ECOLOGY OF THE MYCOPHAGOUS NEMATODE, *APHELENCHUS AVENAE*


by


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Thesis submitted to The University of Adelaide
in fulfilment of the requirements for the
degree of Doctor of Philosophy


July, 1984.

*Awarded Feb. 1985*

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## *SUMMARY*

The mycophagous nematode *Aphelenchus avenae* Bastian, 1865 was found to be abundant in soil from South Australian wheat-fields. Mean population density from 57 fields under wheat was 349, 242 $m^{-2}$ in the top 20cm of soil and comprised 9% of all nematodes. Population density was positively correlated with soil pH and the nematode tended to be relatively more abundant in sandier soils and in soils with higher levels of soluble salts. Studies on the distribution and abundance of *A. avenae* in saline soils surrounding brackish lagoons suggested that type of plant cover - and associated soil mycoflora - was a more important influence than salinity *per se* on population density of the nematode. The effects of salinity and pH of culture medium on population increase of *A. avenae* in monoxenic culture suggested that these factors were more likely to influence population density in soil by their actions upon host fungi rather than on the nematode. Subsequent studies concentrated on the relationship between the soil mycoflora and population density of *A. avenae.*

Abundance of *A. avenae* was studied in two soils, a field under wheat and a pine-forest, which, because of the differences in their plant covers, were expected to differ in composition of the mycoflora. *A. avenae* was more abundant in the wheat-field soil than in the pine-forest soil and litter where it was comparatively rare. *Aphelenchoides* spp. appeared to be the most common mycophagous nematodes in the pine-forest, particularly in litter. Various methods were used to compare mycofloras of soil, roots and organic debris from the two sites. It was concluded that the sites possessed distinct mycofloras and that the mycoflora of the wheat-field soil was more diverse than that of

the pine-forest soil which was dominated by *Penicillium* spp. It is suggested that composition of the soil mycoflora is a major factor influencing abundance of *A. avenae*.

To test the hypothesis that composition of the soil mycoflora influenced abundance of *A. avenae*, feeding trials were conducted using isolates of *A. avenae* and various fungi derived from wheat-field and pine-forest soils. Other mycophagous nematodes - *Aphelenchoides* spp. - from these soils were also tested to determine the degree of resource overlap between them and *A. avenae*. Genera and species groups of fungi, and individual isolates, varied markedly in their suitability as food-hosts for *A. avenae* and other mycophagous nematodes. The more diverse mycoflora of wheat-field soil afforded a greater range of suitable fungal hosts than that of pine-forest soil. *Penicillium* spp., the fungi which dominated pine-forest soil, were comparatively poor hosts for the nematode. Individual isolates of *A. avenae* from the wheat-field and pine-forest soils varied greatly in their rates of population increase in feeding trials, suggesting an underlying genetic diversity, apparently in the form of genetically distinct clones. Little host specialization appeared to exist between *A. avenae* and *Aphelenchoides* spp. that would preclude the possibility of competition for food resources. Feeding trials indicated that actinomycetes and bacteria from the two soils were little used, if at all, by *A. avenae* as food sources.

All mainland isolates of *A. avenae* examined were apparently parthenogenetic, however, a population from Dangerous Reef, an island in Spencer Gulf, proved to be amphimictic. Parthenogenetic isolates of *A. avenae*, even when derived from the same field, varied markedly in their propensity to produce males at temperatures above 25°C.

Populations of the nematode sampled north of 34°S latitude were found to have n = 9 chromosomes while those to the south had n = 8 chromosomes. There was no relationship between karyotype and propensity to produce males at high temperatures, nor were the two karyotypes correlated with any known environmental variables. Intraspecific variation between parthenogenetic populations was also observed in rates of egg-laying and population growth in monoxenic cultures. It was concluded that evolutionary development had not halted with the adoption of parthenogenesis in *A. avenae* and that mutation rates and the automictic mode of reproduction of this nematode allowed for considerable genetic flexibility. A mechanism by which heterozygosity could be maintained in this nematode is discussed.

At 25°C rates of egg-laying by females of a parthenogenetic isolate of *A. avenae* were equal to those of amphimictic females, prompting an expectation of a twofold advantage in reproductive rate for the parthenogenetic isolate. However, when inoculated together on to fungal cultures the amphimictic isolate was not selectively displaced by the parthenogenetic isolate, possibly because of an inhibitory effect on egg-laying of parthenogenetic females induced by amphimictic males. Thus, amphimictic populations may be able to maintain themselves in nature in the presence of parthenogenetic competitors. The parthenogenetic population appeared to be better adapted to higher temperatures than the amphimictic population, the rates of egg-laying and egg-hatching at 30°C being higher for the former population. The ecological correlates of parthenogenesis in this nematode are discussed.

## DECLARATION

I hereby declare that this thesis contains no
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*19th July, 1984*
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## ACKNOWLEDGEMENTS

# I. INTRODUCTION

Although *A. avenae* has been found in lesions on plant roots (Christie and Arndt, 1936), within root parenchyma tissue (Steiner, 1936) and to feed upon root hairs (Chin and Estey, 1966) and to multiply to some extent upon plant callus tissue (Barker and Darling, 1965), it is regarded as being primarily mycophagous (Hooper, 1974). Evans and Womersley (1980) considered that the reproduction of *A. avenae* in tomato root tissues observed by Chin and Estey (1966) conclusively demonstrated that at least some populations of the nematode may act as facultative plant pathogens. However, Chin and Estey allowed that the nematodes may have entered the roots to feed upon *Verticillium albo-atrum* with which the test plants had also been inoculated. Nevertheless, it is clear that the classification of *A. avenae* as a strict, obligate fungivore made by Mankau and Mankau (1963) was premature. The high rate of reproduction of this nematode upon a wide range of fungi (Townshend, 1964), certainly suggests that fungi are its preferred food. That some browsing on roots may also occur is not surprising and is in accord with the hypothesis put forward by taxonomists (Maggenti, 1971; Triantaphyllou and Hirschmann, 1980) in deriving the evolutionary development of plant parasitic nematodes from mycophagous ancestors.

Plant pathologists have concentrated mainly on the effects of *A. avenae* on root-pathogenic fungi (Rhoades and Linford, 1959; Barker, 1964; Klink and Barker, 1968; Barnes *et al.*, 1981; Caubel *et al.*, 1981) in the hope of enlisting the nematode as an agent for biological control and, more recently, on possible adverse effects on plants through feeding on mycorrhizal fungi (Sutherland and Fortin, 1968; Hussey and Roncadori, 1981). Apart from these aspects its ecological role in the soil has re-

ceived scant attention. Evans and Womersley (1980) have recently reviewed information on its behaviour, physiology and experimental uses. The factors controlling its distribution and abundance are largely unknown and are liable to remain so until there is a better understanding of the ecology of its food resources - soil fungi - and of its relationships with other soil fauna. Studies of soil fungi pose many problems owing to their enormous diversity and variety of form and all isolation methods are more or less selective for particular groups and/or types of propagules. New techniques, which aim to quantify the amount of living and active mycelium in soil (Frankland, 1975; Söderström, 1977), may eventually be of use in studies on soil fauna which feed on fungal protoplasm, but present great analytical problems when comparing different soils (Bååth and Söderström, 1982).

In surveying the literature on this nematode it was found that at least 92 species of fungi from 50 genera and including all sub-divisions of the Eumycota have been recorded as food sources for various *A. avenae* isolates in culture. Studies in which a single *A. avenae* isolate has been tested on a variety of fungi in culture (Mankau and Mankau, 1963; Townshend, 1964) also suggest that this nematode acts as an ecological generalist (that is, utilizing a wide range of resources), but that it prefers plant pathogenic fungi. However, a study has not previously been made using *A. avenae* and fungi isolated from the same soil. The present study aims to test the hypothesis that abundance of *A. avenae* is influenced by composition of the soil mycoflora. Population densities of *A. avenae* and soil mycofloras have been examined in two habitats - a field under wheat and a pine-forest - which differ markedly in the composition of their surface vegetation and hence are expected to differ in the composition

of their soil mycofloras (Waid, 1960). The suitability of these myco-
floras to support population growth of *A. avenae* was compared by measuring
rates of population growth of *A. avenae* reared on fungi from both soils.
Other mycophagous nematodes from the same soils were tested on these fungi
to determine the extent of resource overlap and, hence, the likelihood of
competitive interactions between these nematodes and *A. avenae*.

