CHAPTER 5

GENERAL DISCUSSION

The study presented in this report constitutes the first extensive survey of *Pythium* species associated with hydroponically-grown crops in South Africa. Thompson & Labuschagne (2001) previously referred to the presence of four *Pythium* species and two heterothallic groups on seven crop species in South African hydroponica, whereas Botha & Coetzer (1996) reported the isolation of eight species and two groups from six vegetable species, some of which were cultivated hydroponically. The present study included seven vegetable crops in the first survey and an additional 12 crop species in the second survey, which together yielded eight *Pythium* species and all five the existing heterothallic groups. This represents 35% of all the *Pythium* species/groups thus far reported in South Africa (Crous *et al.*, 2000; Thompson & Labuschagne, 2000/2001), and expands the list of entries by 22%. Only two of the species reported from hydroponica by Thompson & Labuschagne (2001), viz. *Pythium dissotocum* Drechsler and *Pythium aristosporum* Vanterpool, could not be isolated. The absence of *P. dissotocum* in the present study remains unclear as it is known to be associated with hydroponically grown lettuce (Stanghellini & Kronland, 1986). However, the identification by Thompson & Labuschagne (2001) of *P. aristosporum* from a hydroponic system growing non-graminaceous crops is queried as this species has only been isolated from members of the Poaceae, also in South Africa (Van der Plaats-Niterink, 1981; Meyer & van Dyk, 2002). *Pythium sylvaticum* W.A. Campb. & J.W. Hendrix, the only *Pythium* species previously reported from lettuce in South Africa, was also not found. Although *P. sylvaticum* appears to be common in aquatic environments (Van der Plaats-Niterink, 1975; Shokes & McCarter, 1976), no reference to its occurrence in a hydroponic system could be traced.

Some of the *Pythium* species/groups seemed to prefer specific types of hydroponic systems. For instance, *Pythium coloratum* Vaartaja and *Pythium* group F occurred mostly in recirculating gravel systems, whereas *Pythium aphanidermatum* (Edson) Fitz. and *Pythium spinosum* Sawada were isolated only from ebb-and-flow and open dripper systems. However, none of the hydroponica surveyed were free of *Pythium* and most contained a *Pythium* population that was neither host-specific nor temperature-restricted, and hence capable of causing losses to diverse crops throughout the year. Mention should be made here of *P.* group F, which was the dominant species/group, in recirculating gravel systems at least. Although *P.* group F reduced the growth of various crops significantly, it did not kill the plants, and can thus be classified as a successful pathogen. This pathogenic competence undoubtedly contributed to the predominance of *P.* group F and should render it difficult to control.

From the above it is clear that management of pythiasis in a hydroponicum would depend on total and persistent suppression of the entire *Pythium* population. Results obtained in Chapter 4 indicated that a number of chemical disinfectants are capable of eradicating *Pythium* from infested gravel substrate. However, substrates are not the only source of pathogens as they can also be introduced through seed/seedlings, air, water and insects (Stanghellini & Rasmussen, 1994). To be successful, a disease management protocol should therefore include (a) use of pathogen-free seedlings reared in steam-pasteurised growth medium, (b) sterilisation of irrigation water by means of an effective treatment such as ozonation or chlorination, (iii) disinfestation of the substrate, and (iv) proper insect control. Regular monitoring of the irrigation water for the presence of *Pythium*, and other potentially pathogenic organisms, would be required to maintain quality control in such a system.

