



REFERENCES



REFERENCES

- ANDERSON, E.J. 1951. A simple method for detecting the presence of *Phytophthora cinnamomi* Rands in soil. *Phytopathology* **41**:187-189.
- ANN, P.J. & KO, W.H. 1990. Growth rate and colony morphology of progenies of zoospores and selfed oospores of *Phytophthora parasitica*. *Mycologia* **82**:693-697.
- ANON, 1993. The Avocado Plant Improvement Scheme (APIS). Unpublished report, available from the South African Growers' Association.
- ARPAIA, M.L. 1993. Avocado clonal rootstock production trial. *Calif. Avocado Res. Symp. Riverside, CA*, pp. 17-23.
- ARPAIA, M.L., BENDER, G.S. & WITNEY, G.W. 1992. Avocado clonal rootstock trial. *Proc. 2nd World Avocado Congr. Riverside, CA*, **1**:305-310.
- BAKER, K.F. 1957. The U.C. System for producing healthy container-grown plants. Univ. Calif. Div. Agric. Sci., Agric. Exp. Stn. Ext. Serv., Man. **23**:1-332.
- BAKER, K.F. & ROISTACHER, C.N. 1957. Heat treatment of soil. pp. 123-137. In: K.F. BAKER (ed.). The U.C. system for producing healthy container grown plants. Univ. Calif. Div. Agric. Sci., Agric. Exp. Stn. Ext. Serv., Man. **23**:1-332.
- BARR, D.J.S. 1992. Evolution and kingdoms of organisms from the perspective of a mycologist. *Mycologia* **84**:1-11.
- BEN YA'ACOV, A. & MICHELSON, E. 1995. Avocado rootstocks. *Hort. Rev.* **17**:381-429.
- BEN-YA'ACOV, A., MICHELSON E. & SELA, I. 1993. Rootstock effect on avocado vigor and productivity. *Acta Hort.* **349**:191-195
- BERGH, B.O. 1969. Avocado (*Persea americana* Miller). pp. 23-51. In: F.P. FERWERDA and F. WIT (eds.). Outlines of perennial crop breeding in the tropics. Misc. Pap. **4**. Wageningen, The Netherlands: Landbouwhogeschool.
- BERGH, B.O. 1975. Avocados. pp. 541-567. In: J. JANICK and J.N. MOORE (eds.). Advances in fruit breeding. Purdue University Press, Lafayette.
- BERGH, B.O. 1992. The origin, nature and genetic improvement of the avocado. *Calif. Avocado Soc. Yearb.* **76**:61-75.
- BERGH, B.O. & ELLSTRAND, N. 1986. Taxonomy of the avocado. *Calif. Avocado Soc. Yearb.* **70**:134-145.
- BIJZET, Zeldá. 1998. Development of avocado rootstocks with improved resistance/tolerance to *Phytophthora* rootrot. *S. Afr. Avocado Growers' Assoc. Yearb.* **21**:7-12.
- BIJZET, Zeldá & SIPPEL, A.D. 2001. Rootstocks. pp. 85-90. In: E.A. DE VILLIERS (ed.). The cultivation of avocado. ARC-Institute for Tropical and Subtropical Crops. Nelspruit.



- BIJZET, Z, SIPPEL, A.D. & KOEKEMOER, P.J.J. 1993. Avocado breeding a progress report. *S. Afr. Avocado Growers' Assoc. Yearb.* **16**:86-89.
- BIJZET Zeld, VAN VUUREN, S.P. & SCHROEDER, Lizette. 1997. Progress with local selections in the quest towards a more *Phytophthora* tolerant/resistant avocado rootstock than Duke 7. *S. Afr. Avocado Growers' Assoc. Yearb.* **20**:17-23.
- BIJZET, Zeld, BREEDT, H.J., KOEKEMOER, P.J.J. & CILLIERS, B. 1996. Avocado rootstock breeding - New developments and intricacies. *S. Afr. Avocado Growers' Assoc. Yearb.* **19**:14-15.
- BITTERS, W.P. 1961. Physical characteristics and chemical composition as affected by scions and rootstocks. pp. 56-95. In: W.B. SINCLAIR (ed.). *The orange: Its Biochemistry and Physiology*. University of California, Division of agricultural Sciences, Berkley, CA.
- BINGHAM, F.T. & NELSON, C.O. 1971. The effects of sodium on mature avocado trees. *Calif. Avocado Soc. Yearb.* **54**:75-78.
- BLACK, W. 1952. A genetical basis for the classification of strains of *Phytophthora infestans*. *Proc. Roy. Soc. Edinb. B.* **65**:36-51.
- BLACKWELL, E. 1949. Terminology in *Phytophthora*. *Mycol. Pap.* **30**:1-24.
- BLOODWORTH, M.E., BURLESON, C.A. & COWLEY, W.R. 1958. Root distribution of some irrigated crops using undisrupted soil cores. *Agron. J.* **50**:317-320.
- BOESEWINKEL, H.J. 1976. Storage of fungal cultures in water. *Trans. Br. Mycol. Soc.* **66**:183-185
- BOTHA, T. & KOTZÉ, J.M. 1989a. Exudates of avocado rootstocks and their possible role in resistance to *Phytophthora cinnamomi* *S. Afr. Avocado Growers' Assoc. Yearb.* **12**:64-65.
- BOTHA, T. & KOTZÉ, J.M. 1989b. Susceptibility of avocado rootstocks to *Phytophthora cinnamomi*. *S. Afr. Avocado Growers' Assoc. Yearb.* **12**:66-67.
- BOTHA, T. WEHNER, F.C. & KOTZÉ, J.M. 1989. An evaluation of *in vitro* screening techniques for determining tolerance of avocado rootstocks to *Phytophthora cinnamomi*. *S. Afr. Avocado Growers' Assoc. Yearb.* **12**:60-64.
- BREEDT, H.J., KOEKEMOER, P.J.J. & BIJZET, Zeld. 1995. Vorderingsverslag: Seleksies van *Phytophthora* bestande avokado onderstamme 1992 tot 1994. *S. Afr. Avocado Growers' Assoc. Yearb.* **18**:4-6.
- BROADBENT, P. & BAKER, K.F. 1974. Behaviour of *Phytophthora cinnamomi* in soils suppressive and conducive to root rot. *Aust. J. Agric. Res.* **25**:121-37.
- BRODRICK, H.T., ZENTMYER, G.A. & WOOD, R. 1976. Comparison of various methods for the isolation of *Phytophthora cinnamomi* from avocado soils. *Calif. Avocado Soc. Yearb.* **59**:87-91.