Parthenogenetic plant parasitic nematodes (Triantaphyllou and
Hirschmann, 1980) and, indeed, all parthenogenetic organisms, (White, 1973),
are commonly regarded as having strictly limited evolutionary potential.
In this study, the genetic diversity amongst parthenogenetic populations
of *A. avenae* from soils given over to the same regime of land use – to
minimize differences in the composition of the soil mycoflora – was examined
as an indication of the genetic flexibility allowed by this mode of repro-
duction. In these soils, planted to wheat, population density of
*A. avenae* was compared with physico-chemical properties of the soil to
determine their influence on abundance of the nematode. Different popu-
lations of the nematode were reared in culture under different environmental
conditions to investigate the possible adaptive significance of existing
genetic variation in relation to soil factors. Genetic variation between
parthenogenetic isolates of *A. avenae* from wheat-field and pine-forest
soils was also studied by comparing reproductive rates of the nematode
reared on various fungi.

Amphimictic populations of *A. avenae* have been found from
Western Australia (Evans, 1968; Evans and Fisher, 1970) and Malawi (Evans
and Womersley, 1980; Hooper and Clark, 1980). All other populations ex-
amined from various parts of the world including Australia (Evans and
Fisher, 1970), North America (Triantaphyllou and Fisher, 1976), South America

(Dao, 1970) and Europe (Goodey and Hooper, 1965; Dao, 1970) have apparently been parthenogenetic. Three parthenogenetic *A. avenae* populations examined by Triantaphyllou and Fisher (1976) were found to undergo meiosis and their mode of reproduction can thus be classified as automictic or meiotic parthenogenesis (White, 1973). The transition from amphimixis to meiotic parthenogenesis is viewed as a relatively simple phenomenon by cytogeneticists (White, 1973; Suomalainen *et al.*, 1979), spontaneous or tycho-parthenogenesis - thought to involve automictic mechanisms - being reported from a variety of otherwise bisexual species (White, 1973; Cuellar, 1977). The nature of the selective forces which maintain sexual reproduction in nature and the advantages accruing to an organism which adopts parthenogenesis have become central issues in evolutionary biology (Williams, 1975; Cuellar, 1977; Maynard Smith, 1978; Charlesworth, 1980; Tooby, 1982). Although parthenogenesis has arisen repeatedly amongst all families of plant parasitic nematodes (Triantaphyllou and Hirschmann, 1980), nematologists have contributed little to this discussion (but see Triantaphyllou and Hirschmann, 1964, and Poinar and Hansen, 1983, for reviews of reproduction in nematodes). Species, like *A. avenae,* which exist in both amphimictic and parthenogenetic forms may present opportunities to test some of the predictions made by evolutionary biologists. In this study, the supposed two-fold advantage of parthenogenesis (Maynard Smith, 1978) is examined with respect to *A. avenae.*

## II. MATERIALS AND METHODS

### 1. SAMPLING SITES

#### (a) *Mid-North Wheatlands Environmental Region*

In 1977 the CSIRO Division of Land Use Research published the results of its ecological survey of South Australia, a study intended to be used as a test case for assessing the suitability of LANDSAT imagery for this purpose (Laut *et al.*, 1977). The approach used to map and describe the environments of South Australia was a modified form of integrated re-connaissance survey in which regions were characterized by combinations of attributes (rather than one single attribute such as soils, vegetation or land use) but with emphasis being given to geomorphology. A simple four-level hierarchy of areal units was used to provide the necessary scales to describe environmental conditions, ranging from the smallest, "environmental units", through "environmental associations" and "environmental regions" to "environmental provinces". This system is suitable for use in organizing field surveys of soil fauna, more so than mapping systems which use an arbitrary grid because the areal units relate to actual environmental conditions. The northern-most region of the Mt. Lofty Block Province, named the Mid-North Wheatlands Environmental Region (Fig. 1) after its pre-dominant land use, provided an ideal basis for a survey of *Aphelenchus avenae* in wheat-fields. It extends from Adelaide to Quorn, the northern boundary marked by the approximate northern limit of wheat cultivation, and encompasses considerable climatic heterogeneity. Mean annual rainfall ranges from 250-700 mm while mean annual evaporation ranges from 1800-2400 mm. It consists of 19 environmental associations covering an area of 13,180 $km^2$; the associations ranging in size from 20 $km^2$ to 2,090 $km^2$. The geomorphology is characterized by narrow ridges separated by wide plains. The dominant

FIG. 1: The Mid-North Wheatlands Environmental
Region (hatched area) of South Australia

Coondambo  Lake Hanson  "Arcoona"  ORRENS  Blinman  Parachilna  "Wirrealpa"

Lake Hart  WOOMERA  7.2  Brachina  St Mary Peak  "Martins Well"

Pimba  Lake Windabout  A.B.C. RANGE  Morolana  Wilpena Pound  Wilpena

7.3  Island Lagoon  MT GUNSON  Pernatty Lagoon  DRUID RA  "Curnamon"

LAKE  "Mahanewo"  Lake Finnis  Woocalla  Lake Dutton  Hawker  6.1  "Baratta"  Sicrus  GAS RIVER  MT VIC

GAIRDNER  Lake MacFarlane  Cradock  FLINDERS  "Plu"

"naree"  "Yudnapinna"  Hesso  MT ARDEN  Willochra  Willochra  Waukaringa  Manna

"Thurlga"  "Corraberra"  Quorn  Carrieton  5.2  Yunta

NUKEY BLUFF  RANGES  "Nonning"  PORT AUGUSTA  MT BROWN  Carrieton  Paratoo

7.1  Wilmington  Orroroo  Manunda

4.4  Iron Knob  MT REMARKABLE  NARIEN RA  NATURAL  PETERBOROUGH

Buckleboo  Lake Gilles  "Gilles Downs"  Iron Baron  False Bay  Port Germein  Booleroo Centre  MT BRYAN

Kimba  MT MIDDLEBACK  WHYALLA  Laura  Jamestown  "Bendigo"

HIGHWAY  "Moonabie"  PORT PIRIE  Gladstone  Georgetown

arramboo  EYRE  "Moonabie"  Crystal Brook  Spalding  MT BRYAN

ncutta  CARALUE BLUFF  Broughton  Brinkworth  Burra  "The Gums"

DARKE PEAK  CARAPPEE HILL  River  4.6  CLARE  Burra Creek

PENINSULA  Snowtown  Mintaro  Robertstown

Lock  Cleve  Cowell  Franklin Harbour  Wallaroo Bay  WALLAROO  Bumbunga  3.3  Morgan

Rudall  KADINA  Balaklava  Riverton  Eudunda

Tooligie  Arno Bay  Tiparra Bay  Moonta  Wakefield  Kapunda  Blanche Town

Port Neill  Port Wakefield  Hamley Bridge  Truro  STURT  2.4

Yeelanna  LINCOLN HIGHWAY  SPENCER  Maitland  Ardrossan  NURIOOTPA

Malata  Cummins  Dublin  Angaston  Swan Reach

Tumby Bay  Wardang Is.  YORKE PENINSULA  Tanunda  BLACK HILL

4.1  GULF  Sir Joseph Banks Group  Hardwicke Bay  GAWLER  MURRAY

Louth Bay  Spilsby Is.  Minlaton  Port Vincent  SALISBURY  ELIZABETH  Mt Pleasant

COLN  Cape Donington  Corny Point  4.5  Klein Pt  Gumeracha  MANNUM

Thistle Is.  Yorketown  ADELAIDE  Lobetha  Nairne  Kanmantoo  MURRAY BRIDGE

edford Ba  Formby Bay  Lake Fowler  Edithburgh  ST VINCENT  MT BARKER  Monarto South  Tailem Bend

Cape Catastrophe  Gambier Islands  Sturt Bay  Port Noarlunga  Echunga  Moorlands

Neptune Islands  Foul Bay  GULF  3.2  Strathalbyn  Milang  Cook Plains

Stenhouse Bay  Willunga  Myponga  Lake Alexandrina  Coomand

Cape Spencer  INVESTIGATOR  STRAIT  Rapid Bay  Goolwa  2.1  Lake Albert  Meningie

MT McDONNELL  Pt Marsden  Fleurieu Pen  VICTOR HARBOR  Encounter Bay  Tintina

Cape Borda  Kingscote  Cygnet R  Nepean Bay  Backstairs Passage  Cape Willoughby

KANGAROO  ISLAND  Parndana  Penneshaw  PRINCES

"Rocky River"  3.1  D'Estrees Bay

Maupertuis Bay  Vivonne Bay  Cape Gantheaume

soil type is a hardsetting pedal red duplex soil, Dr 2.23 in the classifi-
cation of Northcote (1974). This red-brown earth is the mainstay of wheat
growing in South Australia (Stace *et al.*, 1968).

Fifty-seven soil samples were taken from fields under wheat in
the Mid-North Wheatlands Environmental Region during the 1980 wheat season
between 28 July and 17 October. All 19 environmental associations were
sampled at least once, some as many as 8 times (Table 1, Fig. 2).