Fungicides have been excluded from the above strategy. As indicated in Chapter 4, no fungicides are registered for use in hydroponica in South Africa. Various compounds, particularly metalaxyl and fosetyl-Al (Morgan, 1999), have nevertheless been tested successfully for the control of *Pythium* in hydroponic systems. However, as most of them are active only against the *Oomycota* (besides *Pythium*, particularly *Phytophthora* and *Peronosporales* species), they would be of little value against other fungoid pathogens such as protozoa (e.g. *Spongospora subterranea* [Wallr.] Lagerh.) and fungi (mostly *Botrytis*, *Chalara*, *Colletotrichum*, *Fusarium*, *Microdochium*, *Olpidium*, *Rhizoctonia*, *Sclerotinia* and *Verticillium* species) known to infect crops in hydroponica, not to mention viruses (e.g. *cucumber green mottle mosaic*, *lettuce big vein*, *melon necrotic spot* and *tomato mosaic* viruses) and bacteria (e.g. *Clavibacter michiganense*, *Erwinia carotovora* and *Ralstonia solanacearum*) (Staunton & Cormican, 1978; Evans, 1979; Daughtrey & Schippers, 1980; Davies, 1980; Tomlinson & Faithfull, 1980; Jenkins & Averre, 1983; Vanachter *et al.*, 1983 Tomlinson & Thomas, 1986; Van Voorst *et al.*, 1987; Pategas *et al.*, 1989; Brammall & Lynch, 1990; Linde *et al.*, 1990;

Stanghellini *et al.*, 1990a, b; Stanghellini & Rasmussen, 1994; Morgan, 1999). Besides being ineffective against non-target organisms, persistent use of such fungicides can also lead to the development of iatrogenic diseases (Griffiths, 1981). Furthermore, it is commonly known that fungi rapidly develop resistance against selective systemic fungicides.

Another, and very important, reason for the exclusion of fungicides from a control strategy is the growing concern about their negative impact on consumers and the environment, and the global shift towards organic production. This concern is also applicable to other chemicals, including those that were evaluated in the present study, and will have to be addressed by the hydroponic industry. Although hydroponic systems, by nature of their reliance on synthetic fertilisers, are not amenable to organic farming, the intensive cropping practices inherent to hydroponic production render it eminently suited to alternative disease control. Alternative control strategies applicable to hydroponica obviously include resistant cultivars, which is the prerogative of the plant breeding/genetic engineering fraternity, and the use of introduced antagonists. In this regard it is interesting to take cognisance of the existence of a product named Polygandrum®, a formulation of *Pythium oligandrum* Drechsler marketed by Plant Production Institute, Slovakia, as seed or soil treatment for the control of *Pythium ultimum* Trow.

A novel approach to disease control worth mentioning here is the induction of systemic resistance to infection. This can be achieved by exposing plants to UV radiation (Runia, 1995), or to compounds such as salicylic acid (Schneider & Ulrich, 1994), oxalate (Doubrava *et al.*, 1988), phosphates (Gottstein & Kuc, 1989), unsaturated fatty acids (Cohen *et al.*, 1991), jasmonic acid (Cohen *et al.*, 1993), DL-3-amino-n-butanoic acid (Cohen, 1994), silicon (Chérif *et al.*, 1992) or chitosan (Walker-Simmons *et al.*, 1983). Besides inducing resistance in plants, chitosan is also known to initiate the formation of structural barriers in host tissue (El Ghaouth *et al.*, 1994) and to cause morphological and cytological alterations in the pathogen (Benhamou, 1992; El Ghaouth *et al.*, 1992). In addition to the above, antifungal compounds produced by plants have potential as natural fungicides, and some are known to induce systemic plant defence mechanisms, e.g. extracts from giant knotweed (*Reynoutria sacchalinensis* (Nakai) F. Schmidt (Daayf *et al.*, 1997), spinach (*Spinacea oleracea* L.) and rhubarb (*Rheum raponticum*

L.) (Doubrava *et al.*, 1988). Plants can also be "immunised" against disease by prior inoculation with the particular pathogen (Dalisay & Kuc, 1995), a different pathogen (Stroember & Brishammer, 1991), extracts of pathogenic organisms (Ricci *et al.*, 1989), or through the action of plant growth-promoting rhizobacteria (Wei *et al.*, 1991).