- BROEKMAN, J.J. 1993. Die rol van fisiese eienskappe van grond by die verbouing van avokado's. *S. Afr. Avocado Growers' Assoc. Yearb.* **16**:96-99.
- CAMPBELL, W.A. 1949. A method of isolating *Phytophthora cinnamomi* directly from soil. *Plant Dis. Rept.* **33**:134-135.
- CAMPBELL, W.A. & COPELAND, O.L.Jr. 1954. Littleleaf disease of shortleaf and lobbolly pine. *U.S. Dep. Agric. Circ.* **940**:1-41.
- CAVALIER-SMITH, T. 1986. The kingdom Chromista: Origin and systematics. pp. 309 – 347 In: I. ROUND and D.J. CHAPMAN (eds.). *Progress in Phycological Research*. Vol. 4. Biopress. Bristol, England.
- CAVALIER-SMITH, T. 1987. The origin of fungi and pseudofungi. pp. 334-359. In: A.D.M. RAYNER, C.M. BRASIER, and D. MOORE (eds.). *Evolutionary Biology of Fungi*. Cambridge University Press, Cambridge, U.K.
- CHANG, T.T., YANG, W.W. & WANG, W.Y. 1996. Use of random amplified polymorphic DNA markers for the detection of genetic variation in *Phytophthora cinnamomi* in Taiwan. *Bot. Bull. Acad Sinica* **37**:165-171
- CHEE, K. & NEWHOOK, F.J. 1965. Improved methods for use in studies on *Phytophthora cinnamomi* Rands and other *Phytophthora* species. *N.Z.J. Agric. Res.* **8**:96-103.
- COFFEY, M.D. 1987. A look at current avocado rootstocks. *Californian Grower* **11**:15-17.
- COFFEY, M.D. & GUILLEMET, F.B. 1987. Avocado rootstocks. *Calif. Avocado Soc. Yearb.* **71**:173-179.
- CRANDALL, B.S., GRAVATT, G.F. & RYAN, M.M. 1945. Root disease of *Castanea* species and some coniferous and broadleaf nursery stocks caused by *Phytophthora cinnamomi*. *Phytopathology* **35**:162-180.
- DANCE, M.H., NEWHOOK, F.J. & COLE, J.S. 1975. Bioassay of *Phytophthora* spp. in soil. *Plant. Dis. Rept.* **59**:523-527.
- DARVAS, J.M., TOERIEN, J.C. & MILNE, D.L. 1983. Injection of established avocado trees for the effective control of *Phytophthora* root rot. *S. Afr. Avocado Growers' Assoc. Yearb.* **6**:76-81
- DAVIS, R.M & MENGE, J.A. 1977. The influence of endomycorrhizae on *Phytophthora* root rot of three crop plants. *Proc. Am. Phytopathol. Soc.* **4**:146.
- DE BARY, A. 1876. Researches into the nature of the potato fungus, *Phytophthora infestans*. *J.R. Agric. Soc. Engl., Ser.2.* **12**: 239-269. (Cited in Erwin & Ribeiro, 1996)
- DEACON, J.W. & DONALDSON, S.P. 1993. Molecular recognition in the homing responses of zoosporic fungi, with special reference to *Pythium* and *Phytophthora*. *Mycol. Res.* **97**:1153-1171.
- DICK, M.W. 1995a. Sexual reproduction in the Perenosporomycetes (chromistan fungi). *Can. J. Bot.* **73**(suppl. 1): 5712-5724.



- DICK, M.W. 1995b. The Straminipilous Fungi. A new classification for the Biflagellate Fungi and their Uniflagellate relatives with particular reference to lagenidiaceous Fungi. *C.A.B. Internat. Mycol. Pap.* No 168.
- DOIDGE, E.M. & BOTTOMLEY A.M. 1931. A revised list of plant diseases in South Africa. *Mem. Bot. Survey South Africa.* 1:1-78
- DOLAN, T.E & COFFEY, M.D. 1986. Laboratory screening technique for assessing resistance of four avocado rootstocks to *Phytophthora cinnamomi*. *Plant Disease* 70:115-118.
- DU PLOOY, C.P. 1991. Visit to the University of California - Riverside in connection with avocado breeding and selection (24 November 1990 to 24 march 1991). Travel report – CSFRI (now ARC-ITSC).
- DUNCAN, J.M. & COWAN, J.B. 1980. Effect of temperature and soil moisture content on persistence of infectivity of *Phytophthora fragariae* in naturally infested soil. *Trans. Br. Mycol. Soc.* 75:133-139.
- DUNIWAY, J.M. 1983. Role of physical factors in the development of *Phytophthora* diseases. pp. 175-187. In: D.C. ERWIN, S. BARTNICKI-GARCIA and P.H. TSAO. (eds.). *Phytophthora: Its Biology, Taxonomy, Ecology, and Pathology*. American Phytopathological Society, St. Paul, MN.
- DUVENHAGE, J.A., & MAAS, E.M.C. 1990. The occurrence of soils suppressive to *Phytophthora cinnamomi*. *S. Afr. Avocado Growers' Assoc. Yearb.* 13:55.
- DUVENHAGE, J.A., KOTZÉ, J.M. & MAAS, E.M.C. 1992. The influence of nitrogen and calcium on mycelial growth and disease severity of *Phytophthora cinnamomi* and the effect of calcium on resistance of avocado root rot. *S. Afr. Avocado Growers' Assoc. Yearb.* 15:12-14.
- ELLSTRAND, N.C., LEE, J.M., BERGH, B.O., COFFEY, M.D. & ZENTMYER, G.A. 1986. Isozymes confirm hybrid parentage of 'G755' selections. *Calif. Avocado Soc. Yearb.* 70:199-203.
- ERNST, A.A. 1978. New promising technique for rooting difficult-to-root avocado (*Persea americana* Mill.) cuttings. *Citrus Subtrop. Fr.J.* 532:6-10
- ERWIN, D.C. & RIBEIRO, O.K.1996. *Phytophthora* diseases worldwide. The American Phytopathological Society, St. Paul, MN.
- ESAU, K. 1977. Anatomy of seed plants. John Wiley & Sons, Inc. New York.
- FALCONER, D.S. 1989. Introduction to quantitative genetics. 3 rd ed. Longman Scientific & Technical, Essex.
- FLOR, H.H. 1956. The complementary genic systems in flax and flax rusts. *Adv. Genet.* 8: 29-54.