### (b) *Williamstown Wheat-Field and Pine-Forest*

The wheat-field and pine-forest chosen for a more detailed study
of the abundance of *A. avenae* were selected on the basis of their proximity,
both being located near Williamstown (34°40'S, 138°53'E), South Australia in
the Rosedale Environmental Association (3.3.1, see Fig. 2). Mean annual
rainfall in this area is about 560 mm.

The pine-forest, planted with *Pinus radiata* D. Don in 1966, is
located on the northern shore of the South Para Reservoir. The field,
under wheat at the time of sampling, is situated 5 km north-west of the
forest on the northern face of a hill sloping at 10-15°. It had had a
rotation of cereals and pasture grasses since at least before 1960. Wood-
land dominated by *Eucalyptus leucoxylon* and *E. odorata* originally covered
much of the surrounding region (Laut *et al.*, 1977) while the dominant soil
type is a hard setting pedal red duplex soil (Dr 2.23 in the classification
of Northcote, 1974).

## 2. SOIL SAMPLING

### (a) *Mid-North Wheatlands Environmental Region*

In the survey of mid-north wheat-fields, soil samples 18.5 cm wide

TABLE 1: Soil samples taken from fields under wheat from Environmental
Associations of the Mid-North Wheatlands Environmental Region
during the 1980 growing season

| Environmental Association | | No. Samples | Dates Sampled |
|---|---|---|---|
| Rosedale | (3.3.1) | 1 | 28/7 |
| Freeling | (3.3.2) | 8 | 28/7(7),  3/9(1) |
| Stockport | (3.3.3) | 2 | 28/7 |
| Tarlee | (3.3.4) | 3 | 22/9(1), 16/10(2) |
| Shearers Hill | (3.3.5) | 2 | 28/7      16/10 |
| Mopami | (3.3.6) | 6 | 28/7(3),  3/9(3) |
| Rufus | (3.3.7) | 2 | 3/9 |
| Neales Flat | (3.3.8) | 2 | 3/9 |
| Burra Hill | (3.3.9) | 2 | 3/9      17/10 |
| Apoinga | (3.3.10) | 2 | 16/10 |
| Hansen | (3.3.11) | 7 | 22/9(2), 16/10(5) |
| Bald Hill | (3.3.12) | 2 | 16/10 |
| Clare | (3.3.13) | 3 | 22/9(2), 17/10(1) |
| Yongala | (3.3.14) | 2 | 22/9      17/10 |
| Yacka | (3.3.15) | 2 | 22/9 |
| Appila | (3.3.16) | 4 | 22/9(1), 17/10(3) |
| Tarcowie | (3.3.17) | 1 | 17/10 |
| Wirrabara | (3.3.18) | 2 | 17/10 |
| Mt. Remarkable | (3.3.19) | 4 | 17/10 |

FIG. 2 (A,B & C): Mid-North Wheatlands Environmental Region showing Environmental Associations (3.3.1 - 3.3.19) and the locations (numbered) of the 57 fields under wheat sampled. The wheat-field and pine-forest sampled near Williamstown (in Environmental Association 3.3.1) are marked by stars, the more southerly of which corresponds to the pine-forest.

The northern boundary (top of page) of Map A joins the southern boundary of Map B; Map C similarly joins Map B.

ADELAIDE
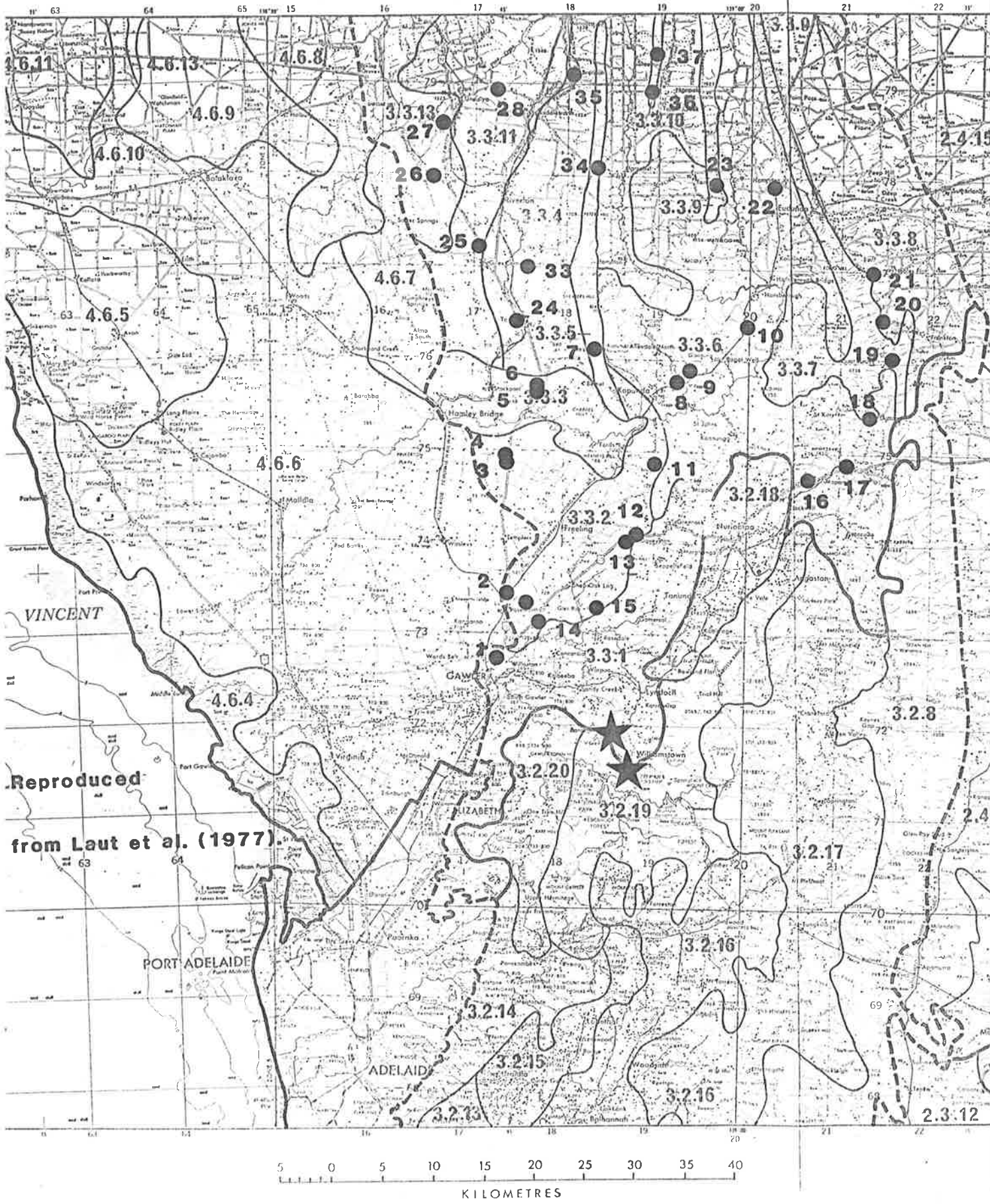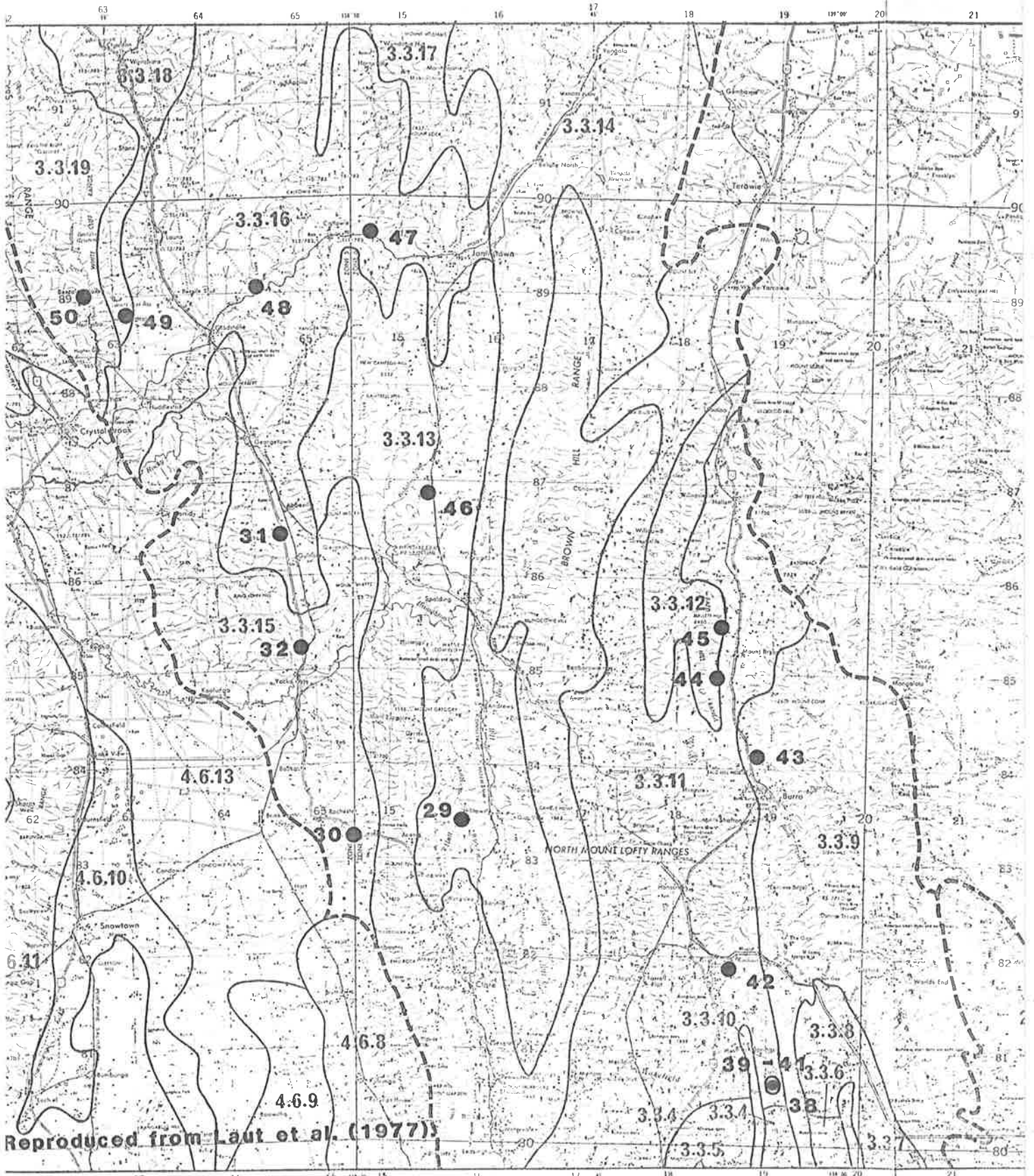
A

