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SOIL EFFECTS ON PHYTOPHTHORA ROOT ROT OF AVOCADOS

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INTRODUCTION

Avocado root rot caused by *Phytophthora cinnamomi* is a problem of the avocado industry in Argentina, Australia, California, Cameroon, Chile, French West Indies, Martinique, Mexico and South Africa (Gustafson, 1976). Israel is the only avocado growing country where it has not yet been found.

Root rot was first reported from Puerto Rico in 1928 (Tucker, 1928). Since then a considerable amount of work has been done on the disease. The relationship between soil and *P. cinnamomi* was also extensively studied.

Even the first reports stated that conditions of waterlogging in the soil mediates the disease (Tucker, 1928). Wager (1942) demonstrated that the disease is adversely influenced by poor soil drainage. Wager (1941) also reported the disease from Western Transvaal and Natal and observed that it first appeared on trees growing in heavy clay soils or on poorly drained sites.

When *P. cinnamomi* is present in the soil, avocado seedlings decline after two-day waterlogging periods, while seedlings in soil without the pathogen collapse from waterlogging periods of 8 to 10 days (Zentmyer & Klotz, 1947). Soil moisture content governed by irrigation had caused more rapid damage of the fungus to trees which were irrigated weekly than to those irrigated bi-weekly (Zentmyer & Richards, 1952).

In relation of H-ion concentration to root rot of avocados Bingham & Zentmyer (1954) found that no disease development occurred at pH 3,0, but all inoculated cultures exhibited root rot between pH 3,5 and 8,0. As the H-ion concentration was increased from pH 6,0 to 3,5 the disease decreased markedly.

With further experiments Zentmyer & Bingham (1956) established the role of nitrate. Seedlings were prevented from *Phytophthora* root rot in glasshouse by the presence of 2 ppm nitrite nitrogen in the culture solution at pH 4,5, while at pH 6,5 40 ppm nitrite nitrogen was required for inhibition of infection. They found no evidence that nitrite predisposes avocado roots to infection by the fungus.

Root rot development in relation to various ratios of exchangeable Ca, Mg, K, Na and H was investigated by Bingham, Zentmyer & Martin (1958). A retarded disease development was noted in solution cultures with high concentrations of N or K. Variations in the ratios of exchangeable cations in soil had no effect on *Phytophthora* root rot.

Pegg (1976) recovered the pathogen from healthy looking trees growing on soil with the following characteristics: high organic levels, high cation exchange capacity, high base saturation, high Ca level, high N level tied up in the organic residues, pH 6—7 and soil extract to lyse the fungus.

Infection of avocado roots by *P. cinnamomi* in saturated sandy loam soil took place at potentials of -0,05 and -0,1 bar, while little infection occurred at a potential of -0,25 bar. In clay soils infection was observed at -0,25 bar or even at higher potentials (Zentmyer, Kaufman & Embleton, 1977).

SOIL SURVEY AT WESTFALIA ESTATE

An extensive soil survey was initiated in 1977 to investigate the physical, chemical composition as well as pathological analysis of our soils and their relation to *Phytophthora* root rot of avocado trees.

Materials and methods

1. Orchards were chosen from various sections of Westfalia Estate according to cultivar, age and condition of trees and previous cultural background of blocks.
2. Usually 10 or more holes of 2 m in depth were dug under either a sick or healthy tree. Soil samples were taken from each layer that could be classified as different in each hole.
3. To detect the presence of *P. cinnamomi* diseased root pieces (collected from each layer) were plated on P_{10}VP, then 50 g soil sieved and plated on P_{10}VP according to the technique of McCain, Holtzmann & Trujillo (1967) and lastly a bait technique was employed with the aid of lupine seedlings.
4. Chemical analysis was carried out by the Citrus and Sub-Tropical Fruit Research Institute in Nelspruit.

TABLE I: ANALYSIS OF VARIOUS SOILS AT WESTFALIA ESTATE UNDER SICK AND HEALTHY AVOCADO TREES

1. BLOCK A 3 EVENROND: Average of soil under healthy and sick trees

Horizon	Depth	pH	% Clay	% Silt	% fine sand	% coarse sand	Resistance	Ca ppm	Mg ppm	K ppm	P ppm	Al ppm	incidence of *P. cinnamomi*
A	35,2	5,3	43,2	12,1	32,1	12,5	2988	283	98	75	1,0	73,7	19
B	71,4	5,4	53,2	13,8	26,0	7,6	8644	65	50	29	0,25	51,3	13
C	114,7	5,5	45,2	21,2	27,5	6,7	9052	54	33	20	0,14	16,8	4
Total Av.		5,4	47,2	15,1	28,7	9,2	6655	143	63	43	0,5	50,7	1,3 /sample

