainage

Borst (1978c) has given interesting estimates of the life expectancy of California avocados on different soils. Slight hazard soils are those with very good to excessive drainage, subsoil permeability of > 16mm hr^{-1}, impervious bedrock or hardpan at more than 1 500 mm depth if present, and exchangeable sodium < 2%. Life expectancy of trees on these soils is about 40 years. For moderate hazard soils it is 20 years, and only 10 years on severe hazard soils. In South Africa, equivalent longevities are shorter because of the more favourable conditions for *P.c.*

A fourth but relatively minor category of avocado soils is now recognized in California, viz. root rot suppressive soils (Borst, G, 1978a). They are developed from calcareous marine sediments or their alluvium. Although they may result in lime-induced chlorosis in avocados, the Israelis have shown that this can be overcome by selected lime-tolerant West Indian rootstocks (Ben Ya'acov, A, 1976).

It must be emphasized that occasional spells of very heavy rain can saturate the best-drained soils, especially those with a high clay content. Even suppressive soils can be "swamped" by such flooding, temporarily tipping the host-pathogen balance in favour of the pathogen. In Australia, over 50% of the avocado trees on the eastern seaboard were killed by the exceptional floods of 1974 (Debney, H, 1978). Very heavy spring rains, followed by very high autumn temperatures, made 1978 a crisis root rot year in California — the weakened trees with reduced root complements could not tolerate the additional stress (Borst, G, 1979a).

I believe that soil and site selection must anticipate these occasional "1 in 10 year" floods in high rainfall areas, which can set back or ruin previously profitable orchards. The Australian system of "ridging" heavy soils for extra drainage, combined with measures for rapid removal of storm water from orchards, is a commonsense precaution.

Even in Israel, it is now standard practice to ridge heavy soils before planting avocados.

It is also worth noting that the Australians are investigating the possibilities of expanding avocado growing into the drier interior. Root rot problems are less in low rainfall areas, although good soil drainage remains a prime necessity.

3. Organic Amendments

Suppressive soils owe their suppressiveness mainly to their high level of microbial activity. Bacteria, actinomycetes and certain antagonistic fungi suppress *P.c.* populations by hyphal and sporangial lysis, and by competition (Broadbent, P & KF Baker, 1974). High populations of these *P.c.* antagonists are apparently favoured by high soil organic matter in particular, and also high soil calcium content (Borst, G, 1978b; Pegg, KG 1976). These conditions exist in rainforest soils in eastern Australia, and presumably also in the indigenous rainforests of central America where *P.c.* is not a problem. Biological control thus attempts to restore suppressiveness to agricultural soils by, *inter alia,* addition of bulky organic amendments.

The application of organic materials is not meant to replace inorganic fertilizers, or even to supply the bulk of the tree's nutrient requirements. A hectare of soil to 30 cm depth has a mass of about 4 000 tonnes. Even a large application of 10 tonnes ha^{-1} of bulky organic material low in N would not drastically change the topsoil. If high N chicken manure or similar compounds are used, however, much more care is needed. Leaf analysis is strongly recommended to monitor the tree's nutrient status. There are reports of excessive use of high N organics in South Africa (Anon, 1979), and growers must beware of the "bigger is better" syndrome.

On the other hand, scepticism about the usefulness of organics in the hot, moist subtropics due to their very rapid breakdown is misplaced. This speed of decomposition is a sure sign of the desired microbial activity. It does of course mean that large amounts of, for example, napier fodder, straw or maize stubble must be applied to reinforce the natural dead leaf mulch under mature avocado trees. This adds to the expense of the biological method, but it is widely accepted amongst progressive growers in the high risk *P.c.* areas of Australia.

Opinion on the value of organic amendments in California (a medium-risk *P.c.* area) is divided. Most advisors take a middle approach, striking a balance between organics and in organics. Gustafson, for example, recommends a "situational decision" based largely on economics (Afflick, ME, 1979).

It must be remembered that bulky organics are not readily available in California, and are expensive to grow. Some authorities believe that the slower decomposition of organics in California's (and Israel's) climate should make biological control easier than in summer fain fall areas, and that California growers have been slow to appreciate the practical implications of the Australian research (Borst, G, 1978b).

Timing of bulky organic matter applications varies according to conditions. In eastern Australia, Pegg recommends autumnlearly winter applications, so that the mulch is partially decomposed when the summer rains start. Summer applications would tend to keep soils too wet, and may even be dangerous (Pegg, KG, 1979). In California, mulches increase the already considerable frost hazard, and must therefore be applied in late spring when the danger of frost is past (Borst, G, 1978b).

4. Inorganic Nutrition

4.1 *Calcium and liming.* Suppressive soils invariably have a high Ca content. This Ca is largely tied up in the organic fraction of high rainfall forest soils, sometimes to the extent of 4 000 to 6 000 ppm in basalt-derived krasnozems (Pegg, KG, 1976). In Florida, Cuba, Israel and the few naturally suppressive soil's in California, the parent material is calcareous. Slightly acid to neutral topsoil pH is thought to favour the microbial antagonists of *P.c.* It probably also improves soil structure and aeration.

In South Africa, avocados are mostly grown on leached, low Ca soils, and the role of liming in ameliorating this situation is being investigated. It appears that here also, some growers have been injudicious and opted for the "if some is good, more is better" approach (Anon. 1979). This is disappointing, as research on liming requirements is advanced in South Africa. Soil analysis and a liming recommendation will preclude the hazards of over-liming, especially on low CEC soils. Much interesting research on this topic is being conducted in California and Australia.