Lastly, the use of glucosinolate-containing brassicaceous crops seems to be an alternative disease control option tailor-made for hydroponic production. Rotation with brassicaceous crops and incorporation of brassica residues into soil or other growth media are known to suppress a variety of pests and disease organisms, including fungi, nematodes, insects, bacteria and weeds. The suppressive effect is due to the presence of ß-D-thioglucosidic compounds referred to as glucosinolates (GSLs) in the Brassicaceae and other families of the order Capparales (Brown & Morra, 1997). GSLs *per se* are not toxic but are hydrolysed in the presence of water to biologically active compounds such as organic cyanides, ionic cyanate, oxazolidinethiones and isothiocyanates (ITCs), by the enzyme myrosinase which occurs endogenously in brassica tissues. Of the various GSL hydrolysis products, ITCs are considered the most toxic. Indeed, methyl isothiocyanate, which proved to be highly effective as sterilant in Chapter 4, is a synthetic derivative of ITC. ITCs are general biocides that interact nonspecifically and irreversibly with proteins and amino acids (Fenwick *et al.*, 1983; Kawakishi *et al.*, 1983; Kawakishi & Kaneko, 1987). As ITCs are volatile, the utilisation of brassicaceous crops in the control of pests and diseases have been termed "biofumigation" (Kirkengaard *et al.*, 1993; Angus *et al.*, 1994). It certainly would be worthwhile to investigate biofumigation in hydroponic systems in South Africa, with brassicaceous plants as rotation crops.

REFERENCES

ANGUS, J.F., GARDNER, P.A. KIRKENGAARD, J.A. & DESMARCHELIER, J.M. 1994. Biofumigation: Isothiocyanates released from *Brassica* roots inhibit growth of the take-all fungus. Plant and Soil 162: 107-112.

BENHAMOU, N. 1992. Ultrastructural and cytochemical aspects of chitosan on *Fusarium oxysporum* f. sp. *radicis-lycopersici*, agent of tomato crown and root rot. Phytopathology 82: 1185-1193.

BOTHA, W.J. & COETZER, R.L.J. 1996. Species of *Pythium* associated with root-rot of vegetables in South Africa. South African Journal of Botany 62: 196-203.

BRAMMALL, R. & LYNCH, K. 1990. Occurrence of *Fusarium* crown and root rot of tomato in New Brunswick, Canada. Plant Disease 74: 1037.

BROWN , P.D. & MORRA, M.J. 1997. Control of soil-borne plant pests using glucosinolate-containing plants. Advances in Agronomy 61: 167-231.

CHÉRIF, M., BENHAMOU, N., MENZIES, J.G. & BÉLANGER, R.R. 1992. Silicon induced resistance in cucumber plants against *Pythium ultimum*. Physiological and Molecular Plant Pathology 41: 411-425.

COHEN, Y. 1994. Local and systemic protection against *Phytophthora infestans* induced in potato and tomato plants by DL-3-amino-n-butanoic acid. Phytopathology 84: 55-59.

COHEN, Y., GISI, U. & MOSINGER, E. 1991. Systemic resistance of potato plants against *Phytophthora infestans* induced by unsaturated fatty acids. Physiological and Molecular Plant Pathology 38: 255-263.

COHEN, Y., GISI, U. & NIDERMAN, T. 1993. Local and systemic protection against

Phytophthora infestans induced in potato and tomato plants by jasmonic acid and jasmonic acid methyl ester. Phytopathology 83: 1054-1062.

CROUS, P.W., PHILLIPS, A.J.L. & BAXTER, A.P. 2000. Phytopathogenic fungi from South Africa. University of Stellenbosch, Department of Plant Pathology Press, Stellenbosch.

DAAYF, F., SCHMITT, A. & BÉLANGER, R.R. 1997. Evidence of phytoalexins in cucumber leaves infected with powdery mildew following treatment with leaf extracts of *Reynoutria sacchalinensis*. Plant Physiology 113: 719-727.

DAUGHTREY, M.L. & SCHIPPERS, P.A. 1980. Root death and associated problems. Acta Horticulturae 98: 283-291.

DALISAY, R.F. & KUC, J.A. 1995. Persistence of induced resistance and enhanced peroxidase and chitinase activities in cucumber plants. Physiological and Molecular Plant Pathology 47: 315-327.