- FROLICH, E.F. & PLATT, R.G. 1972. Use of etiolation technique in rooting avocado cuttings. *Calif. Avocado Soc. Yearb.* **55**: 97-109.
- FROLICH, E.F., SCHROEDER, C.A. & ZENTMYER, G.A. 1958. Graft compatibility in the genus *Persea*. *Calif. Avocado Soc. Yearb* **42**:102-105.
- GABOR, B.K. & COFFEY, M.D. 1990. Quantitative analysis of the resistance to *Phytophthora cinnamomi* in five avocado rootstocks under greenhouse conditions. *Plant Disease* **74**:882-885.
- GABOR, B.K., GUILLEMET, F.B. & COFFEY, M.D. 1990. Comparison of field resistance to *Phytophthora cinnamomi* in twelve avocado rootstocks. *HortScience* **25**:1655-1656.
- GARBERS, C.F. 1987. Opening address. First World Avocado Congress (Pretoria 1987). *S. Afr. Avocado Growers' Assoc. Yearb.* **10**:5-8.
- GARDENER, F.E. 1969. A study of rootstock influence on citrus fruit quality by fruit grafting. *Proc. Int. Citrus Symposium* **1**:259-364.
- GERRETSON-CORNELL, L. 1974. A comparative test of isolation of *Phytophthora cinnamomi* Rands between the lupin baiting and a newly devised apple trap. *Phyton* **32**:35-36.
- GISI, U. 1983. Biophysical aspects of the development of *Phytophthora*. pp. 109-119. In: D.C. ERWIN, S. BARTNICKI-GARCIA and P.H. TSAO. (eds.). *Phytophthora: Its Biology, Taxonomy, Ecology, and Pathology*. American Phytopathological Society, St. Paul, MN.
- GISI, U., ZENTMYER, G.A. & KLURE, L.J. 1980. Production of sporangia by *Phytophthora cinnamomi* and *Phytophthora palmivora* in soils at different matric potentials. *Phytopathology* **70**:301 – 306.
- GOODWIN, S.B. 1997. The population genetics of *Phytophthora*. *Phytopathology* **87**:462-473.
- GREENHALGH, F.C. 1978. Evaluation techniques for quantitative detection of *Phytophthora cinnamomi*. *Soil Biol. Biohem.* **10**: 257-259.
- GRIFFITH, J.M., DAVIS, A.J., & GRANT, B.R. 1992. Target sites of fungicides to control Oomycetes. pp. 69-100. In: W. KÖLLER, (ed.). *Target Sites of Fungicide Action*. CRC Press, Boca Raton, Fla.
- GRIMM, G.R. & ALEXANDER, A.F. 1973. Citrus leaf pieces as traps for *Phytophthora parasitica* from soil slurries. *Phytopathology* **63**:540-541.
- HALMA, F.F. 1954. Avocado rootstock experiment – 10 year report. *Calif. Avocado Soc. Yearb.* **38**:79-86.
- HANDRECK, K.A. & BLACK, N.D. 1984. *Growing media for ornamental plants and turf*. New South Wales University Press, Kensington, NSW.



