Sydowia, Annales Mycologici Ser. II.
Vol. 38: 383–399 (1985)
Verlag Ferdinand Berger & Söhne Gesellschaft m.b.H., 3580 Horn, Austria

Rhizoplane mycoflora of two understorey species in the dry Sclerophyll forest of the Brisbane Ranges

H. Y. Yip & G. Weste

Botany School, University of Melbourne, Parkville 3052, Australia

Summary. – The rhizoplane mycoflora of *Gahnia radula* (Cyperaceae) and *Isopogon ceratophyllus* (Proteaceae) in an undisturbed dry shrubby sclerophyll forest was studied over a two-year period by plating washed root segments. A total of 91 sporing and 56 sterile fungi were cultured from the roots of the two plants. The rhizoplane mycoflora of both plants was diverse, particularly in species of *Penicillium*. The species composition of the fungi that were regularly isolated from young and old roots was essentially similar for *G. radula* or *I. ceratophyllus* but old roots yielded more fungal isolates than young ones. The mycoflora of the two plants differed in fungal dominants. On the rhizoplane of *G. radula* these fungi were represented by *Penicillium spinulosum* strain A, *P. decumbens* and *Aspergillus parvulus*, whereas on the rhizoplane of *I. ceratophyllus* the fungal dominants were *Mortierella nana* and DS 52, a dark sterile fungus. A list of the fungi isolated is appended. It includes three new species and a variant of *Aspergillus nutans*, the former have been described elsewhere, the latter is described and illustrated here.

Introduction

During earlier field studies of disease due to *Phythophthora cinnamomi* Rands in the dry sclerophyll forest of the Brisbane Ranges, Victoria (Weste & Vithanage, 1977; 1978), it became evident that very little was known concerning fungi associated with roots of native species in natural Victorian forest. In these studies counts were made of microbial populations isolated from soil samples and from rhizoplane and rhizosphere of plants common in diseased and disease-free forest. The results demonstrated that microbial populations in dry sclerophyll forest soils were extremely low compared with those from garden or wet sclerophyll forest less than 100 km away. Population densities of bacteria were one or two orders of magnitude below that of wetter soils. Rhizosphere fungal populations were less than half those of wetter forests, whereas rhizoplane and soil fungal populations were similar in numbers. Seasonal variations in microbial populations were particularly high in dry sclerophyll forest, the numbers being maximum in autumn for actinomycetes, winter for fungi and spring for bacteria. On the basis of these results, it was considered worthwhile to examine in detail the rhizoplane mycoflora of two native species common in the understorey of the Brisbane Ranges dry sclerophyll forest.

Study Area

The Brisbane Ranges, 80 km south-west of Melbourne, are formed from a dissected tertiary plateau rising 400 m a. s. l. with tertiary laterites overlaying Ordovican slates and sandstone. The soils, derived from the tertiary laterites, grade into yellow or grey sands with a pH range of 4.7–5.8. The top soil is shallow (0.6–2.0 m) and has an underlying clay pan which restricts roots and impedes drainage.

The climate is modified Mediterranean with an average annual rainfall of 660 mm, most of which is received during winter and spring when the shallow soil may become saturated. Soil conditions during spring and early summer are wet and warm favouring the activities of *P. cinnamomi*. During late summer and autumn, the soil becomes dry and the soil matric potential may fall to –80 bars.

The forest consists of two strata. Trees in the upper storey consist of stringy barks dominated by *Eucalyptus baxteri* (Benth.) Maiden & Blakely and *E. macrorhyncha* Muell. The understorey has a species rich composition, and in many areas is dominated by the grass tree *Xanthorrhoea australis* R. Br. *Isopogon ceratophyllus* R. Br. occurs frequently. After invasion by *P. cinnamomi* both *X. australis* and *I. ceratophyllus* and other susceptible understorey species are replaced by the sedge *Gahnia radula* (R. Br.) Benth.

Materials and Methods

The two species examined for rhizoplane fungi may be described as follows:

Isopogon ceratophyllus (Proteaceae) is a small shrub 0.3–0.5 m in height. It has a number of branches arising from near ground level. The root system consists of a stout tap root with few large laterals, both tap and lateral roots produce fine feeder roots including proteoid roots which occur in dense clusters. Proteoid roots, whose formation is induced by microorganisms, increase both the absorption surface and efficiency in the uptake of minerals by the root system (Lamont, 1981).

Gahnia radula (Cyperaceae) grows in tufts consisting of up to ten individual plants which arise from branching underground rhizomes. The plant, when fully grown is up to 1 m in height, has a fibrous root system. Primary roots, 2–3 mm diameter, are produced from the base of the plant or from the rhizome. These roots in turn continually give rise to lateral roots on which dauciform roots may be found. Dauciform roots form in response to microorganisms and have functions similar to proteoid roots (Lamont, 1981).

Samples of both plant species were taken seasonally eight times, during a two-year study period commencing from the summer of 1979 and ending in the spring of 1980. Each samling date was within a few days of mid-season. Soils from sampling sites were baited with radicles of *Lupinus angustifolium*. L. (Chee & Newhook, 1965), then plated onto a selective medium (Tsao & Ocana, 1969) and were found free from *P. cinnamomi*. Plants were removed with an intact block of soil enclosing the root system. Soil was then carefully removed from the blocks and roots were sampled as follows:

G. radula:

Old roots, 1.5–2 mm diam., 1st order roots, cortex intact, dark brown.

Young roots, 0.5–0.75 mm diam., 3rd order roots, cortex and apex intact, white.
I. ceratophyllus:
Old roots, ca. 0.5 mm diam., from tap root, cortex intact, reddish brown.
Young roots, ca. 0.5 mm diam., from tap root, cortex and apex intact, white.