Reproduced from Laut et al. (1977).

VINCENT

PORT ADELAIDE

ADELAIDE

KILOMETRES
5  0  5  10  15  20  25  30  35  40

BURRA

B

3.3.18
3.3.19
3.3.17
3.3.14
3.3.16
● 47
● 48
50
● 49
3.3.13
● 46
31 ●
3.3.15
32 ●
3.3.12
● 45
● 44
● 43
3.3.11
2.9 ●
30 ●
4.6.13
NORTH MOUNT LOFTY RANGES
4.6.10
3.3.9
● 42
6.11
3.3.10
3.3.8
4.6.8
39 ─ 41
3.3.6
4.6.9
● 38
3.3.4
3.3.4
Reproduced from Laut et al. (1977)
3.3.5
3.2.7

5    0    5    10    15    20    25    30    35    40
KILOMETRES

# PORT AUGUSTA — ORROROO

55

54

53

56

57

3.3.16

3.3.19

52

4.6.16

3.3.17

3.3.18

51

3.3.14

KILOMETRES
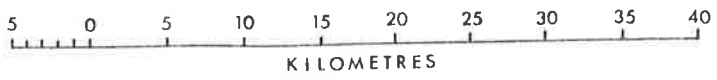
and 20 cm deep, were taken with a spade.   Three sub-samples were arbitrarily
taken from each wheat-field sampled and bulked to give a combined sample of
5-7 kg in weight.   Large stones were removed and soil clods broken by
hand and the sample was thoroughly mixed by shaking in a polythene bag for
one minute.

### (b)  *Williamstown Wheat-Field and Pine-Forest*

A 3-hectare area, 200 by 150 m, was arbitrarily chosen for study
at each site and soil sampled from each of 12 quadrats, 50 m square.   The
locality within each quadrat sampled was chosen by a random-walk technique
in which numbers of paces (from 0-60, 60 paces corresponding to about 50 m)
north and east of the south-west corner of each quadrat were assigned by
random number tables.   At the locality so chosen, six sub-samples were
taken with a 5 cm diameter auger to a depth of 10 cm from an area of one-
metre square and bulked together.   Large stones were removed and soil clods
broken by hand and the sample was thoroughly mixed by shaking in a polythene
bag for one minute.   An additional sample was taken from each quadrat of
the wheat-field with a spade from the nearest row of wheat to measure plant
height.

The surface litter was brushed away from the floor of the pine-
forest before sampling of the mineral horizons but coverings of mosses and
liverworts were not removed.   Samples of litter from each of the L, F and
H-layers defined by Hesselman (1926) and Kubiena (1953) were also taken from
each quadrat in the pine-forest.   These layers could be distinguished by
the stage of decomposition of the pine-needles.   The L-layer was character-
ized by undecomposed, non-compacted litter composed of brown, intact needles.
The F-layer was more compacted and was composed of darker brown, partially
fragmented needles.   Where the litter was sufficiently deep it could be

divided into $F_1$- and $F_2$-layers.  Needles were often intact in the $F_1$-layer but were more fragmented and compressed in the $F_2$-layer.  Fungal hyphae were very dense in the $F_2$-layer, with basidiomycetes, especially *Amphinema byssoides*, forming a continuous mat.  The H-layer was composed of dark, amorphous humus.

## 3. PHYSICO-CHEMICAL CHARACTERISTICS OF SOILS

### (a) *Mid-North Wheatlands Environmental Region*

#### (1) Soil pH

Soil pH was measured with soil suspended in 0.01 M $CaCl_2$ solution (Peech, 1965).

#### (2) Total soil salinity

Electrical conductivity of 1:5 soil:water extracts in $\mu$ S $cm^{-1}$ at 25°C was determined to give an indication of total soil salinity.

#### (3) Soil texture

Soil texture was estimated using the method of Jaenike *et el.* (1980).  Soil was first dried at 90°C for 72 hours and sifted through a 2 mm sieve.  Ten g of soil was added to a large test-tube, mixed with 30 ml distilled water and agitated for 2 min. at maximum speed on a laboratory test-tube shaker. The suspension was allowed to settle for 30 sec., the components separated, dried at 90°C for 72 hours and weighed.  The component that settled in 30 sec. was designated sand, and that remaining in suspension was designated silt and clay.

The results obtained by this simple technique were found to be reproducible.  For example, results from 5 replicate assays on soil from sample no. 40 are given on the next page.

| Replicate | % Silt and Clay | % Sand | Total |
|-----------|-----------------|--------|-------|
| 1 | 60.1 | 39.5 | 99.6 |
| 2 | 59.5 | 40.0 | 99.5 |
| 3 | 59.8 | 39.8 | 99.6 |
| 4 | 57.8 | 41.6 | 99.4 |
| 5 | 54.3 | 45.0 | 99.3 |

Totals do not attain 100% due to small losses of material, ranging from 0.04-0.07 g, during separation of components. Results obtained by this method on wheat-field soils are very similar to those obtained with more elaborate hydrometer methods (Table 2).

### (b) Williamstown Wheat-Field and Pine-Forest

Soil pH and total soil salinity were determined for soil samples from these sites by the methods described above. In addition, % soil moisture was determined for 2 replicate 50 g sub-samples per sample by drying in a 90°C oven for 72 hours. Soil texture was determined for a sample from each site by both the methods of Jaenike et al. (1980) and the hydrometer method (Piper, 1950), allowing a comparison of these methods to be made. Results obtained by the two methods were similar, especially with the wheat-field soil (Table 2). With the much coarser pine-forest soil the hydrometer methods gave somewhat higher readings for the silt and clay component.

### 4. EXTRACTION OF NEMATODES

A modified Baermann method (after Whitehead and Hemming, 1965) was used throughout for extraction of nematodes from soil. Large numbers of samples can be processed simultaneously by this method. Fifty ml of soil were evenly spread over a 2-ply facial tissue supported by a stainless-steel wire mesh placed in water in a 140 mm Petri dish. Nematodes were extracted over 48 hours at room temperature and counted in Doncaster dishes. *Aphelenchus avenae* could be readily identified under a stereoscopic dissecting

TABLE 2: Comparison of hydrometer (H) method and method of Jaenike *et al.*
(1980) for determining soil texture in wheat-field (W) and pine-
forest (P) soils

| Soil | Replicate | % silt and clay | | % sand | |
|------|-----------|------|------|------|------|
|      |           | H    | J    | H    | J    |
| W | 1 | 50.36 | 53.5 | 49.64 | 46.2 |
|   | 2 | 51.96 | 50.6 | 48.04 | 49.2 |
|   | 3 | 52.16 | 54.0 | 47.84 | 45.8 |
|   | 4 | – | 53.0 | – | 46.4 |
|   | Mean | 51.49 | 52.8 | 48.51 | 46.9 |
| P | 1 | 14.56 | 8.7 | 85.44 | 91.0 |
|   | 2 | 14.76 | 8.5 | 85.24 | 91.4 |
|   | 3 | 15.16 | 8.5 | 84.84 | 91.2 |
|   | Mean | 14.82 | 8.6 | 85.17 | 91.2 |

microscope and specimens removed for starting cultures. Two replicate 50 ml soil samples were processed for each sample from the Williamstown wheat-field and pine-forest.