- HARDHAM, A.R. 1995. Polarity of vesicle distribution in oomycete zoospores – Development of polarity and importance for infection. *Can. J. Bot.* **73**:400-407.
- HEMMES, D.E. 1983. Cytology of *Phytophthora*. pp. 9-40. In: D.C. ERWIN, S. BARTNICKI-GARCIA and P.H. TSAO. (eds.). *Phytophthora: Its Biology, Taxonomy, Ecology, and Pathology*. American Phytopathological Society, St. Paul, MN.
- HO, H.H. & ZENTMYER, G.A. 1977. Infection of avocado and other species of *Persea* by *Phytophthora cinnamomi*. *Phytopathology* **67**:1085-1089.
- HO, H.H., ANN, P.J. & CHANG, H.S. 1995. The genus *Phytophthora* in Taiwan. *Ints. Bot. Academia Sinica Monograph Series no. 15.* (ICCN 0258-5170). Taipei, Taiwan.
- JEFFERS, S.N. & MARTIN, S.B. 1986. Comparison of two media selective for *Phytophthora* and *Pythium* species. *Plant Dis.* **70**: 1038-1043.
- KADMAN, A. 1977. Effect of the age of juvenile stage avocado seedlings on the rooting capacity of their cuttings. *Calif. Avocado Soc. Yearb.* **58**: 58-60.
- KADMAN, A & BEN-YA'ACOV, A. 1976. Selections of avocado rootstocks for saline conditions. *Acta Hort.* **57**:189-197.
- KANNWISCHER, M.E., & MITCHELL, D.J. 1978. The influence of a fungicide on the epidemiology of black shank of tobacco. *Phytopathology* **68**: 1760-1765.
- KELHAM, M.K. & COFFEY, M.D. 1985. Quantitative comparison of the resistance to *Phytophthora* root rot in three avocado rootstocks. *Phytopathology* **75**: 230-234.
- KHEW, K.L. & ZENTMYER, G.A. 1973. Chemotaxic response of zoospores of five species of *Phytophthora*. *Phytopathology* **63**:1511-1517.
- KHEW, K.L. & ZENTMYER, G.A. 1974. Electrophoretic response of zoospores of seven species of *Phytophthora*. *Phytopathology* **64**:500-507.
- KLEMMER, H.W. & NAKANO, R.Y. 1962. Techniques in isolation of pythiaceous fungi from soil and diseased pineapple tissue. *Phytopathology* **52**:955-956.
- KLOTZ, L.J. & DEWOLFE, T.A. 1960. The production and the use of zoospore suspension of *Phytophthora* spp. for investigations on disease of citrus. *Plant Dis. Rept.* **44**:572-573.
- KLOTZ, L.J., WONG, P.P. & DE WOLFE, T.A. 1959. Survey of irrigation water for the presence of *Phytophthora* spp. pathogenic to citrus. *Plant Dis. Rept.* **43**:830-832.
- KOEKEMOER, P.J.J., BREEDT, H.J., MANICOM, B.Q. & BIJZET, Zeld. 1994. Selection of *Phytophthora* tolerant avocado rootstocks. *S. Afr. Avocado Growers' Assoc. Yearb.* **17**:72-74.
- KÖHNE, J.S. 1992. Field evaluations of Hass avocado grown on Duke 7, G6 and G755C rootstocks. *Proc. 2nd World Avocado Congr. Riverside, CA*, 1:301-303.
- KOPP, L.E. 1966. A taxonomic revision of the genus *Persea* in the Western Hemisphere. (*Persea*- Lauraceae). *Mem. New York Bot. Garden* **14**:1-117.



- KOTZÉ, J.M. 1985. Strategy for combating avocado root rot. *S. Afr. Avocado Growers' Assoc. Yearb.* **8**:13-14.
- KOTZÉ, J.M. 1986. Research in perspective. *S. Afr. Avocado Growers' Assoc. Yearb.* **9**:5-6
- KOTZÉ, J.M. 1987. What rootstocks should I use? *Avokad* **7**:10-11.
- KREZDORN, 1973. Influence of rootstock on cold hardiness of avocado. *Proc. Fla State Hort. Soc.* **86**:346-348
- LA FORGE, F.B. 1917. D-mannoketoheptose – A new sugar from avocado. *J. Biol. Chem.* **28**:511-522.
- LINDE, C. 1998. Population structure of *Phytophthora cinnamomi* in South Africa. PhD thesis. University of Orange Free State. South Africa
- LINDE, C., DRENTH, A., KEMP, G.H., WINGFIELD, M.J. & VON BROEMSEN, S. 1997. Population structure of *Phytophthora cinnamomi* in South Africa. *Phytopathology* **87**:822-827.
- LINDERMAN, R.G. & ZEITOUN, F. 1977. *Phytophthora cinnamomi* causing root rot and wilt of nursery-grown native western azalea and salal. *Plant Dis. Rept.* **61**: 1045-1048.
- MANNING, W.J. & CROSSAN, D.F. 1966a. Effects of a particular soil bacterium on sporangial production in *Phytophthora cinnamomi* in liquid culture. *Phytopathology* **56**:235-237.
- MANNING, W.J. & CROSSAN, D.F. 1966b. Variation in degree of pathogenicity of isolates of *Phytophthora cinnamomi* to cultivars of *Taxus*. *Plant Dis. Rept.* **50**:84-87.
- MARKS, G.C. & KASSABY, F.Y. 1974. Detection of *Phytophthora cinnamomi* in soils. *Aust. For.* **36**:198-203.
- MASON, J. 1990. Commercial hydroponics. Kangaroo Press. New South Wales.
- MCINTOSH, D.L. 1966. The occurrence of *Phytophthora* spp. in irrigation systems in British Columbia. *Can. J. Bot.* **44**:1591-1596.
- MCKAY, R. 1957. The longevity of the oospores of onion downy mildew *Peronospora destructor* (Berk.) Casp. *Sci. Proc. Royal Dublin Soc. New series* **27**:295-307.
- MENGE, J.A., GUILLEMTE, F., CAMPBELL, S. JOHNSON, E. & POND, E. 1992. The performance of rootstocks tolerant to root rot caused by *Phytophthora cinnamomi* under field conditions in southern Californian *Proc. 2nd World Avocado Congr. Riverside, CA,* **1**:53-59.
- MITCHELL, D.J. & KANNWISCHER-MITCHELL, M.E. 1992. *Phytophthora* pp. 31-38. In: L.L. SINGELTON, J.D. MIHAIL and C.M. RUSH. (eds.). Methods for research on Soilborne Phytopathogenic Fungi. The American Phytopathological Society, St Paul, MN.