4.2 *Nitrogen.* Soil suppressiveness to *P.c.* has been associated with high (0,6 0,8%) total soil N. Levels of NH^{+}_{4} N and NO^{-}_{3} N are usually low, so that most of the N is tied up in humic residues and released slowly (Broadbent, P, & KF Baker, 1974). To what extent these aspects are necessary for *P.c.* suppression is under investigation in Australia and California. It seems that organic substances give rise to NH^{+}_{4} and NH_3 at higher pH values, and to nitrite or nitrous acid at lower pH, and that all of these compounds can suppress *P.c.*

Recommendations as to N carrier are more controversial. Pegg (1976) originally advised high N organics, with urea or ammonium sulphate as second choice. In California, acidifying N carriers such as ammonium sulphate are not recommended, except on calcareous soils. Calcium nitrate has a neutral effect on soil pH and is the preferred choice of Borst (1978b).

4.3 *Cation-anion balance.* The interesting possibility of sufficiently lowering rhizosphere pH by appropriate fertilization to suppress *P.c.* zoospores, is being tested in Australia (Wolstenholme, BN, 1979). It is too early to speculate on this novel approach. The use of micronized sulphur for *P.c.* control (Myers, AE, 1979) requires further investigation.

5. Disease-free Nursery Trees

The production of disease-free nursery trees remains a fundamental principle of avocado growing. The California nursery tree certification requirement are well known. In 1978, the Australian industry initiated

a voluntary accreditation scheme based on strict hygiene guidelines (Debney, H, 1978; Pegg, KG, 1978). It has been shown that the systemic fungicide ®Ridomil can provide additional insurance in this regard (Allen, RN, KG Pegg, LI Forsberg & DJ Firth, 1979).

6. Judicious Use of Chemicals

In the last year or two, prospects for effective chemical containment of *P. c.* have changed dramatically, and South Africa is well to the fore in *field* evaluation of new generation systemic fungicides. Before discussing ®Ridomil, the most promising of these, the status of older chemicals will be briefly outlined.

Dexon was effective in laboratory and greenhouse tests, but economically questionable and only marginally effective in the field. It has been withdrawn from the market.

Methyl bromide is used for spot fumigation of small *P.c.* infected areas in otherwise healthy groves. Munnecke has developed an effective deep injection technique under a polythene tarpaulin. Clay soils, however, are almost impossible to get dry enough for adequate diffusion of the gas.

Ethazole (®Terrazole) was finally approved by the U.S. Environmental Protection Agency in June 1978, after seven years of testing in California. Its field performance is usually good, although it is not a wonder chemical. Ten treatments per year are recommended, costing about 20 U.S. cents/application on young trees, up to $1,85 per application on mature trees in 1978 (Myer, AE, 1978a). It is useful only for retarding the spread of *P.c.* on lightly affected trees, preferably on tolerant rootstocks (Matson, R, 1978).

CGA 48988 (®Ridomil) continues to show promise in California and is far superior to ®Terrazole. If Ciba-Geigy proceeded with registration, it would take one to two years to achieve clearance for avocado. Zentmyer has high hopes for ®Ridomil, and believes it would be most effective with trees on tolerant rootstocks and on soils that do not favour *P.c.* (Anon. 1977).

A comprehensive report on ®Ridomil for nursery and field trees in Australia is now in press (Allen, RN, KG Pegg, LI Forsberg & DJ Firth, 1979). At least four months' control of *P.c.* was obtained by an application of 1 g a.i. $10l^{-1}$ potting medium with nursery trees. On orchard trees, two applications of 5 g a.i. rrr^{2} of soil beneath the canopy controlled *P.c.*. Biological antagonists and earthworm populations were not affected. The treated soil became friable, and healthy root systems permitted the trees to recover over a 12 month period.

Pegg (Pegg, KG, 1979) states that Australian registration at 5 g a.i. m^{-2} is expected shortly. At 2 g a.i. m^{-2}, only 50% response was obtained. 10 and 20 g a.i. m^{-2} were more spectacular than 5 g, but fruit residue problems became apparent at 20 g.

A word of caution

Avocado people can be excused the euphoria and optimism that has come with the release of the first really effective, highly specific fungicide ®Ridomil (with ®Aliette also very promising). However, we should guard against complacency, injudicious use of this powerful new weapon, and an attitude that the problem has been solved. The cloud on the horizon is the development of resistance and new strains of *P.c.*. The more we rely on ®Ridomil, the quicker this will come about. Perhaps we have only a few years' breathing space, although hopefully related fungicides will also be effective. In the words of a Scottish researcher on downy mildews, ®Ridomil "should be regarded only as a short-term palliative". He believes that ®Aliette, which is heavy-metal based, may prove better in this respect (Dixon, G, 1979).

I am in full agreement with workers who caution us not to neglect the other proven weapons in our *P.c.* armoury. The beauty of ®Ridomil is that it can be brought in a broad-based integrated control programme in high-risk *P.c.* areas.

CONCLUSION

At first sight, the release of the new and effective systemic fungicide ®Ridomil may appear to reduce the importance of other control strategies for avocado root rot. The writer believes that such a philosophy would be short-sighted and dangerous. The greater the *P.c.* risk due to a particular combination of climate and soil, the greater is the need for an integrated, holistic, multi-facetted approach. In South Africa at present the *P.c.* risk can be rated high, and we cannot afford to ignore the cardinal importance of soil selection, disease-free nursery trees, and tolerant rootstocks as they become available. Integration of these weapons with judicious use of ®Ridomil is an absolute minimum strategy for "living with" *P.c.* The complete integrated approach, incorporating in addition the correct use of organic amendments and probably also liming, is recommended to more knowledgeable and progressive growers.

ACKNOWLEDGEMENT

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