Nematodes were extracted from basidiomycete fructifications using a thermal misting apparatus or the modified Baermann method. Thermal misting and a modified Minderman (1956) technique were used to extract nematodes from pine-forest litter. Pine-needle fragments were supported on a nylon mesh with 1 mm openings in a beaker of water and agitated gently at 20 oscillations per minute in an orbital shaking water bath for 24 hours at 20°C. Reproducible results could be obtained by this technique; 10 replicate 300 mg samples of litter from the $F_2$-layer yielded a mean of 91.2 ± 6.1 (S.E.) nematodes. Yields from litter extracted by thermal misting attained 212 nematodes per g of litter.

## 5. MONOXENIC CULTURES OF MYCOPHAGOUS NEMATODES

Monoxenic cultures of *A. avenae* obtained from all soil samples were established using a fungus as a food source growing on neutral Dox yeast (NDY) agar (Appendix 1), pH 5.5 with 100 ppm streptomycin and 10 ppm tetracycline, in 90 mm Petri plates. Cultures were normally started using two adult female specimens of the nematode. These were treated with 0.5% chlorhexidine gluconate, a bacteriocidal and fungicidal agent (Peacock, 1959), for 5 minutes and washed in sterile distilled water before being transferred by hand to a drop of sterile water on the surface of the agar. Plates were incubated at 25°C. Once cultures were established a single female from each was used to start new cultures and thus obtain nematodes of common descent for use in experiments.

A strain of *Rhizoctonia solani* obtained from Dr. J.M. Fisher was initially used as a food source to establish *A. avenae* from Mid-North

Wheatlands soil samples but this proved to be an unsuitable host for a number of isolates of the nematode. A strain of *Botrytis cinerea* isolated from a *Myoporum* sp. by Dr. J.H. Warcup proved to be a universally acceptable host for *A. avenae* isolates and was subsequently used to maintain all cultures of the nematode.

The same procedures were used to attempt culture of other possible mycophagous nematodes such as *Aphelenchoides* spp. and Dorylaims.

## 6. KARYOTYPE DETERMINATION IN *APHELENCHUS AVENAE*

Meiotic chromosomes in *A. avenae* oocytes were stained with acetic orcein following a similar procedure to that of Triantaphyllou and Hirschmann (1966). Adult female *A. avenae* were smeared across clean microscope slides with the tip of a hypodermic needle and the cuticles removed. Slides were hydrolyzed in 1N HCl for 5-10 min., fixed in 1:3 acetic acid: ethanol for 20-40 min., stained in 2% orcein in 45% acetic acid for 20-30 min. and rinsed briefly in 45% acetic acid before mounting.

## 7. SEPARATION OF POLYPEPTIDES IN NEMATODE HOMOGENATES BY POLYACRYLAMIDE GEL ELECTROPHORESIS

*A. avenae* were cultured in mass on *Botrytis cinerea* as a food source using the method of Evans (1970). The nematodes were concentrated into a small volume, suspended in cold 0.125 M Tris-HCl buffer, pH 6.8, spun down for several minutes in a bench centrifuge and the supernatant removed. Further buffer was then added equal to the wet weight of the nematodes. Nematodes were homogenized at 5°C with a teflon pestle, spun down for 10 min. at 12,800 g and the supernatant stored at -70°C until use.

## 8. SEPARATION OF LENGTH-CLASSES OF *APHELENCHUS AVENAE*

Attempts were made to separate mass cultures of *A. avenae* into uniform length-classes to compare polypeptide patterns of adult and larval stages by polyacrylamide gel electrophoresis.   Laboratory sieves and poly-amide monofilament cloth (Myers *et al.*, 1971) were found to be more convenient for this purpose than glass microbeads (Chow and Pasternak, 1969). Sieves were placed in containers partially filled with water and a suspension of  nematodes added.   After varying periods of time nematodes retained on sieves were separated from those having passed through and the lengths of ten randomly selected nematodes from each group measured from drawings made with a camera lucida (Appendix 2).   Although useful separations of length-classes could be achieved by this technique, results varied with cultures of different ages.

## 9. GENERAL METHODS OF ISOLATION OF FUNGI FROM SOIL

Fungi were isolated from Williamstown soil samples using dilution and soil plate methods (Warcup, 1950) with neutral Dox yeast (NDY) agar, pH 5.5, containing 100 ppm streptomycin.

Dilution plates were prepared at a dilution of $10^{-4}$, incubated at 25°C and colonies sub-cultured onto NDY after 2-5 days.   Soil plates were prepared by transferring about 5 mg of soil with a sterile spatula to a drop of sterile water in a Petri dish, dispersing the soil in the drop and pouring cooled but molten NDY into the dish.   Soil plates were treated in the same manner as dilution plates.

Mycelial cultures of basidiomycetes were started from fruiting bodies by inoculation of 2% malt agar (Appendix 1) with small portions of cap or  stipe tissue.

## 10. ISOLATION OF FUNGI FROM PLANT ROOTS

Washed wheat and *Pinus* roots were cut into 1 cm lengths, treated with either a solution containing 1000 ppm of both neomycin and streptomycin (30 min) or 0.5% sodium hypochlorite (1 min), washed in sterile water and plated onto NDY with 100 ppm streptomycin.

## 11. ISOLATION OF ACTINOMYCETES AND BACTERIA FROM SOIL

Actinomycetes and bacteria were isolated from Williamstown soil samples using dilution plates with 2% water agar, pH 7.2 (Lingappa and Lockwood, 1962). Dilution plates were prepared at a dilution of 1/5000 and incubated at 28°C for one week before counts were made of colonies and sub-cultures made. Actinomycetes were sub-cultured onto Krainsky's medium and bacteria onto nutrient agar (Appendix 1).

## 12. FEEDING TRIALS

Nematodes to be used in feeding trials were extracted from 2-week old cultures maintained at 25°C on *Botrytis cinerea* on NDY agar using Baermann funnels through 4 layers of facial tissue. This procedure removed much of the fungal debris and, provided cultures were kept in the dark to inhibit sporulation, fungal spores were rarely a problem. Since stock cultures were maintained on *B. cinerea* and nematodes used in feeding trials were subsequently discarded, each feeding trial represented a novel situation in that neither the nematodes nor their progenitors had been previously exposed (at least in the laboratory) to the test organism before.

Nematodes were treated with either 0.5% chlorhexidine gluconate for 2-10 min or a solution containing 1000 ppm benzyl-penicillin, 1000 pm streptomycin and 10 ppm tetracycline for 1 hour before washing in sterile

water.    A drop of sterile water was placed on the surface of the agar of
test plates and 5 adult female nematodes transferred to the drop by hand.

### (a)  *Fungi*

Fungi to be tested as food sources were grown at 25°C on NDY
agar plates.    Discs, 6 mm in diameter, were taken from the growing margin
of 2 week-old cultures, or, in the case of slow-growing forms such as many
of the basidiomycetes, from 4-6 week-old cultures.    One disc was placed in
the centre of the agar surface in each test plate which consisted of 9 cm
plastic Petri dishes containing 10-12 ml of NDY agar, pH 5.5, with 100 ppm
streptomycin and 10 ppm tetracycline.

### (b)  *Actinomycetes*

Actinomycetes were maintained on Krainsky's medium at 25°C and
9 cm plastic Petri dishes containing 10-12 ml of the same agar medium in-
oculated with actinomycetes by streaking with a sterile loop passed over the
surface of the stock culture.

### (c)  *Bacteria*

Bacteria were tested as food sources of  nematodes in the same
manner as were actinomycetes, except that nutrient agar was used.

### (d)  *Harvesting of Nematodes*

Plates inoculated with nematodes and test organisms were incu-
bated for 2 weeks in the dark at 25°C before harvesting.    Plates were
harvested by dicing the agar and placing on 2-ply facial tissue supported
in a Petri dish of water by a coarse nylon mesh for 48 hours.    An aliquot
of the nematode suspension was examined under a dissecting microscope and
the number of adults (of each sex) and larvae counted such that at least
100 individuals were counted per plate.    The total number of nematodes per

plate was then calculated.    If there were less than 100 nematodes per plate the total number was counted.

At least 4 replicate  plates per test organism were used and in many cases this number was exceeded.    However, plates were discarded if contaminated with extraneous bacteria or fungi.