- MOLL, J.N. & WOOD, R. 1980. An efficient method for producing rooted avocado cuttings. *Subtropica* **1**:9-12.
- MONTEVERDE, E.E., REYES, F.J., LABOREM, G. & RUIZ, J.R. 1988. Citrus rootstocks in Venezuela: Behaviour of "Valencia" orange on ten rootstocks. *Proc. VIth Int. Citrus Congr.* **1**:47-55.
- MULLICK, D.B. 1975. A new tissue essential to necrophylactic periderm formation in the bark of four conifers. *Can. J. Bot.* **53**:2443-2457.
- NEWHOOK, F.J., WATERHOUSE, G.M. & STAMPS, D.J. 1978. Tabular key to the species of *Phytophthora* de Bary. *Mycol. Pap.* **143**: 1-20
- OLD, K.M., DUDZINSKY, M.J. & BELL, J.K. 1988. Isozyme variability in field populations of *Phytophthora cinnamomi* in Austria. *Aust. J. Bot.* **36**:355-360.
- OLD, K.M., MORAN, G.F. & BELL, J.S. 1984. Isozyme variability among isolates of *Phytophthora cinnamomi* from Australia and Papua, New Guinea. *Can. J. Bot.* **62**:2016-2022.
- PEGG, K.G. 1977. Soil application of elemental sulphur as a control of *Phytophthora cinnamomi* root and heart rot of pineapple. *Aust. J. Exp. Agric. Anim. Husb.* **17**:859-865.
- PHILLIPS, D., GRANT, B.R. & WESTE, G. 1987. Histological changes in the roots of an avocado cultivar, Duke 7, infected with *Phytophthora cinnamomi*. *Phytopathology* **77**:691-698.
- PITTIS, J.E. & COLHOUN, J. 1984. Isolation and identification of pythiaceous fungi from irrigation water and their pathogenicity to antirrhinum, tomato and *Chameacyparis lawsoniana*. *Phytopathol. Z.* **110**: 301-318.
- PLOETZ, R.C. & SCHAFFER, B. 1987. Effects of flooding and *Phytophthora* root rot on photosynthetic characteristics of avocado. *Proc. Fla State Hort. Soc.* **100**:290-294.
- PLOETZ, R.C. & SCHAFFER, B. 1989. Effects of flooding and *Phytophthora* root rot on net gas exchange and growth of avocado. *Phytopathology* **79**:204-208.
- PLOETZ, R.C. & SCHAFFER, B. 1992. Effects of flooding and *Phytophthora* root rot on net gas exchange and growth of avocado in Dade County, Florida. *Proc. 2nd World Avocado Congr. Riverside, CA*, **1**:111-117
- PODGER, F.D., DOEPEL, R.F. & ZENTMYER, G.A. 1965. Association of *Phytophthora cinnamomi* with a disease of *Eucalyptus marginata* forest in Western Australia. *Plant Dis. Rept.* **49**:943-947.
- POEHLMAN, J.M. 1987. Breeding field crops. 3 rd ed. AVI Publishing Company, Inc. Westport, Connecticut.
- POPENOE, W. 1927. Manual of Tropical and Sub-Tropical Fruits. The Macmillan Co., New York.



- RANDS, R.D. 1922. Streeptkanker von kaneel, veroorzaakt door *Phytophthora cinnamomi* n. sp. *Meded. Inst. Plantenziekten* **54**:1-41.
- RECUPERCO, R.G., STARRANTINO, A., MERTELLI, S. & SELLETI, A. 1992. Performance of 'Navelina' ISA315 on 15 rootstocks in 'Metaponto' area. *Proc. Int. Soc. Citric.* **1**:259-261.
- REUTHER, W. 1961. Review of avocado research in California, Riverside. *Calif. Avocado Soc. Yearb.* **45**:45-52.
- RIBEIRO, O.K. 1978. A source book of the genus *Phytophthora*. J. Cramer. Lehre.
- ROBBERTSE, P.J. 2001. Botanical aspects. pp. 13-18. In: E.A. DE VILLIERS (ed.). The cultivation of avocado. ARC-Institute for Tropical and Subtropical Crops. Nelspruit.
- ROBBERTSON, N.F. 1975. A paper disc technique for the recovery of *Pythium* spp. from soil water. *N.Z. J. Agric. Res.* **18**:409-410.
- ROBINSON, R.A. 1969. Disease resistance terminology. *Rev. Appl. Mycol.* **48**:593-606.
- ROE, D.J. & MORUDU, T.M. 1999. Performance of new avocado rootstocks at Westfalia Estate. *S. Afr. Avocado Growers' Assoc. Yearb.* **22**:34.
- ROTH, L.F. & KUHLMAN, E.G. 1963. Field tests of the capacity of *Phytophthora* root rot to damage Douglas fir. *J. For.* **61**:199-205.
- SCHAFFER, B., ANDERSEN, P.C. & PLOETZ, R.C. 1991. Responses of fruit trees to flooding. *Hort. Rev.* **13**: 257-313.
- SCHONBECK, F. & SCHLOSSER, E. 1976. Preformed substances as potential protectants. *Physiological Plant Pathology.* **12**:653-678.
- SHANER, G., STROMBERG, E.L., LACY, G.H., BARKER, K.R. & PIRONE, T.P. 1992. Nomenclature and concepts of pathogenicity and virulence. *Ann. Rev. of Phytopath.* **30**:47-66.
- SHAW, D.S. 1988. The *Phytophthora* species. pp. 27-51. In: G.S. SIDHU (eds.). Advances in Plant Pathology. Vol. 6: Genetics of Plant Pathogenic Fungi. Academic Press, London.
- SHEPHERD, C.J. & FORRESTER, R.I. 1977. Influence of isolation method on growth rate of populations of *Phytophthora cinnamomi*. *Aust. J. Bot.* **25**:477-482.
- SIPPEL, A.D., BIJZET, ZELDA, SNIJDER, B. & DU PLOOY, C.P. 1994. The current status of avocado phase II evaluations at the ITSC. *S. Afr. Avocado Growers' Assoc. Yearb.* **17**:67-69.
- SMITH, D.G. 1993. Horticultural performance of imported cultivars and rootstocks in northern Transvaal. *S. Afr. Avocado Growers' Assoc. Yearb.* **16**:28-30.
- STERNE, R.E., ZENTMYER, G.A. & KAUFMAN, M.R. 1977. The effect of matric potential, soil texture and soil amendment on root disease caused by *Phytophthora cinnamomi*. *Phytopathology* **67**:1495-1500.