Proteoid and dauciform roots were not sampled for study because of their seasonal occurrence, both types of roots being abundant only when soil conditions were moist.

At each sampling date 12 twenty mm lengths of both young and old roots were taken from each plant species. The roots were given two crude washes by shaking in tap water to dislodge loosely adhering soil and then subjected to serial washing in sterile water according to the technique of HARLEY & WAID (1955). After washing, the roots were cut into 2 mm segments to provide 120 segments for each sample of 12 root lengths. Half the number of segments from each sample of root lengths were plated on 2% malt extract agar and the remainder on Czapek-Dox agar. Both media were adjusted to pH 4.8 with HCl, and streptomycin sulphate (30 µg/ml) was added to suppress bacterial growth.

Fungi growing from the root segments were isolated and identified after the plates were incubated at 20–21° C for 7 days. The examined plates were further incubated for 3 weeks during which slow growing fungi were isolated or identified. The frequency of each fungus in a sample of root lenghts was recorded as the number of root segments from which the fungus was isolated.

Results

1. Rhizoplane mycoflora

During the two-year study period a total of 91 species of sporing fungi and 56 different cultures of sterile fungi were isolated from the rhizoplanes of *G. radula* and *I. ceratophyllus* (Table 1). Included in this flora were three fungi described as new species, these were *Coniochaeta angustispora, Penicillium maclennaniae* and *Mortierella ovata* (HAWKSWORTH & YIP, 1980; YIP, 1981; 1982). Among the sporing fungi, *Penicillium* with 20 species and *Mortierella* with 14 species were respectively the dominant and codominant genera. However, only a few species in each of these two genera were isolated with regularity and high frequency during the study period, examples being *Penicillium spinulosum* and *Mortierella nana.* The genus *Aspergillus* was represented by seven species of which only *Aspergillus parvulus* was frequently isolated. A variant of *Aspergillus nutans* with broadly elliptical conidia was isolated rarely and only from the rhizoplane of *G. radula.* A description and illustration of this fungus is provided*). Sterile fungi consisted of either white

*) Description of *Aspergillus nutans* variant (Fig. 1). – Colonies on Malt Extract Agar at 25° C after 7 days attaining 41–42 mm diameter; texture velutinous; margins subsurface, 1.5–2 mm wide, regular; conidiogeneris heavy, Brownish Orange (6C3) (KORNERUP & WANSCHER, 1967); reverse Greyish Yellow (4B5). – Conidiophores arising from substrate hyphae, 20–50 × 3.5–4 µm, walls smooth and brownish orange; foot cells inconspicuous; vesicles subglobose (6–)10–12 µm diameter, brownish orange or darker in colour, typically nodding to one side; sterigmata uniseriate, ampulliform, 5–6 × 2.2–2.5 µm, produced on 0.3 to 0.5 surface area of vesicle, closely arranged; conidia broadly elliptical, 3–3.5(–5) × (2.2–)2.5–2.8(3.5) µm, walls smooth, en masse brownish orange, disjunctors prominent and persistent, borne in short but compact and well defined columns.

or dark forms, these were further identified into different cultures according to a number of colony features such as colour, growth rate, texture and nature of exudates. Of the two colour forms of sterile fungi, dark sterile cultures were isolated more frequently. Attempts at inducing sterile cultures to sporulate by growing on a range of media, or under blacklight (LEACH, 1962) were unsuccessful. Ascomycetes were rarely isolated and were represented only by 4 genera (Table 1).

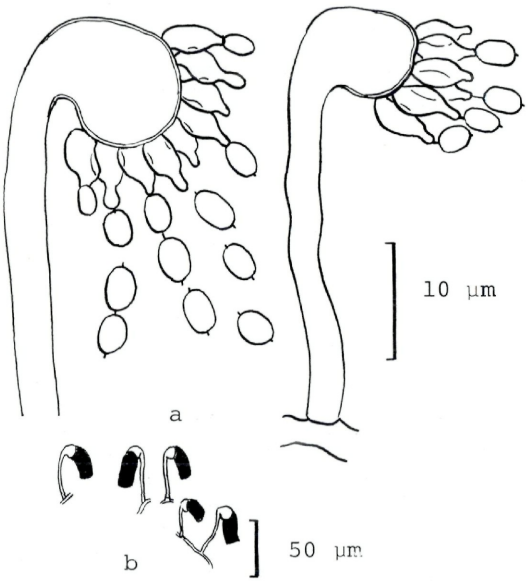

Fig. 1: *Aspergillus nutans* DAR 38020: a, conidiophores and conidia; b, habit sketches.

All features of this fungus agree closely with those in the type culture of *A. nutans* (MCLENNAN & al., 1954) except for the broadly elliptical conidia. In the type culture, the conidia are globose. Only three isolates of this variant culture were obtained and a culture (DAR 38020) was deposited in the Department of Agriculture, Rydalmere, N. S. W., Australia.

2. Rhizoplane mycoflora of *G. radula*

The fungi colonizing the rhizoplane of *G. radula* may be classified into two groups independent of root age or seasons. A few

species were dominant, these occurred in relatively high frequency, others were casual in that they were isolated with low frequency (Table 2). Some fungi in the former group could be termed as occasional dominants because they appeared rarely but with high frequency. Examples of these fungi were *Mucor* sp. on old roots, DS 8 (dark sterile) on young roots and *Trichoderma* sp. on roots of both ages. *Penicillium spinulosum* strain A was the most regularly isolated dominant, it was isolated in high frequency on most seasonal samples of both young and old roots. *Aspergillus parvulus* and *Penicillium decumbens* also occurred regularly as dominant species on roots of both ages, but only in 1980.