DAVIES, J.M.L. 1980. Diseases in NFT. Acta Horticulturae 98: 299-305.

DOUBRAVA, N.S., DEAN, R.A. & KUC, J. 1988. Induction of systemic resistance to anthracnose caused by *Colletotrichum lagenarium* in cucumber by oxalate and extracts from spinach and rhubarb leaves. Physiological and Molecular Plant Pathology 33: 69-79.

EL GHAOUTH, A., ARUL, J., ASSELIN, A. & BENHAMOU, N. 1992. Antifungal activity of chitosan on post-harvest pathogens: Induction of morphological and cytological alterations in *Rhizopus stolonifer*. Mycological Research 96: 769-779.

EL GHAOUTH, A., ARUL, J., GRENIER, J., BENHAMOU, N., ASSELIN, A. & BÉLANGER, R. 1994. Effect of chitosan on cucumber plants: Suppression of *Pythium aphanidermatum* and induction of defense reactions. Phytopathology 84: 313-320.

EVANS, S.G. 1979. Susceptibility of plants to fungal pathogens when grown by the nutrient-film technique (NFT). Plant Pathology 28: 45-48.

FENWICK, G.R., HEANEY, R.K. & MULLIN, W.J. 1983. Glucosinolates and their breakdown products in food and food plants. Critical Reviews in Food Science and Nutrition 18: 123-201.

GOTTSTEIN, H.D. & KUC, J. 1989. Induction of systemic resistance to anthracnose in cucumber by phosphates. Phytopathology 79: 176-179.

GRIFFITHS, E. 1981. Iatrogenic plant diseases. Annual Review of Phytopathology 19: 69-82.

JENKINS, S.F. & AVERRE, C.W. 1983. Root diseases of vegetables in hydroponic culture systems in North Carolina greenhouses. Plant Disease 67: 968-970.

KAWAKISHI, S., GOTO, T. & NAMIKI, M. 1983. Oxidative scission of the disulfide bond of cystine and polypeptides by the action of allyl isothiocyanate. Agricultural and Biological Chemistry 47: 2071-2076.

KAWAKISHI, S. & KANEKO, T. 1987. Interaction of proteins with allyl isothiocyanate. Journal of Agricultural and Food Chemistry 35: 85-88.

KIRKENGAARD, J.A., GARDNER, P.A., DESMARCHELIER, J.M. & ANGUS, J.F. 1993. Biofumigation - using *Brassica* species to control pests and diseases in horticulture and agriculture. Pp. 77-82 *in*: N. Wratten & R.J. Mailer (eds). 9th Australian Research Assembly on Brassicas. Agricultural Research Institute, Wagga Wagga.

LINDE, A.R., STANGHELLINI, M.E. & MATHERON, M.E. 1990. Root rot of hydroponically grown lettuce caused by *Phytophthora cryptogea*. Plant Disease 74: 1037.

MEYER, L. & VAN DYK, K. 2002. Susceptibility of pasture crops to *Rhizoctonia solani* and other fungi associated with crater disease of wheat on the Springbok Flats, South Africa. African Plant Protection 8 (in press).

MORGAN, L. 1999. Hydroponic lettuce production. Casper Publications, Narrabeen.

PATEGAS, K.G., SCHUERGER, A.C. & WETTER, C. 1989. Management of tomato mosaic virus in hydroponically grown pepper (*Capsicum annuum*). Plant Disease 73: 570-573.

RICCI, P., BONNETT, P., HUET, J.-C., SALLANTIN, M., BEAUVAIS-CANTE, F., BRUNETEAU, M., BILLARD, V., MICHEL, G. & PERNOLLET, J.-C. 1989. Structure and activity of of proteins from pathogenic fungi *Phytophthora* eliciting necrosis and acquired resistance in tobacco. European Journal of Biochemistry 183: 555-563.

RUNIA, W.Th. 1995. A review of possibilities of disinfection of recirculation water from soilless cultures. Acta Horticulturae 382: 221-227.