- STERNE, R.E., ZENTMYER, G.A. & KAUFMAN, M.R. 1978. Effect of *Phytophthora* root rot on water relations of avocado: Interpretation with a water transport model. *Phytopathology* **68**:595-602.
- STOREY, W.B., BERGH, B.O. & ZENTMYER, G.A. 1986. The origin, indigenous range, and dissemination of the avocado. *Calif. Avocado Soc. Yearb.* **70**:127-133.
- THOMPSON, S.V. & ALLEN, R.M. 1974. Occurrence of *Phytophthora* species and other potential plant pathogens in recycled irrigation water. *Plant Dis. Rept.* **58**:945-949.
- TIPPET, J.T., CROMBIE, D.S. & HILL, T.C. 1987. Effect of phloem water relations on the growth of *Phytophthora cinnamomi* in *Eucalyptus marginata*. *Phytopathology* **77**:246-250.
- TIPPET, J.T., HILL, T.C. & SHEARER, B.L. 1985. Resistance of *Eucalyptus* spp. to invasion by *Phytophthora cinnamomi*. *Aust. J. Bot.* **33**:409-418.
- TORGESON, D.C. 1954. Root rot of Lawson cypress and other ornamentals caused by *Phytophthora cinnamomi*. *Contrib. Boyce Thompson Inst.* **17**:359-373.
- TOXOPEUS, H.J. 1956. Reflections on the origin of new physiologic races in *Phytophthora infestans* and the breeding for resistance in potatoes. *Euphytica* **5**:221-237.
- TSAO, P.H. 1983. Factors affecting isolation and quantitation of *Phytophthora* from soil. pp. 219-236. In: D.C. ERWIN, S. BARTNICKI-GARCIA and P.H. TSAO. (eds.). *Phytophthora: Its Biology, Taxonomy, Ecology, and Pathology*. American Phytopathological Society, St. Paul, MN.
- TSAO, P.H. & GARBER, M.J. 1960. Methods of soil infestation watering and assessing the degree of root infection for greenhouse *in situ* ecological studies with citrus phytophthoras. *Plant Dis. Rept.* **44**:710-715.
- TSAO, P.H. & GUY, S.O. 1977. Inhibition of *Mortierella* and *Pythium* in a *Phytophthora*-isolation medium containing hymexazol. *Phytopathology* **67**:796-801.
- TSAO, P.H. & OCANA, G. 1969. Selective isolation of species of *Phytophthora* from natural soils on an improved antibiotic medium. *Nature* (London) **223**:636-638.
- TUCKER, C.M. 1927. *Sabal causiarum* (Cook) Beccari: A new host of the coconut bud-rot fungus. *J. Agric. Res.* **34**:879-888.
- VAN DER MERWE, M. 1995. Application of the detached root technique to studies on avocado root rot. MSc (Agric) Thesis, University of Pretoria. South Africa.
- VAN DER PLANK, J.E. 1963. *Plant Diseases: Epidemics and Control*. Academic Press, New York.
- VAN VUUREN, S.P. 1997. Influence of four disease inducing factors on container-grown citrus. pp. 209-215. In: E. RABE (ed.). *Proceedings of the IV world Congress of the International Society of Citrus Nurserymen*.



- VON BROEMBSSEN, S. L. 1984a. Occurrence of *Phytophthora cinnamomi* on indigenous and exotic hosts in South Africa, with special reference to the South-Western Cape Province. *Phytophylactica* **16**:221-225.
- VON BROEMBSSEN, S.L. 1984b. Distribution of *Phytophthora cinnamomi* in rivers of the South-Western Cape Province. *Phytophylactica* **16**:227-229.
- VON BROEMSEN, S.L. & KRUGER, F.J. 1985. *Phytophthora cinnamomi* associated with mortality of native vegetation in South Africa. *Plant Disease* **69**:715-717.
- WAGER, V.A. 1931. Diseases of plants in South Africa due to members of the Pythiaceae. *S. Afr. Dep. Agric. Sci. Bull.* **105**:1-60.
- WATERHOUSE, G.M. 1963. Key to the species of *Phytophthora* de Bary. *Mycological Papers* **92**:1-22.
- WESTE, G. 1975. Pathogenicity of *Phytophthora cinnamomi* towards *Nothofagus cunninghamii*. *Aust. J. Bot.* **23**:277-283.
- WESTE, G. & VITHANAGE, K. 1979. Survival of chlamydospores of *Phytophthora cinnamomi* in several non-sterile, host-free forest soils and gravels at different soil water potentials. *Aust. J. Bot.* **27**:1-9.
- WHITE, R.P. 1937. Rhododendron wilt and root rot. *N.J. Agric. Exp. Stn. Bull.* **615**:1-32.
- WILKINSON, H.T., MILLER, R.D. & MILLER, MILLAR, R.L. 1981. Infiltration of fungal and bacterial propagules into soil. *Soil. Sci. Soc. Am.J.* **45**:1034-1039.
- WOLSTENHOLME, B.N. 1987. Some aspects of avocado research world-wide. *S. Afr. Avocado Growers' Assoc. Yearb.* **10**:8-10.
- WOLSTENHOLME, B.N. 2001. Climatic and soil requirements. pp. 19-44. In: E.A. DE VILLIERS (ed.). The cultivation of avocado. ARC-Institute for Tropical and Subtropical Crops. Nelspruit.
- YOUNG, P.J. 1992. Inherent influence of rootstock race on avocado fruit maturity. *Proc. 2nd World Avocado Congr. Riverside, CA* **1**:149-154.
- ZAKI, A.I, ZENTMYER, G.A., PETTUS, J., SIMS, J.J., KEEN, N.T. & SING, V.O. 1980. Borbonol from *Persea* spp. – chemical properties and antifungal activity against *Phytophthora cinnamomi*. *Physiological Plant Pathology* **16**:205-212.
- ZENTMYER, G. A. 1952. Collecting avocados in Central America for disease resistance. *Calif. Avocado Soc. Yearb.* **36**:107-111.
- ZENTMYER, G.A. 1961. Chemotaxis of zoospores for root exudates. *Science* **133**:1595-1596.
- ZENTMYER, G.A. 1978. Origin of root rot resistant rootstocks. *Calif Avocado Soc. Yearb.* **62**:78-89.
- ZENTMYER, G.A. 1979. Report of *Phytophthora* root rot of avocado in South Africa. *S. Afr. Avocado Growers' Assoc. Yearb.* **3**:7-9.