In results shown in Tables 1 and 2, it was evident that the mycoflora of young and old roots differed in several rarely isolated species of fungi such as *Mortierella alpina, Acremonium diversisporum* and *Aspergillus nidulans*. The species composition of regularly encountered fungi was, however, essentially similar for roots of both ages. *Oidiodendron* spp. and DS 52, however, occurred more regularly on young than on old roots. The most obvious difference between the two root ages was the significantly higher number of fungal isolates obtained from old roots compared with young roots in each season (Fig. 2).

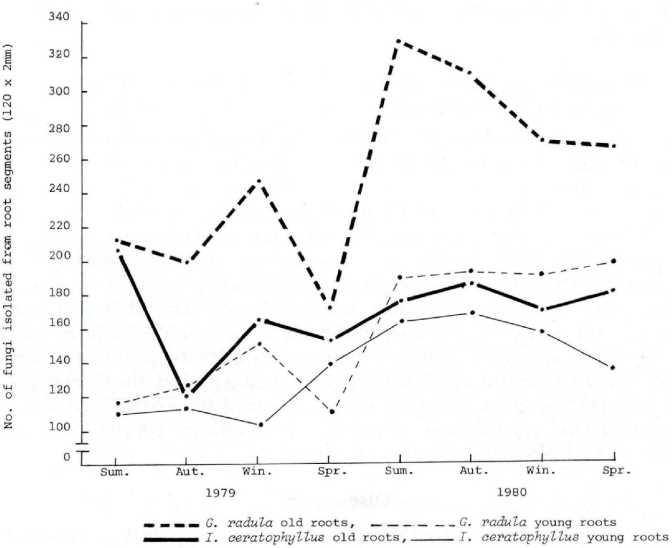

Fig. 2: Number of fungal isolates obtained from *G. radula* and *I. ceratophyllus* roots.

3. Rhizoplane mycoflora of *I. ceratophyllus*

The fungal populations on both young and old roots in each season consisted of a few dominants and many casual species (Table 3) in a similar pattern to that previously noted for *G. radula*. *Mortierella nana* and DS 52 were the only dominants isolated quite regularly in high frequency from both young and old roots. Occasional dominants included species such as DS 39 on young roots, *Aspergillus parvulus* and *Oidiodendron* spp. on old roots, and *Pencicillium simplicissimum* on roots of both ages.

The rhizoplane mycoflora on young roots differed from that on old roots by a number of rarely isolated species such as *Acremonium bacillisporum, Chloridium caudigerum* and *Cladosporium cladosporioides* (Table 1). This pattern resembles that obtained for *G. radula* but the rarely isolated fungi were quite different in genera and species. The species composition of the fungi that were regularly isolated from the two ages of roots was, however, basically similar. *Acremonium diversisporum* was, however, recorded more regularly from young than old roots, whereas *Penicillium thomii* and DS 6 occurred more regularly on old than young roots. The number of fungal isolates obtained from old roots in each season was higher than from young roots, but the difference in each case was not as large as that observed between young and old *G. radula* roots (Fig. 2).

4. Differences between rhizoplane mycoflora of *G. radula* and *I. ceratophyllus*

A striking dissimilarity between the rhizoplane mycoflora of the two plants was a difference in regular fungal dominants. As previously noted, *Penicillium spinulosum* strain A, *Aspergillus parvulus* and *Penicillium decumbens* were the regular dominants on the rhizoplane of *G. radula*. In contrast, *Mortierella nana* and DS 52 were the regular dominants on the rhizoplane of *I. ceratophyllus*. This influence due to plant species, illustrated in Fig. 3, was also apparent for some regularly isolated fungi. The rhizoplane of *G. radula* particularly favoured the occurrence of *Trichoderma viride, Trichoderma* sp., *Mortierella parvispora, Mortierella rammaniana* var. *angulispora* and *Mucor* sp. On the other hand, the rhizoplane of *I. ceratophyllus* was frequently colonized by *Penicillium* sp. 1, *Penicillium spinulosum* strain C, *Penicillium simplicissimum*, DS 42 and *Mortierella marburgensis*.

Discussion

The rhizoplane mycoflora of a variety of plants, consisting mostly of crop plants and few forest species, have been investigated

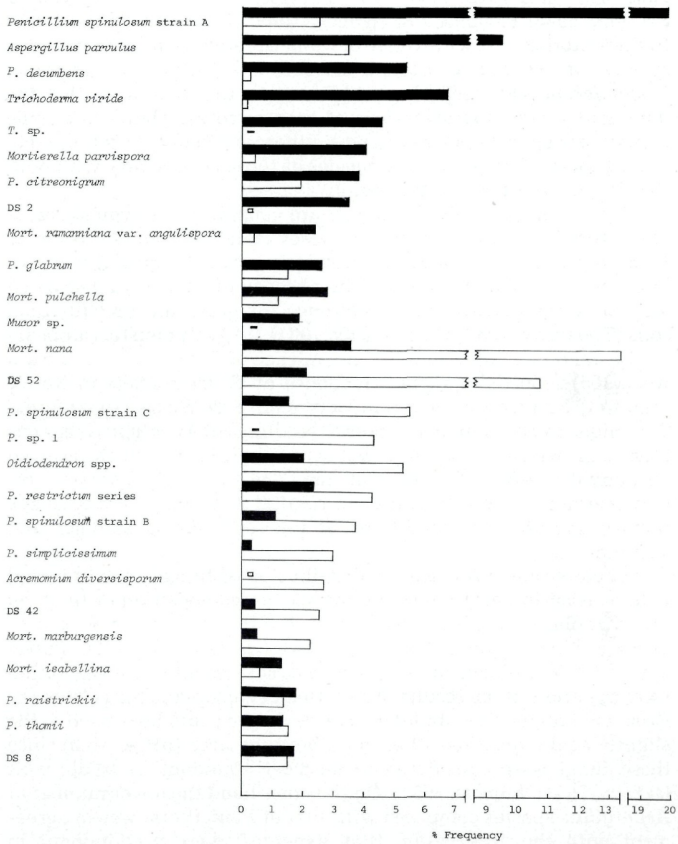

Fig. 3: Frequency of fungi isolated regularly from the rhizoplane of *G. radula* and *I. ceratophyllus*.