TABLE 1 CONTINUED ON FOLLOWING PAGE

Horizon	Depth	pH	% Clay	% Silt	% fine sand	% coarse sand	Resistance	Ca ppm	Mg ppm	K ppm	P ppm	Al ppm	incidence of *P. cinnamomi*
1 (a) BLOCK A3 EVENROND: Soil under sick trees													
A	31,0	5,4	40,4	15,1	34,5	12,3	1068	238	85	84	1,2	81,5	13
B	58,3	5,4	49,7	15,3	26,7	8,2	9828	58	46	36	0,2	59,6	7
C	108,6	5,6	42,0	22,7	28,1	8,2	8234	50	24	22	0,2	21,6	4
Total Av.		5,4	44,1	16,6	29,8	9,6	6694	119	53	48	0,5	56,1	1,5 /sample
1 (b) BLOCK A3 EVENROND: Soil under healthy trees													
A	41,0	5,4	47,4	11,1	28,7	12,9	4055	35	119	61	0,8	62,1	6
B	91,5	5,3	57,0	11,4	24,9	6,7	6868	75	56	18	0,4	38,9	6
C	130,0	5,6	53,3	17,4	26,1	3,2	11100	63	56	15	–	4,9	–
Total Av.		5,4	52,4	12,5	26,6	8,4	6589	183	81	35	0,5	41,4	1,2 /sample
2. BLOCK A4 EVENROND: Average of both healthy and sick trees													
A	33,0	5,4	39,8	12,0	35,0	13,2	3193	268	53	88	7,8	150,4	7
B	95,4	5,4	53,3	9,5	27,0	10,1	5507	120	19	62	1,2	120,9	3
C	119,2	5,5	56,0	13,8	22,8	7,4	4580	105	23	61	1,1	91,8	
D	72,0	5,7					8180	25	27	22	1,0	18,0	
Total Av.		5,4	48,5	11,3	29,4	10,8	4541	170	33	70	3,7	122,7	0,38/sample
2 (a) BLOCK A4 EVENROND: Soil under sick trees													
A	28,6	5,4	49,8	10,1	36,5	11,7	3610	165	54	109	8,3	149,8	7
B	88,2	5,5	53,3	8,5	32,3	11,3	6208	75	25	46	1,2	122,4	3
C	73,0	5,4	58,9	11,7	25,4	8,3	4285	38	30	49	1,3	89,1	
D	72,0	5,8					8180	25	27	22	1,0	18,0	
Total Av.		5,4	49,5	9,3	30,4	10,8	5055	96	36	67	3,7	126,6	0,71/sample
2 (b) BLOCK A4 EVENROND: Soil under healthy trees													
A	37,4	5,5	37,5	13,8	33,6	15,1	2776	370	52	67	7,3	151,0	
B	102,6	5,4	53,4	10,5	27,2	8,9	4806	120	13	78	1,3	119,0	
C	150,0	5,7	56,6	20,3	18,1	5,0	4700	200	21	84	1,0	32,4	
Total Av.		5,5	47,3	13,5	28,4	10,8	3943	256	30	74	3,8	118,1	
3 BLOCK 1 FOWEY: Average of both under healthy & sick trees													
A	27,8	5,5	38,6	6,9	40,0	14,5	4220	1008	191	125	2,2	34,4	
B	102,2	5,5	47,4	8,9	33,3	10,4	1545	791	119	129	1,6	39,0	
C	20,0	5,6	41,7	13,9	30,7	13,6	4866	466	126	44	0,5	10,2	2
D	120,0	5,8	29,6	18,0	35,4	17,0	4730	358	158	41	0,5	12,3	
Total Av.		5,5	40,5	10,6	35,5	13,4	3521	738	151	99	1,4	28,2	2
3 (a) BLOCK 1 FOWEY: Soil under sick trees													
A	25,0	5,4	39,2	5,4	45,6	16,4	4941	1083	166	134	3,7	30,6	
B	31,0	5,4	47,5	6,5	35,3	10,6	1747	583	102	62	0,7	55,8	
C	20,0	5,7	41,7	14,0	30,8	13,6	4867	467	127	44	0,5	10,2	2
D	120,0	5,8	29,6	18,0	35,5	17,0	4730	358	158	41	0,5	12,3	
Total Av.		5,6	37,8	11,0	36,8	14,4	4071	623	138	70	1,3	27,2	0,08/sample
3 (b) BLOCK 1 FOWEY: Soil under healthy trees													
A	21,4	5,6	44,8	8,3	34,4	12,5	3500	933	215	116	0,8	38,1	
B	169,3	5,6	47,3	11,2	31,4	10,1	1343	1000	138	195	2,7	22,2	
Total Av.		5,6	46,0	9,8	32,9	11,3	2421	967	176	156	1,8	30,2	–
4 BLOCK 9C FOWEY: Soil under healthy trees													
Average		6,2	57,2	12,9	26,6	3,3	3023	625	144	122	0,3	5,4	0,6 /sample
5 BLOCK 9D FOWEY: Soil under sick trees													
Average		6,2	55,1	8,2	31,7	5,0	11100	316	162	53	0,5	4,2	–