- ZENTMYER, G.A. 1980. *Phytophthora cinnamomi* and the disease it causes. *American Phytopathology Society. Monograph No. 10*:1-96. St Paul, MN.
- ZENTMYER, G.A. 1982. Testing for resistance of avocado to *Phytophthora* in nutrient solution. *Avocado Grower* **6**:32-35.
- ZENTMYER, G.A. 1983. The world of *Phytophthora*. pp. 1-8 In: D.C. ERWIN, S. BARTNICKI-GARCIA and P.H. TSAO. (eds.). *Phytophthora: Its Biology, Taxonomy, Ecology, and Pathology*. American Phytopathological Society, St. Paul, MN.
- ZENTMYER, G.A. 1985. Origin and distribution of *Phytophthora cinnamomi*. *Calif. Avocado Soc. Yearb.* **69**:89-94.
- ZENTMYER, G.A. & GUILLEMET, F.B. 1981. Evidence for strains of *Phytophthora cinnamomi*. *Plant Disease* **65**:475-477.
- ZENTMYER, G.A. & MIRCHETICH, S.M. 1960. Results with new method of testing for resistance to *Phytophthora* root rot of avocado. *Calif. Avocado Soc. Yearb.* **44**:107-109.
- ZENTMYER, G.A. & MIRCETICH, S.M. 1965. Testing for resistance of avocado to *Phytophthora* in nutrient solution. *Phytopathology* **55**:487-489.
- ZENTMYER, G.A. & MIRCETICH, S.M. 1966. Saprohytism and persistence in soil by *Phytophthora cinnamomi*. *Phytopathology* **56**:710-712.
- ZENTMYER, G.A. & OHR, H.D. 1978. Avocado root rot. *Univ Calif. Div. Agric. Sci., Berkeley. Leaflet.* **2440**:1-15.
- ZENTMYER, G.A. & RICHARDS. S.J. 1952. Pathogenicity of *Phytophthora cinnamomi* to avocado trees, and the effect of irrigation on disease development. *Phytopathology* **42**:35-37.
- ZENTMYER, G.A. & SCHIEBER, E. 1982. Clonal rootstocks: personal observations and a peek into the future. *Calif. Avocado Soc. Yearb.* **66**:81-92.
- ZENTMYER, G.A. & SCHROEDER, C.A. 1958. Resistance of species of *Persea* to *Phytophthora* root rot. *Calif. Avocado Soc. Yearb.* **42**:106-107.
- ZENTMYER, G.A. & THORN, W.A. 1956. Resistance of the Duke variety of avocado to *Phytophthora* root rot. *Calif. Avocado Soc. Yearb.* **40**:71-75.
- ZENTMYER, G.A. GILPATRICK, J.D. & THORN, W.A. 1960. Methods of isolating *Phytophthora cinnamomi* from soil and from host tissue. (Abstr.) *Phytopathology* **50**:87.
- ZENTMYER, G.A., PAULUS, A.O. & BURNS, R.M. 1967. Avocado root rot. Calif. Agric. Exp. Stn. Ext. Serv. Circ. 511. Revised 16 pp.
- ZENTMYER, G.A., SCHIEBER, E. & GUILLEMET, F.B. 1988. The origin of the G6 Rootstock. *Calif. Avocado Soc. Yearb.* **72**:243-248.
- ZENTMYER, G.A., THORN, W.A. & BURNS, R.M. 1963. The Duke avocado. *Calif. Avocado Soc. Yearb.* **45**:106-107.



- ZENTMYER, G.A. GUILLEMET, F.B. GOODALL, G., GUSTAFSON, C.D. & LEE, B.W. 1976. Avocado rootstocks resistant to *Phytophthora cinnamomi*. *Calif. Avocado Soc. Yearb.* **60**:165-167.
- ZENTMYER, G.A., JEFFERSON, L., HICKMAN, C.J. & YUNG, C.H. 1974. Studies of *Phytophthora citricola* from *Persea americana*. *Mycologia* **66**:830-845.
- ZILBERSTEIN, M. & PINKAS, Y. 1987. Detached root inoculation – a new method to evaluate resistance to *Phytophthora* root rot in avocado trees. *Phytopathology* **77**: 841-844.



SUMMARY



SUMMARY

Screening of avocado rootstock material for tolerance to *Phytophthora cinnamomi*

by

Zelda Bijzet

Supervisor: Prof Dr PJ Robbertse

Co-supervisor: Prof Dr F C Wehner

Department of Plant Production and Soil Science

Magister Scientiae Agriculturae

During the initiation and execution of a rootstock breeding programme to overcome the financially crippling disease, *Phytophthora* root rot of avocado, various constraints have been identified for both the breeding as well as the screening aspect of the programme. A review of the literature revealed a complex host-pathogen interaction that should be taken into account in the recombination and screening of genetic material.