% frequency for each fungus on the rhizoplane of each plant was derived from totalling the frequency of the fungus for 8 seasons from both young and old roots and expressing the figure as a percentage of the total number of all fungal isolates obtained from the plant in the 8 seasons.

G. radula, *I., ceratophyllus*, - absent, ▫ frequency less than 0.1%.

previously (PETERSON, 1958, 1961; STENTON, 1958; CATSKA & al., 1960; PARKINSON & CLARK, 1961; DIX, 1964; PETERSON & al., 1965; THORNTON, 1965; TAYLOR & PARKINSON, 1965; PETERSON & ROUATT, 1967; CHU & STEPHEN, 1968; PARKINSON & GROUCH, 1969; ASHTON & WILLIS, 1982). In these studies, the wide range of fungi isolated frequently included species of *Fusarium, Cylindrocarpon, Penicillium, Mortierella, Trichoderma* and sterile fungi. All investigations indicate that the dominant rhizoplane mycoflora of crop or forest plants in a wide climatic range from northern and southern hemispheres is limited to a few genera of fungi, but the species of those genera vary with both the climate and flora of the region.

Fusarium and *Cylindrocarpon* are considered as typical rhizoplane fungi, but the former was never isolated from *G. radula* or *I. ceratophyllus* roots and *C. destructans* (syn. *radicicola*) was isolated only once in this study. The absence of species of *Fusarium* may be attributed to their preference for grassland or cultivated soils (THORNTON, 1960; CHRISTENSEN, 1981), and soil moisture appears to play an important role in the prevalence of *C. destructans*. THORNTON (1965) reported a higher incidence of *C. destructans* in wetter than in drier pasture soils. Similarly ASHTON & WILLIS (1982) found the fungus to be common on roots of seedlings of *Eucalyptus regnans* MUELL. grown in the soil of a wet sclerophyll forest which received an annual rainfall of 1100–2000 mm. The rarity of *C. destructans* may therefore be related to the low rainfall (660 mm) of the Brisbane Ranges and the dry conditions of the soils during summer and autumn.

Factors that influence the distribution of fungal species in soil will, at least in part, determine the species composition of fungi on the rhizoplane. This is due to the fact that the soil is the main source of fungi which colonize the root surface (CATSKA & al., 1960; PETERSON, 1958). The effects of factors such as soil reaction and vegetation were apparent in the results of isolation of rhizoplane fungi from the Brisbane Ranges. The abundance of *Penicillia* could be related to the slightly acidic reactions of soils in the study area (pH 4.7–5.8) since these fungi were considered to be most abundant in acidic soils (JENSEN, 1931; WARCUP, 1951). On the other hand the lower number of *Aspergillus* species compared with that of *Penicillium* was in agreement with the observation that *Aspergilli* were predominant in warmer soils of the tropics while cooler temperate soils were characterized by an abundance of *Penicillia* (WARCUP, 1951; DOMSCH & al., 1980).

The high diversity of the genus *Mortierella* (14 species) observed in this study appeared to be unusual in view of the results of PETERSON (1958) and TAYLOR & PARKINSON (1964). These authors reported a higher incidence of species of *Mortierella* on root surfaces

in alkaline than in acidic soils. Neither author, however, identified fungi to species level and the results might therefore not be applicable to all species of *Mortierella* since LINNEMANN (1941) had demonstrated that different species of the genus might vary in their reaction to pH.

CHRISTENSEN (1981) has collated the results of numerous studies on soil fungi in relation to vegetation and provided a list of fungi and their habitat specificity for soils under different types of vegetation. The species listed by CHRISTENSEN as forest or forest-heath associated included species that were isolated frequently from either or both *G. radula* and *I. ceratophyllus* such as *Mortierella nana, M. ramanniana, M. isabellina, Oidiodendron* spp., *Penicillium spinulosum* and *P. thomii.* These results therefore support CHRISTENSEN's study and indicate that the rhizoplane mycoflora of the two plants was related to the local forest vegetation.

Seven species of *Aspergillus* were isolated including *A. cervinus, A. nutans* and *A. parvulus* of the *A. cervinus* group. The first two species were seldom isolated but *A. parvulus* was recorded frequently, particularly from the roots of *G. radula* on which it was a dominant species. Little is recorded concerning the distribution of *A. parvulus.* According to RAPER & FENNELL (1965), this fungus has been previously isolated from soils of pine and sweetgums forest in South Carolina, a deciduous forest in Georgia, USA and two Scots pine communities in Britain. These records suggest that *A. parvulus* is associated with forest soils. *Aspergillus cervinus* was considered to occur principally in tropical soils (RAPER & FENNELL, 1965). Three of the five records came from soils in Sudan, Puerto Rica and Malaya, and two from soils in New Zealand and Wisconsin, USA; in each case few isolates were obtained. *Aspergillus cervinus* was, however, found to be common in soils of a sclerophyll shrub woodland at Wilson's Promontory and of a wet sclerophyll forest at Wallaby Creek, Victoria, Australia (YIP, unpublished data). In view of these recent findings, the distribution of *A. cervinus* appears to be widespread in both tropical and temperate soils and is associated with forest soils in Victoria, Australia. *Aspergillus nutans* has been isolated from South Africa, from an oak forest soil in Wisconsin (RAPER & FENNELL, 1965), and was reported to be commonly encountered in Australian heathland podzol soils (MCLENNAN & al., 1954). This fungus was isolated three times from the roots of *G. radula.*