SCHNEIDER, S. & ULRICH, W.R. 1994. Differential induction of resistance and enhanced enzyme activities in cucumber and tomato caused by treatment with various abiotic and biotic inducers. Physiological and Molecular Plant Pathology 45: 291-304.

SHOKES, F.M. & McCARTER, S.M. 1976. Occurrence of plant pathogens in irrigation ponds in Southern Georgia. Proceedings of the American Phytopathological Society 3: 342.

STANGHELLINI, M.E., ADASKAVEG, J.E. & RASMUSSEN, S.L. 1990a. Pathogenicity of *Plasmopara lactucae-radicis*, a systemic root pathogen of cultivated lettuce. Plant Disease 74: 173-178.

STANGHELLINI, M.E. & KRONLAND, M.E. 1986. Yield loss in hydroponically grown lettuce attributed to subclinical infection of feeder rootlets by *Pythium dissotocum*. Plant Disease 70: 1053-1056.

STANGHELLINI, M.E. & RASMUSSEN, S.L. 1994. Hydroponics. A solution for zoosporic pathogens. Plant Disease 78: 1129-1138.

STANGHELLINI, M.E., RASMUSSEN, S.L. & BARTA, D.J. 1990b. Thielaviopsis root rot of corn-salad. Plant Disease 74: 81.

STAUNTON, W.P. & CORMICAN, T.P. 1978. The behavior of tomato pathogens in a hydroponic system. Acta Horticulturae 82: 133-135.

STROEMBER, A. & BRISHAMMER, S. 1991. Induction of systemic resistance in potato (*Solanum tuberosum* L.) plants to late blight by local treatment with *Phytophthora infestans* (Mont.) de Bary, *Phytophyhora cryptogaea* Pathybr. & Laff. or dipotassium phosphate. Potato Research 34: 219-225.

TOMLINSON, J.A. & FAITHFULL, E.M. 1980. Studies on the control of lettuce big-vein disease in recirculated nutrient solutions. Acta Horticulturae 98: 325-331.

TOMLINSON, J.A. & THOMAS, B.J. 1986. Studies on melon necrotic spot virus disease of cucumber and on control of the fungus vector (*Olpidium radicale*). Annals of Applied Biology 108: 71-80.

THOMPSON, A.H. & LABUSCHAGNE, N. 2001. Root disease caused by waterborne fungi in closed hydroponic systems. Pp 154-159 in: Guide to hydroponic vegetable production. J.G. Niederwieser (ed.). ARC Roodeplaat Vegetable and Ornamental Plant Institute, Pretoria.

VANACHTER, A., VAN WAMBEKE, E. & VAN ASSCHE, C. 1983. Potential danger for infection and spread of root diseases of tomatoes in hydroponics. Acta Horticulturae 133: 119-128.

VAN DER PLAATS-NITERINK, A.J. 1975. Species of *Pythium* in the Netherlands. Netherlands Journal of Plant Pathology 81: 22-37.

VAN DER PLAATS-NITERINK, A.J. 1981. Monograph of the genus Pythium. Studies in Mycology 21: 1-242.

VAN VOORST, G., VAN OS, E.A. & ZADOKS. J.C. 1987. Dispersal of *Phytophthora nicotianae* on tomatoes grown by nutrient film technique in a greenhouse. Netherlands Journal of Plant Pathology 93: 195-199.

WALKER-SIMMONS, M., HADWIGER, M. & RYAN, C.A. 1983. Chitosan and pectic polysaccharides both induce the accumulation of the antifungal phytoalexin pisatin in pea pods and antinutrient proteinase inhibitors in tomato leaves. Biochemical and Biophysical Research Communications 110: 194-199.

WEI, G., KLOEPPER, J.W. & TUZUN, S. 1991. Induction of systemic resistance of cucumber to *Colletotrichum orbicularae* by select strains of plant-growth-promoting rhizobacteria. Phytopathology 81: 1508-1512.