## III. INTRASPECIFIC VARIATION AND ABUNDANCE OF
### *APHELENCHUS AVENAE*

Variation between populations of *A. avenae* and abundance of the nematode were studied firstly, in soil from a single type of habitat from a defined area - wheat-fields of the Mid-North Wheatlands Environmental Region - and secondly, in soil from a variety of habitats from different areas.

### 1. ABUNDANCE OF *APHELENCHUS AVENAE* IN WHEAT-FIELDS OF THE MID-NORTH WHEATLANDS ENVIRONMENTAL REGION

*A. avenae* was found in soil from all 57 fields under wheat from the Mid-North Wheatlands Environmental Region. Mean population density was $92.2 \pm 15.0$ (S.E.) per 50 ml soil (corresponding to 349, 242 $m^{-2}$ in the top 20 cm of soil) with numbers ranging from 4 to 520. It is clear that *A. avenae* comprises a numerically important part of the nematode fauna of South Australian wheat-field soils, a fact emphasized by a comparison with data from other sites. For instance, *A. avenae* ranged from 3000-28000 $m^{-2}$ in the top 10 cm of soil from five New Zealand sites under pasture (Yeates, 1981). Under permanent pasture at the Waite Agricultural Research Institute, *A. avenae* was found at a mean population density of 12.9 per 50 ml soil.

*A. avenae* made up $9.0 \pm 1.2$ (S.E.) % of total nematodes extracted from wheat-field soil. Relative abundance ranged from 0.4 to a massive 50.9% of total nematodes, the latter figure coming from soil first planted to wheat in the year of sampling on the edge of a brackish lagoon (see Black Springs Lagoon transect p. 31). Relative abundances were generally lower in the other wheat-fields which normally also had much longer cropping histories. *A. avenae* is known to be a significant component of the nematode fauna under other field crops; thus it made up 2-7% of total nematodes in soybean fields (Norton *et al.*, 1971). Relative abundance in wheat-field

soil was, however, much higher than that found in soils under pasture.
*A. avenae* made up only 1.5% of total nematodes under permanent pasture at
the Waite Agricultural Research Institute, while Yeates (1981) found it
comprised 0.3-3.5% of total nematodes in five New Zealand soils under grazed
pasture.

Mean population density of nematodes from wheat-field soil was
1105 ± 127.3 (S.E.) for 50 ml soil corresponding to 4184 000 $m^{-2}$ in the top
20 cm of soil;  a moderate value compared with other terrestrial ecosystems
(Sohlenius, 1980) and exceeding that − 638.4 ± 83 (S.E.) − calculated from
data of Oostenbrink *et al.* (1956) for an equivalent amount of soil from 8
Dutch wheat-fields.

Washed wheat roots from several soil samples were treated with
boiling lactophenol containing 0.1% cotton blue to stain nematodes but
*A. avenae* were not detected in roots.

2. ASSOCIATIONS BETWEEN ABUNDANCE OF *APHELENCHUS AVENAE* AND ENVIRON-
   MENTAL FACTORS IN MID-NORTH WHEATLANDS ENVIRONMENTAL REGION

Correlation and regression analyses were applied to data on
abundance of *A. avenae* (no. per 50 ml soil and % of total nematodes) and the
following environmental variables:  EC 1:5 − electrical conductivity of 1:5
soil − water suspension in μ S $cm^{-1}$ at 25°C;  ECe − electrical conductivity
of soil-water suspension (EC 1:5) multiplied by a conversion factor (F)
which varies with soil texture (Berstein, 1964).  Conversion factors used
were those listed in Heanes (1981) and soil texture classes of Chittleborough
(1981) were assigned on the basis of % clay content;  soil pH;  % sand − soil
fraction settling in 30 sec;  P/E − mean annual precipitation/mean annual
evaporation (mm) for the particular Environmental Association as listed by
Laut *et al.* (1977);  MA − mean altitude (m) of the particular Environmental
Association as listed by Laut *et al.* (1977).

The resulting correlation matrix is presented in Table 3. At sites where *A. avenae* was abundant the nematode also tended to be relatively more abundant (as % of total nematodes), that is, the density of this nematode did not vary simply with the total population of nematodes. This suggests that some fields were more favourable than others for population development of *A. avenae*. Population densities of *A. avenae* tended to be higher in more alkaline soils and the nematode tended to be relatively more abundant in soils with higher levels of soluble salts (as reflected by higher ECe and EC 1:5 values). This does not necessarily mean that *A. avenae* prefers soils of higher pH or that it is less sensitive to salinity than other nematodes of wheat-field soils; these factors may be influencing population densities indirectly. *A. avenae* tended to be relatively more abundant in sandier soils. Norton *et al.* (1971) also found *A. avenae* tended to be relatively more abundant in sandier soils compared with soils with higher clay contents from 40 soybean fields.

Soil pH was positively correlated with the level of soluble salts (EC 1:5 and, to a greater extent, with ECe). ECe (but not EC 1:5) was positively correlated with soil pH and, not surprisingly, % sand. A higher correlation was found between % total nematodes and ECe than with EC 1:5. These results suggest conversion of data to ECe is a useful step to take in ecological surveys of soil fauna. Mean altitude was negatively correlated with the precipitation/evaporation ratio and with soil pH.

Regression analyses were summarized in Table 4 and data are depicted in Figs. 3-8. Conclusions drawn were that *A. avenae* tends to be relatively more abundant in soils with higher levels of soluble salts (a relationship more clearly illustrated, once again, by the use of ECe) and in sandier soils; and numerically more abundant in more alkaline soils.

TABLE 3: Correlation matrix (55 d.f.) between absolute and relative (% of total nematodes) abundance of *A. avenae* in 57 wheat-fields in the Mid-North Wheatlands Environmental Region and various environmental factors

|         | No.    | % total | EC 1:5 | pH     | % sand | P/E    | ECe  | MA   |
|---------|--------|---------|--------|--------|--------|--------|------|------|
| No.     | 1.00   |         |        |        |        |        |      |      |
| % total | 0.46*  | 1.00    |        |        |        |        |      |      |
| EC 1:5  | 0.25   | 0.31*   | 1.00   |        |        |        |      |      |
| pH      | 0.36*  | 0.18    | 0.52*  | 1.00   |        |        |      |      |
| % sand  | −0.18  | 0.26*   | −0.03  | −0.04  | 1.00   |        |      |      |
| P/E     | −0.01  | 0.08    | −0.09  | 0.07   | 0.04   | 1.00   |      |      |
| ECe     | 0.01   | 0.41*   | 0.83*  | 0.27*  | 0.38*  | −0.01  | 1.00 |      |
| MA      | 0.03   | 0.18    | 0.18   | −0.26* | −0.22  | −0.36* | 0.14 | 1.00 |

*Correlation coefficient significant at 5% level.

TABLE 4: Summary of regression analysis and analysis of variance for
absolute and relative (% of total nematodes) abundance of
*A. avenae* in 57 wheat fields of Mid-North Wheatlands Environ-
mental Region on various environmental variables

| Regression | Regression Coefficient | F-value | % Variance accounted for |
|---|---|---|---|
| No. on EC 1:5 | 1.88 | 3.54 | 4.3 |
| % total on EC 1:5 | 2.37* | 5.64* | 7.6 |
| No. on ECe | 0.07 | 0.01 | R |
| % Total on ECe | 3.30* | 10.90* | 15.0 |
| No. on pH | 2.89* | 8.33* | 11.6 |
| % Total on pH | 1.35 | 1.82 | 1.4 |
| No. on % sand | −1.38 | 1.90 | 1.6 |
| % Total on % sand | 1.97* | 3.89 | 4.9 |
| No. on P/E | −0.08 | 0.01 | R |
| % Total on P/E | 0.57 | 0.32 | R |
| No. on MA | 0.21 | 0.05 | R |
| % Total on MA | 1.32 | 1.73 | 1.3 |

* Significant at 5% level.

R – Residual variance exceeds variance of y-variate.

FIG. 3: Fitted regression lines for number of
*A. avenae* per 50 ml soil (a) and as
% of total nematodes (b) on electrical
conductivity of 1:5 soil:water sus-
pension from 57 wheat fields of Mid-
North Wheatlands Environmental Region.