Sterile fungi, particularly dark cultures, isolated frequently from roots of both *G. radula* and *I. ceratophyllus* were also reported to be common on roots of crop plants such as rye-grass, white clover, leek, onion, wheat and dwarf beans (PARKINSON & CLARK, 1961, 1964; THORNTON, 1965; TAYLOR & PARKINSON, 1965), and on roots of forest species such as pine and beech (HARLEY & WAID, 1955; PARKINSON &

Crouch, 1969). Apart from their occurrence, little is known of sterile fungi with respect to their relation to plant growth. Waid (1957) found an abundance of dark sterile fungi in the inner and outer cortex of rye-grass roots and believed them to be early colonizers of those tissues. Thornton (1965) demonstrated that a sterile dark fungus when grown on sterile white clover roots was capable of some pathogenic activity. Despite this finding, frequent isolation of sterile fungi from healthy plant roots indicates that most of these fungi are normally harmless saprophytes.

Old roots of both plants produced more fungal isolates than young roots (Fig. 2). This difference may be associated with increased microbial substrate, such as root exudates and senescent cells, on old roots. Microbial activities may damage roots and increase root exudation (Schroth & Teakle, 1963). Increased exudate on older roots in natural soil (Dix, 1967) may be due to a combination of ageing and longer exposure to microbial activities, but the amount of exudate also varies with root species (Rovira, 1959).

Seasonal variation in counts of fungal isolates in 1979 and 1980 for *G. radula* or *I. ceratophyllus* roots was small (Tables 2 and 3). For *G. radula* the maximum number of fungi isolated was in winter for 1979 and in spring-summer for 1980. For *I. ceratophyllus* maximum counts were recorded in spring-summer for 1979 and in the autumn of 1980. These differences may be related to a difference in periods of maximum root growth. *I. ceratophyllus* shows summer growth whereas *G. radula* produces most growth in winter-spring. Counts of fungi are also affected by soil matric potentials and soil temperatures, these normally support high populations of fungi in spring and autumn rather than during the dry summer when the soil matric potential may fall to –80 bar or cold winter when soil temperatures are less than 10° C.

The differences between the mycoflora of *G. radula* and *I. ceratophyllus* (Fig. 3) indicated that the roots of the two plants were somewhat selective for colonizing soil fungi. Similar results demonstrating this selectivity have been reported for a number of crop plants (Peterson, 1961; Parkinson & al., 1963). The selective mechanisms are not clearly understood. Root exudates of different plants are known to stimulate or inhibit the growth of particular fungi (Rovira, 1965). Hence, the qualitative and quantitative differences in root exudates on roots of different plant species may explain, at least in part, the selective action of different plant roots (Rovira, 1959; Ayers & Thornton, 1968; Kovacs, 1971). Other factors, which undoubtedly have important roles, either direct or indirect, in the selective action of roots are the complex interactions among microorganisms, and influence of soil factors such as temperatures

and moisture on growth of both plant and colonizing microorganisms.

Acknowledgements

We gratefully acknowledge a critical reading of the manuscript by Dr. H. J. SWART and provision of facilities for this study by the Botany School, University of Melbourne. This study represents part of an approved Ph. D. thesis by H. Y. Y. submitted in the University of Melbourne. The senior author was the recipient of a University of Melbourne scholarship.

References

ASHTON, D. H. & WILLIS, E. J. (1982). Antagonisms in the regeneration of *Eucalyptus regnans* in mature forest. – pp. 133–138. In: NEWMAN, E. I. (ed.), The plant community as a working mechanism. Blackwell Scientific Publications, Oxford.

AYERS, W. A. & THORNTON, R. H. (1968). Exudation of amino acids by intact and damaged roots of wheat and peas. – Plant and Soil 28: 193–207.

CATSKA, V., MACURA, J., & VAGNEROVA, K. (1960). Rhizosphere microflora of wheat. III. Fungal flora of wheat rhizosphere. – Folia Microbiologica 5: 320–330.

CHEE, K. H. & NEWHOOK, F. J. (1965). Improved methods for use in studies on *Phytophthora cinnamomi* and other *Phytophthora* species. – N. Z. J. Agric. Res. 3: 88–95.

CHRISTENSEN, M. (1981). Species diversity and dominance in fungal communities. – pp. 201–232. In: WICKLOW, D. T. & CARROLL, G. C. (eds.), The Fungal Community: Its Organization and Role in the Ecosystem. Marcel Dekker, Inc. New York.

CHU, M. & STEPHEN, R. C. (1968). A study of the free living and root-surface fungi in cultivated and fallow soils in Hong Kong. – Nova Hedwigia 14: 301–311.

DIX, N. J. (1964). Colonization and decay of bean roots. – Trans. Brit. Mycol. Soc. 50: 23–31.

— (1967). Mycostasis and root exudation: factors influencing the colonization of bean roots by fungi. – Trans. Brit. Mycol. Soc. 50: 23–31.

DOMSCH, K. H., GAMS, W., & ANDERSON, N. T. (1980). Compendium of Soil Fungi. – Academic Press, London.