With the detection of beneficial genotypes being the crux of a breeding programme, this dissertation was focused on the screening of rootstock material for tolerance to *Phytophthora cinnamomi*. Screening should be scientific but at the same time also be time and cost effective. Specific attention was given to (i) the correct medium for screening mass numbers of seedlings, (ii) fast and effective cloning of single selections, and (iii) evaluation of clonal material for tolerance to *P. cinnamomi*.

Soil as a screening medium was compared with three inert hydroponic media as well as one aeroponic system. Only soil was found to be ineffective due to its properties. The other media tested, namely, sand, vermiculite, water and the aeroponic system were equal in performance. The medium to be used will depend on the preference of the breeder as each medium has its own pro's



and con's. It was, however, found that the evaluation criterion to be applied depends on the medium that is used.

With regard to cloning of single selections, a definite difference with regard to the cloning ability of the different selections was found. An inability to be etiolated was displayed by some of the selections and these could thus not be vegetatively propagated and were not further tested.

One of the tolerance mechanisms in the standard cultivar Duke 7, is root regeneration. It was thus expected that this characteristic cloning would give an indication of the rootstock's ability to tolerate *P. cinnamomi*. This could not be confirmed, but most of the selections did, however, perform better than Duke 7.

Comparison of feeder root percentage in non-inoculated and inoculated treatments was not sufficient for facilitating the final selection of candidate rootstocks from a large number of potential clonal selections. Four selections were made, based on the hypothesis that a larger root system will be a better forager and thus enhance the horticultural aspects of the rootstock-scion combination.

Valuable information was obtained with regard to various mediums and criteria to be used during mass screening and final screening of clonal selections. This knowledge must be taken into account in the planning of future breeding projects. During this project a total of 38 984 seedlings were screened and four selections were made. For both the nursery and the producer, knowledge of the clonal ability of a potential new rootstock is important from a financial point of view.



Samevatting

Onderzoek van avokado onderstam materiaal vir verdraagsaamheid teenoor *Phytophthora cinnamomi* .

deur

Zelda Bijzet

Leier: Prof Dr PJ Robbertse

Mede-leier: Prof Dr F C Wehner

Departement Plantproduksie en Grondkunde

Magister Scientiae Agriculturae

Tydens die implementering van 'n onderstamteelprogram met die oog op die teëwerking van die finansiële impak wat *Phytophthora* wortelvrot of die avokado bedryf is verskillende tekortkominge aangedui. Struikelblokke in die kruisingsprogram sowel as in die sifting van die nageslag is geïdentifiseer. Literatuur het aangedui dat rekombinasie en seleksie van genetiese materiaal onderhewig is aan komplekse gasheer-patogeen interaksies.

Die mees kritieke aspek van 'n teelprogram is die identifisering van voordelige nuwe genotipes en daarom is gefokus op die seleksie van onderstammateriaal. Alhoewel finansiële beperkinge bepaal dat sifting van potensiële nuwe onderstamme so koste- en tydseffektief as moontlik gedoen moet word, moet dit steeds wetenskaplik uitgevoer word. Aandag is veral aan die volgende aspekte gegee: (i) identifisering van geskikte media vir massasifting, (ii) evaluering van *Phytophthora cinnamomi* verdraagsaamheid van vegetatiewe onderstammateriaal, en (iii) klonering van enkel seleksies.

Vir 'n geskikte siftingsmedium is grond vergelyk met drie inerte hirdoponiese mediums, naamlik sand, vermikuliet en water, asook met 'n aeroponiese sisteem. Slegs grond is as ongeskik gevind as gevolg van sekere fisiese eienskappe. Die ander media wat getoets is, naamlik sand, vermikuliet, water

en die aeroponiese sisteem blyk almal ewe bruikbaar te wees. Die medium wat gebruik gaan word hang grootliks af van die navorser se voorkeur en begroting aangesien elkeen sy eie voor- en nadele inhou. Verskillende evalueringskriteria is egter vir elke medium geïdentifiseer.

Definitiewe verskille ten opsigte van die vinnige en effektiewe vermeerdering van enkel seleksies is gevind, selfs vir die met 'n gemeenskaplike ouer. Van die seleksies het swak gereageer op etiolering en kon dus nie verder vermeerder of getoets word nie.

Wortelregenerasie is by Duke 7 een van die oorlewingsmeganismes teen *P. cinnamomi*. Daar is dus verwag dat hierdie kenmerk 'n aanduiding sou kon gee van 'n seleksies se verdraagsaamheid teenoor *P. cinnamomi* te wees. Die hipotese kon egter nie vanuit die data bevestig word nie.

Die verskil tussen persentasie voedingswortels van geïnfekteerde en nie-geïnfekteerde plante was nie voldoende om die finale selektering van potensiële onderstamme vanuit 'n groep klonaal vermeerderde onderstamme te bewerkstellig nie. Behalwe in drie van die seleksies kon geen statistiese verantwoordbare verlies aan voedingswortels gevind word nie en het meeste van die seleksies soos Duke 7 vertoon. Vier seleksies is gemaak op grond van die hipotese dat onderstamme met 'n groter wortelmasse beter voeders is en dus tuinboukundige eienskappe van die onderstam–bostam kombinasie verbeter.

Waardevolle inligting is ingesamel ten opsigte van die onderskeie media en die metingskriteria wat gebruik kan word vir die sifting van groot aantalle saailinge en die finale sifting van klonale seleksies. Die kennis moet gebruik word in die beplanning van toekomstige onderstamteelprogramme. Tydens hierdie projek is 38 984 saailinge getoets en vier seleksies gemaak. Vanuit 'n finansiële oogpunt is die vinnige en ekonomiese vermeerdering van dié potensiële onderstamme 'n belangrike aspek.