DISCUSSION

It is difficult to give a short characterisation of our soils because of the tremendous variations, even within a single orchard. In general, however, the texture of the soil examined was clay, to a lesser extent sandy clay, sandy clay loam, clay loam and sandy loam. There were orchards with fairly uniform soil type, like Block 9C and 9D Fowey, where all samples were classified as clay texture. On the other hand Block A4 at Evenrond consited of clay, sandy clay, sandy clay loam and clay loam types. The clay content of the samples varied between 20,5 and 61,7%. Usually the topsoil (Horison A) contained somewhat less clay than subsoils, while subsoils held more silt than topsoil. Fine and coarse sand occurs at a higher volume in the upper horisons. Resistance, which was measured in electric conductivity of the soil solutions showed no definite pattern relating to horisons. There were exceptions, but in general Ca, Mg, K, P and Al concentrations were lower in subsoils. Most of the soils were very acid and subsoils were slightly more acid than topsoils.

When it comes to correlating the figures with the condition of trees one finds a very complex problem, that involves a number of soil factors and the role of *Phytophthora cinnamomi.*

The depth of the topsoil is greater under healthy trees than under sick ones (on Block A3 and A4 at Evenrond). This layer being richer in nutrients and organic matter may contribute positively to the condition of trees when deeper.

The pH was uniform under both healthy and sick trees. This confirms that the H-ion concentration within given values (all our measurements fall within these values) allows the development of *Phytophthora* root rot, which was perhaps more serious at lower pH. Percentage clay, silt, fine sand and coarse sand content of the soil did not follow the condition pattern of the trees.

Electric resistance is interestingly coupled with the conditions of trees if analysed within the same block. In all examined orchards soil under sick trees exhibited higher resistance (lower concentration of soluble salts) than under healthy trees. A very good example of this is Block 9C and 9D, which are divided into two "sub-blocks" only by a road. They appear to be very similar regarding most of the characteristics, except that Ca content is lower and resistance is extremely high in 9D. The lack of *P. cinnamomi* in the soil suggests that the trees die from non-pathogenic cause. Ca content is lower than in 9C, but it is improbable that this would be the problem since in Evenrond Block 4A trees look healthy with even lower Ca concentration. The only significant difference is then in resistance, according to which in soil types trees die when only one-fifth of the soluble salts of a good soil are present.

Calcium seems another important soil factor correlating with conditions of trees. When Ca content of the soil under healthy and sick trees was compared in a given orchard, a higher concentration was found consistently under the healthy trees.

From this survey none of the other elements (Mg, K, P, Al) could conclusively be related to avocado root rot in our orchards. Unfortunately for the successful implementation of soil sieving technique requires a thorough rotation of the soil to achieve a uniform distribution of the fungus which cannot be applied in avocado orchards. Attempts to isolate the fungus out of dead roots on $P_{10}VP$ have failed to be a consistent tool for studying distribution of the pathogen. Therefore, a final account on the incidence of *P. cinnamomi* was based on results obtained with the use of lupine seedlings as trap plants. This semi-quantitative technique proved suitable for estimating the number of viable infective propagules of the fungus in the soil. It was found that incidence of *P. cinnamomi* was highest at the topsoil in horison A, which decreased in deeper levels and was considerably lower under healthy trees than under sick trees. As an exception, Block 9D at Fowey can be quoted, which, as mentioned before, must primarily have been a soil disorder rather than a pathogenic problem.

SUMMARY

From a preliminary study on soils of avocado orchards, it was concluded that the bad condition of trees stems from more than one cause. It seems that on sites where some of the soil factors may be highly disadvantageous, trees die without *P. cinnamomi.* Block 9D is an example of this case. In other blocks, where we found soil factors mediative rather than causative for inferior tree growth, *P. cinnamomi* is playing a very important role. It is suggested that on Blocks A3 and A4 at Evenrond, trees on soil with high resistance, low Ca content and high H-ion concentration could still be in good shape *if P. cinnamomi* is controlled. Where all soil factors are favourable, trees grow and produce well even in the presence of *P. cinnamomi,* like in Block 9C at Fowey.

To summarise the following factors found to be very closely linked with avocado decline: high soil resistance (concentration of soluble salts) low Ca content *Phytophthora cinnamomi* and possibly shallow topsoil.

The role of *P. cinnamomi* was predominant in soils where resistance exceeded about 5000, and Ca content was lower than approximately 150 ppm in acid soils, while the damage caused by the pathogen was negligible when resistance was as low as 3000 with over 600 ppm Ca in close to neutral clay soil.

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