HARLEY, J. L. & WAID, J. S. (1955). A method of studying active mycelia on living roots and on other surfaces in the soil. – Trans. Brit. Mycol. Soc. 38: 104–118.

HAWKSWORTH, D. L. & YIP, H. Y. (1981). *Coniochaeta angustispora* sp. nov. from roots in Australia, with a key to the species known in culture. – Aust. J. Bot. 29: 377–384.

JENSEN, H. L. (1931). The fungus flora of the soil. – Soil Sci. 31: 123–158.

KORNERUP, A. & WANSCHER, J. H. (1967). Methuen Handbook of Colour. – Edit. 2. Eyre Methuen, London.

KOVACS, M. F. Jr. (1971). Identification of aliphatic and aromatic acids in root and seed exudates of pea, cotton and barley. – Plant and Soil 34: 441–45.

LAMONT, B. B. (1981). Specialized roots of non-symbiotic origin in healthlands. – ch. 18. In: SPECHT, R. L. (ed.), Heathlands and Related Shrublands of the World. B. Analytical Studies. Elsevier, Amsterdam.

LEACH, C. M. (1962). Sporulation of diverse species of fungi under near-ultraviolet radiation. – Can. J. Bot. 40: 151–161.

LINNEMANN, G. (1941). Die Mucorineen-Gattung *Mortierella* COEMANS. – Pflanzenforschung 23: 1–64.

MCLENNAN, E. I., DUCKER, S. C. & THROWER, L. B. (1954). New soil fungi from Australian heathland: *Aspergillus, Penicillium, Spegazzinia.* – Aust. J. Bot. 2: 355–364.

PARKINSON, D. & CLARK, J. H. (1961). Fungi associated with the roots of *Allium porrum* L. – Plant and Soil 13: 384–390.

PARKINSON, D. and CLARK, J. H. (1964). Studies on fungi in the root region. III. Root surface fungi of three species of *Allium*. – Plant and Soil 20: 167–173.

— & GROUCH, R. (1969). Studies on fungi in a pinewood soil. V. Root mycoflora of seedlings of *Pinus nigra* var. *laricio*. – Rev. Ecol. Biol. Sol. 6: 263–275.

PETERSON, E. A. (1958). Observation of fungi associated with plant roots. – Can. J. Bot. 4: 254–265.

— (1961). Observation on the influence of plant illumination on the fungal flora of roots. – Can. J. Microbiol. 7: 2–6.

— & ROUATT, J. W. (1967). Soil microorganisms associated with flax roots. – Can. J. Microbiol. 13: 199–203.

— & KATZNELSON, H. (1965). Microorganisms in the root zone in relation to soil moisture. – Can. J. Microbiol. 11: 483–489.

RAPER, K. B. & FENNELL, D. I. (1965). The genus *Aspergillus*. – Williams and Wilkins Co., Baltimore.

ROVIRA, A. D. (1959). Root excretions in relation to the rhizosphere effect. IV. Influence of plant species, age of plants, light, temperature, and clacium nutrition on exudation. – Plant and Soil 11: 53–64.

— (1965). Plant root exudates and their influence upon soil microorganisms. – pp. 170–181. In: BAKER, K. F. & SNYDER, W. C. (eds.). Ecology of Soil-borne Plant Pathogens. University of California Press, Berkeley.

SCHROTH, M. N. & TEAKLE, D. S. (1963). Influence of virus and fungus lesions on plant exudation and chlamydospore germination of *Fusarium solani* f. *phaseoli*. – Phytopathology 53: 610–612.

STENTON, H. (1958). Colonization of roots of *Pisum sativum* by fungi. – Trans. Brit. Mycol. Soc. 41: 74–80.

TAYLOR, G. S. & PARKINSON, D. (1965). Studies of fungi in the root region. IV. Fungi associated with the roots of *Phaseolus vulgaris* L. – Plant and Soil 22: 1–20.

THORNTON, R. H. (1960). Growth of fungi in some forest and grassland soils. – pp. 84–91. In: PARKINSON, D. & WAID, J. S. (eds.). The Ecology of Soil Fungi. Liverpool University Press, Liverpool.

— (1965). Studies of fungi in pasture soils. I. Fungi associated with live roots. – N. Z. J. Agric. Res. 8: 417–449.

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.

WAID, J. S. (1957). Distribution of fungi within decomposing tissues of rye-grass roots. – Trans. Brit. Mycol. Soc. 40: 399–406.

WARCUP, J. H. (1951). The ecology of oil fungi. – Trans. Brit. Mycol. Soc. 34: 376–399.

WESTE, G. & VITHANAGE, K. (1977). Microbial populations of three forest soils: Seasonal variations and changes associated with *Phytophthora cinnamomi*. – Aust. J. Bot. 25: 377–383.

— (1978). Effects of *Phytophthora cinnamomi* on microbial populations associated with the roots of forest flora. – Aust. J. Bot. 26: 153–167.

YIP, H. Y. (1981). *Penicillium maclennaniae* sp. nov. – Trans. Brit. Mycol. Soc. 77: 202–203.

— (1982) *Mortierella ovata* sp. nov. – Trans. Brit. Mycol. soc. 78: 162–165.