(a) No. _A. avenae_

(b) % Total Nematodes

$EC_{1:5}$
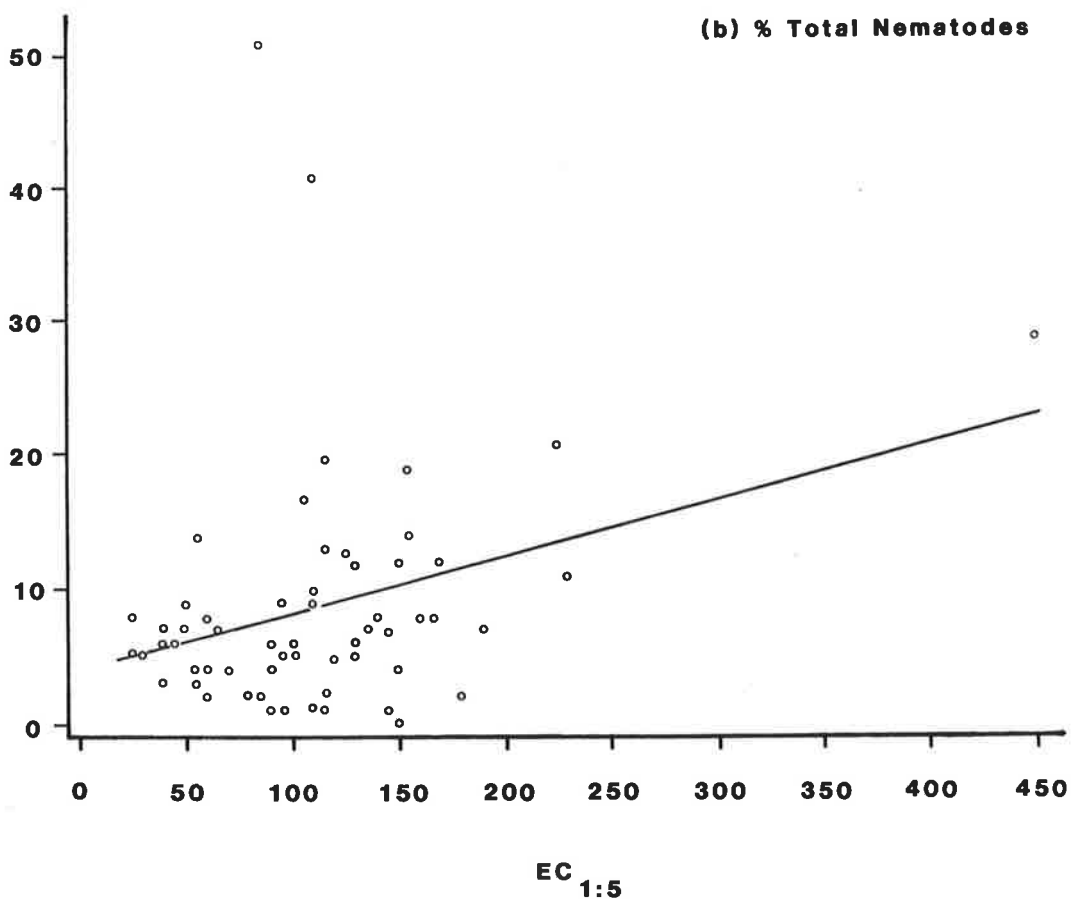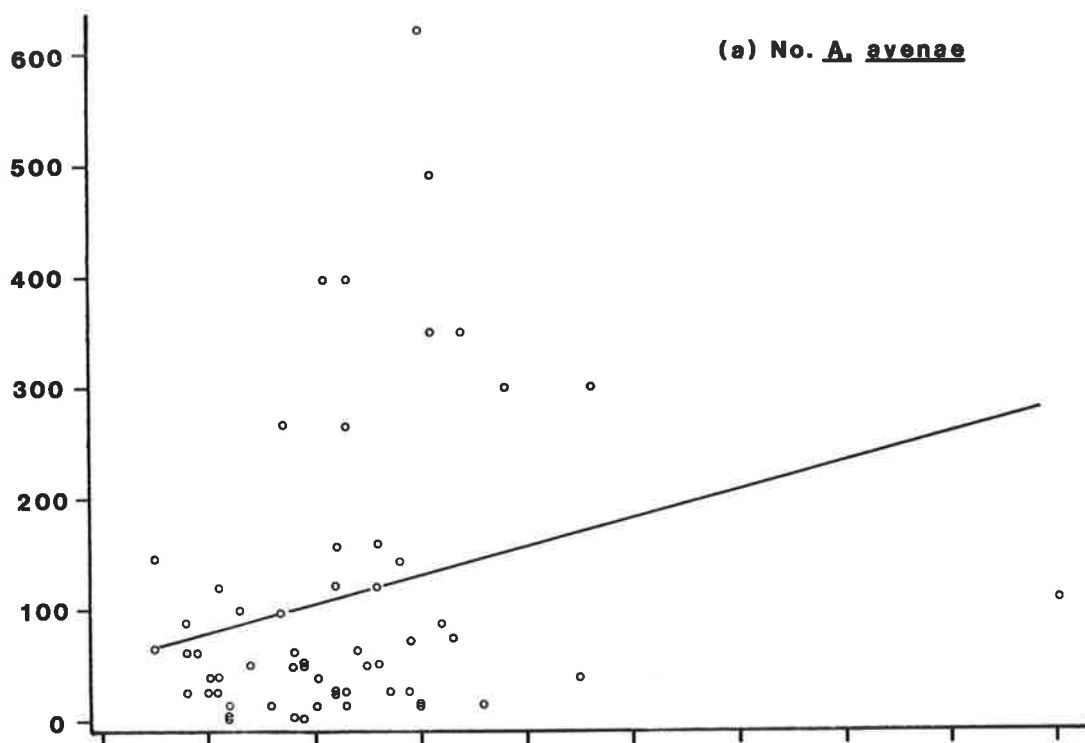
FIG. 4: Fitted regression lines for number of
*A. avenae* per 50 ml soil (a) and as %
of total nematodes (b) on electrical
conductivity of soil-water suspension,
modified to take account of variation
arising from different soil textures
(ECe) from 57 wheat fields of Mid-North
Wheatlands Environmental Region.

(a) No. _A. avenae_

(b) % Total Nematodes

ECe
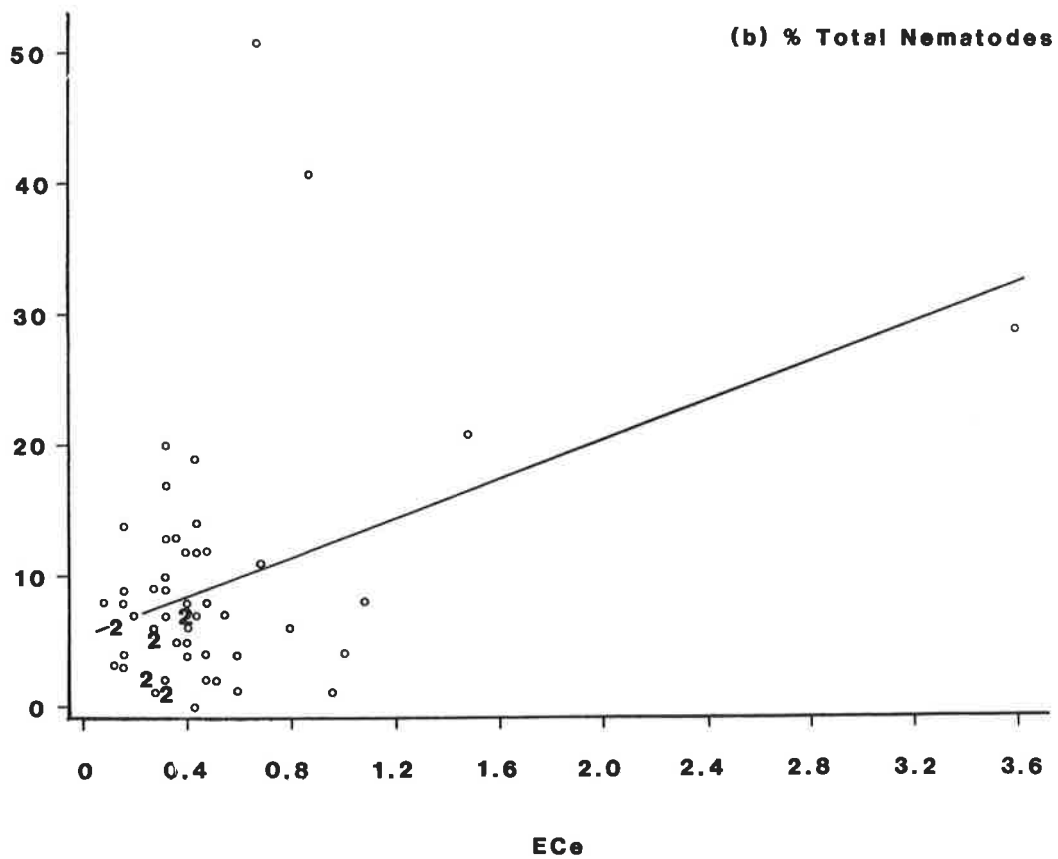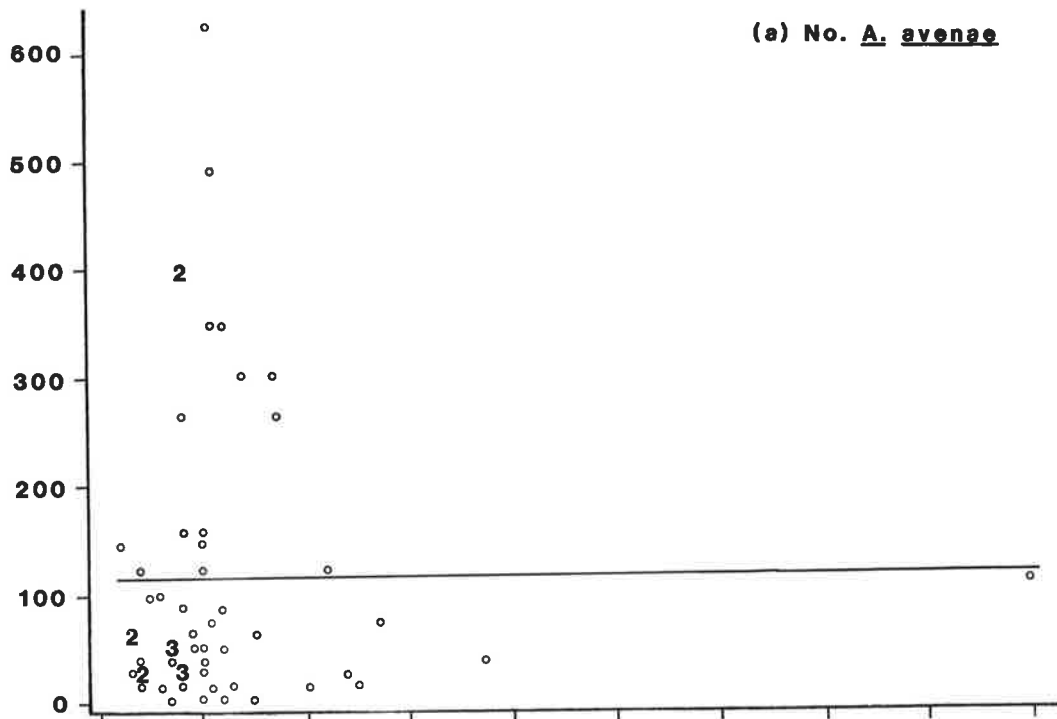
FIG. 5: Fitted regression lines for number of
A. *avenae* per 50 ml soil (a) and as %
of total nematodes (b) on soil pH for
samples from 57 wheat fields of Mid-
North Wheatlands Environmental Region.