Table 1: Fungi isolated from the rhizoplane of *Gahnia radula* and *Isopogon ceratophyllus*

Fungal species	Total frequency for 8 seasons from young and old roots (resp. YR and OR)			
	Gahnia		*Isopogon*	
	YR	OR	YR	OR
PHYCOMYCETES				
Absidia glauca HAGEM	3	9	–	9
A. spinosa LEND.	1	2	–	2
Circinella sp.	–	–	–	1
Mortierella alpina PEYRONEL	1	–	3	13
M. ? exigua	–	2	2	4
M. ? gemmifera	2	6	–	–
M. gamsii MIL'KO	–	–	1	6
M. humilis LINNEM.	–	3	–	1
M. isabellina OUDEM.	14	22	1	5
M. marburgensis LINNEM.	7	4	18	36
M. nana LINNEM.	43	67	162	177
M. ovata YIP	–	–	2	–
M. parvispora LINNEM.	19	107	4	2
M. pulchella LINNEM.	23	64	9	17
M. ramanniana (MÖLLER) LINNEM.	7	6	5	12
M. ramanniana var. angulispora (NAUMOV) LINNEM.	16	56	4	–
M. vinacea DIXON-STEWART	2	4	–	–
Mucor hiemalis WEHMER	2	–	–	1
M. plumbeus BON.	–	–	1	1
M. sp.	5	51	–	–
Rhizopus nigricans EHRENBERG	–	–	1	1
FUNGI IMPERFECTI				
Acremonium bacillisporum (ONIONS & BARRON) GAMS	–	–	2	–
A. diversisporum (VAN BEYMA) GAMS	1	–	52	12
A. murorum (CORDA) GAMS	–	–	3	3
Alternaria alternata (FRE.) KEISSLER	–	1	–	1
Aspergillus cervinus (MASSEE) NEILL	2	4	11	6
A. fumigatus group	3	15	–	1
A. niger group	–	–	–	1
A. nidulans (EIDAM) WINTER	–	1	–	–
A. nutans MCLENNAN & DUCKER	2	1	–	–
A. parvulus G. SMITH	86	209	47	36
A. ? ustus	–	1	–	–
Beauveria sp.	1	–	–	–
Chloridium caudigerum (HÖHNEL) HUGHES	2	–	1	–
Cladosporium cladosporioides (FRE.) DE VRIES	–	2	–	2
Cylindrocarpon destructans (ZINS.) SCHOLTEN	–	–	2	1
? Cylindrotrichum sp.	–	–	–	2
Dactylaria sp.	–	–	–	1
Exophiala sp.	–	–	1	–
Geotrichum sp.	–	–	1	–
Gliocladium roseum (LINK) THOM	–	–	–	1
G. virens MILLER, GIDDEN & FOSTER	–	–	2	10
Ostracoderma sp.	1	1	–	–

Table 1 (continued)

Fungal species	Total frequency for 8 seasons from young and old roots (resp. YR and OR)			
	Gahnia		*Isopogon*	
	YR	OR	YR	OR
Oidiodendron flavum SZILVINYI	2	–	–	–
O. griseum ROBAK	39	13	73	49
O. periconioides MOALL	5	–	1	2
O. tenuissium (PECK) HUGHES	–	–	–	1
Paecilomyces carneus (DUCHE & HEIM) BROWN & SMITH	2	–	–	–
P. spp.	4	2	2	1
Penicillium brevicompactum DIERCKX	–	3	1	2
P. chrysogenum THOM	–	1	–	–
P. citroeonigrum DIERCKX	58	65	–	–
P. decumbens THOM	75	93	2	3
P. dendriticum PITT	2	–	–	–
P. expansum LINK	–	1	2	–
P. fellutanum BIOURGE	–	1	–	–
P. funiculosum THOM	–	–	–	1
P. glabrum (WEHMER) WESTLING	42	37	8	26
P. islandicum series	2	–	2	4
P. janczewski ZALESKII	10	23	1	5
P. janthinellum BIOURGE	7	15	3	8
P. lividum WESTLIING	–	1	–	–
P. maclennaniae YIP	–	3	–	–
P. melinii THOM	5	1	–	–
P. miczynskii ZALESKII	1	–	1	–
P. montanense CHRISTENSEN & BACKUS	1	–	–	1
P. purpurescens (SOPP) BIOURGE	2	–	–	3
P. pseudostromaticum HODGES, WARNER & ROGERSON	–	–	–	1
P. raistrickii G. SMITH	33	21	13	20
P. resedanum MCLENNAN & DUCKER	6	2	–	–
P. restrictum series	36	37	60	42
P. rugulosum series	–	–	–	3
P. simplicissimum (OUEDEM.) THOM	2	2	31	44
P. spinulosum THOM: Strain A	196	439	34	27
Strain B	12	22	23	68
Strainc C	14	31	61	70
P. thomii MAIRE	18	22	14	28
P. verruculosum PEYRONEL	1	17	3	5
P. ? viridicatum	–	1	–	–
P. sp. 1	–	–	24	81
Phialophora sp.	–	–	–	1
Sesquicillium candelabrum (BON.) GAMS	1	6	2	8
Torulomyces lagena DELITSCH	1	–	2	–
Trichoderma hamatum (BON.) BAIN.	–	2	1	2
T. polysporum (LINK ex PERS.) RIFAI	8	4	–	–
T. viride PERS. ex S. F. GREY	85	130	9	16
T. sp.	35	107	–	–
Verticillium bulbillosum GAMS & MALLA	9	4	9	11
V. psalliotae TRESCHOW	–	–	1	–

Table 1 (continued)

Fungal species	Total frequency for 8 seasons from young and old roots (resp. YR and OR)			
	Gahnia		*Isopogon*	
	YR	OR	YR	OR
DS 2 (Dark sterile fungus)	25	84	1	4
DS 8	45	10	1	34
DS 42	9	–	37	24
DS 52	62	2	144	117
Other Dark sterile fungi (36 different cultures)	122	86	117	176
White sterile fungi (16 different cultures)	28	18	72	94
ASCOMYCETES				
Coniochaeta angustispora HAWK. & YIP	1	–	–	1
Eupenicillium fractum series	1	–	–	–
E. pinetorum STOLK	–	–	–	2
Sporomiella australis (SPEG.) AHMED & CAIN	–	–	–	1
Total number of isolates	1250	1944	1090	1251

Table 2: Frequency of fungi regularly isolated from the rhizoplane of *G. radula*. Numerator and denominator denote frequency on young and old roots respectively, – signifies absent.

Fungal species	SEASONS							
	1979			1980				
	Sum.	Aut.	Win.	Spr.	Sum.	Aut.	Win.	Spr.
Aspergillus parvulus	11/10	0/2	5/16	2/4	20/66	18/43	13/24	17/44
Mortierella isabellina	–	–	0/2	0/1	4/3	2/11	5/1	3/4
M. nana	9/4	1/0	3/15	10/10	4/16	7/3	4/17	6/2
M. parvispora	5/13	0/6	0/29	4/20	3/5	0/14	1/16	5/4
M. pulchella	3/5	1/2	2/15	1/6	2/7	1/10	10/13	3/6
M. ramanniana var. *angulispora*	–	1/6	2/9	–	2/6	1/13	4/4	6/18
Mucor sp.	1/44	1/1	–	–	0/1	0/1	1/0	2/4
Oidiodendron spp.	6/0	5/0	2/0	7/11	4/0	10/2	6/0	6/0
Penicillium citreonigrum	1/1	0/3	1/7	6/0	11/27	4/5	13/3	22/19
P. decumbens	–	–	–	0/2	16/26	28/36	22/7	9/22
P. glabrum	–	3/1	0/2	3/2	12/4	2/1	18/19	4/8
P. raistrickii	–	4/1	1/5	–	7/2	1/1	11/7	9/5
P. restrictum series	2/3	1/0	7/1	1/3	6/10	4/1	8/16	7/3
P. spinulosum strain A	28/69	25/72	11/50	19/48	29/52	26/54	23/62	35/32
P. spinulosum strain B	1/3	7/0	1/1	0/1	0/4	2/3	0/2	1/7
P. spinulosum strain C	3/1	3/0	0/1	5/1	2/20	3/2	0/3	0/3
P. thomii	0/1	–	4/1	0/1	3/6	2/4	8/7	1/3
Trichoderma viride	4/13	6/15	43/12	1/5	7/11	10/27	2/19	12/3
T. sp.	0/30	2/70	20/0	–	0/1	9/0	1/0	3/6
DS 52 (Dark sterile)	4/0	13/0	3/1	14/0	1/0	18/0	5/0	4/1
DS 8	4/0	19/0	–	4/1	5/4	9/0	2/4	2/1
DS 2	2/3	9/1	10/25	0/38	1/11	1/3	2/3	–
Other species *	31/8	23/16	35/49	33/15	46/38	29/55	27/33	36/36
Total isolates	115/208	124/196	150/241	110/169	185/320	187/290	186/261	193/259

* Fungi isolated irregularly and usually in low frequency.

Table 3: Frequency of fungi regularly isolated from the rhizoplane of *I. ceratophyllus*. Numberator and denominator denote frequency on young and old roots respectively, – signifies absent.

Fungal species	SEASONS							
	1979			1980				
	Sum.	Aut.	Win.	Spr.	Sum.	Aut.	Win.	Spr.
Acremonium diversisporum	10/0	2/1	12/4	9/1	5/0	2/1	7/0	5/5
Aspergillus parvulus	2/0	–	2/0	0/2	12/6	6/20	11/2	4/6
Mortierella marburgensis	1/13	0/2	1/0	0/7	9/8	2/1	3/4	0/1
M. nana	4/16	9/7	10/13	19/24	32/32	30/32	42/34	16/19
Oidiodendron spp.	7/0	4/1	14/30	4/3	13/2	11/4	14/5	7/7
Penicillium citreonigrum	–	2/5	3/3	0/1	–	12/3	7/8	–
P. glabrum	0,17	0/5	–	3/1	0/1	3/1	2/0	0/1
P. raistrickii	3/11	–	4/1	0/2	–	4/1	2/5	–
P. restrictum series	14/0	0/3	3/5	3/8	6/7	11/6	12/9	11/4
P. simplicissimum	0/19	9/4	0/2	2/5	18/2	0/7	2/5	–
P. spinulosum strain A	8/5	–	–	5/2	5/3	5/3	0/5	11/9
P. spinulosum strain B	3/30	2/4	–	1/1	10/3	3/9	3/16	1/5
P. spinulosum strain C	7/20	2/0	–	5/1	7/17	26/23	8/4	6/5
P. thomii	7/11	2/3	0/1	0/3	0/3	3/4	2/1	0/2
P. sp. 1	–	3/17	0/4	–	6/23	5/22	2/4	8/11
Trichoderma viride	2/14	1/0	–	–	2/0	1/0	1/1	2/1
DS 6	0/1	8/4	0/1	1/14	0/2	2/1	0/1	0/5
DS 8	–	–	–	–	0/4	0/7	0/3	1/20
DS 21	–	6/0	–	9/13	–	–	–	–
DS 39	–	19/0	1/1	–	–	–	–	3/0
DS 42	–	9/0	0/15	16/1	0/1	0/7	8/0	4/0
DS 52	3/2	18/5	33/39	36/26	3/7	20/3	10/11	21/24
Other species	45/46	23/60	18/45	25/42	33/52	20/32	20/50	33/52
Total isolates	116/205	119/121	101/164	138/157	161/172	166/187	156/168	133/177