(a) No. A. avenae

(b) % Total Nematodes

Soil pH
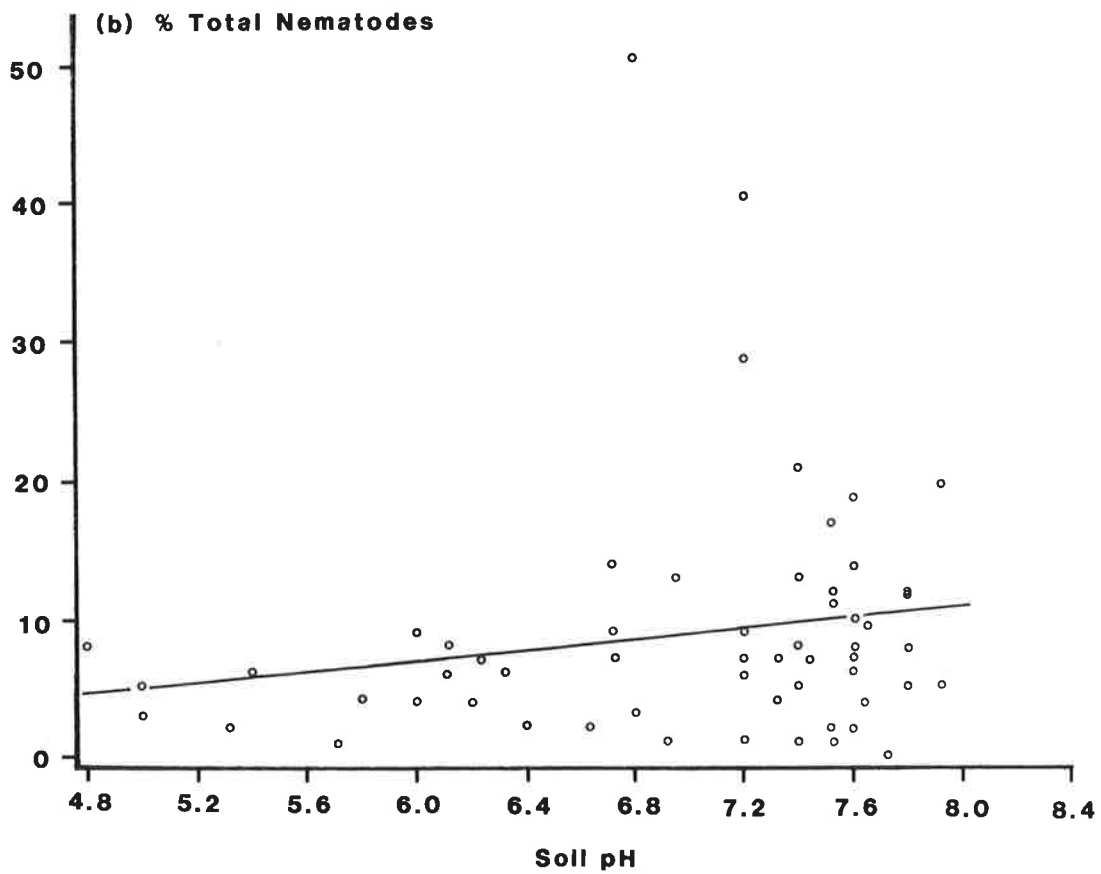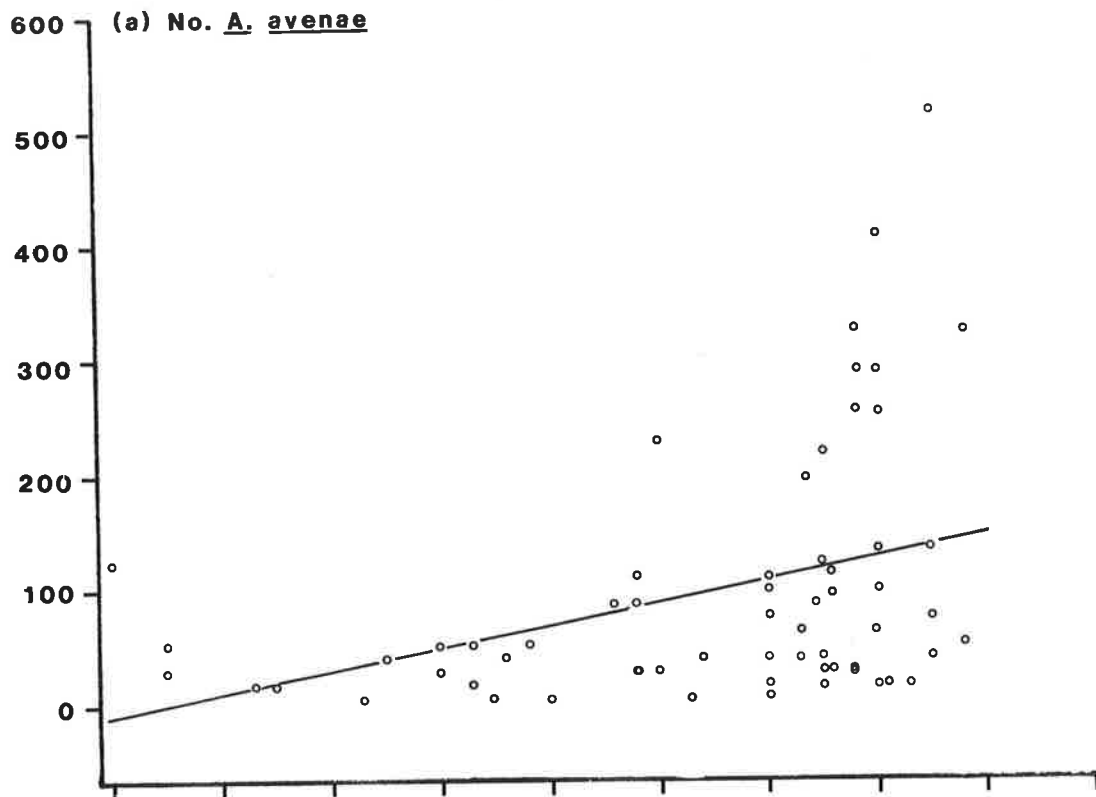
FIG 6:  Fitted regression lines for number of
        *A. avenae* per 50 ml soil (a) and as %
        of total nematodes (b) on soil texture
        (% sand) from 57 wheat fields of Mid-
        North Wheatlands Environmental Region.

(a) No. A. avenae

(b) % Total Nematodes

% Sand
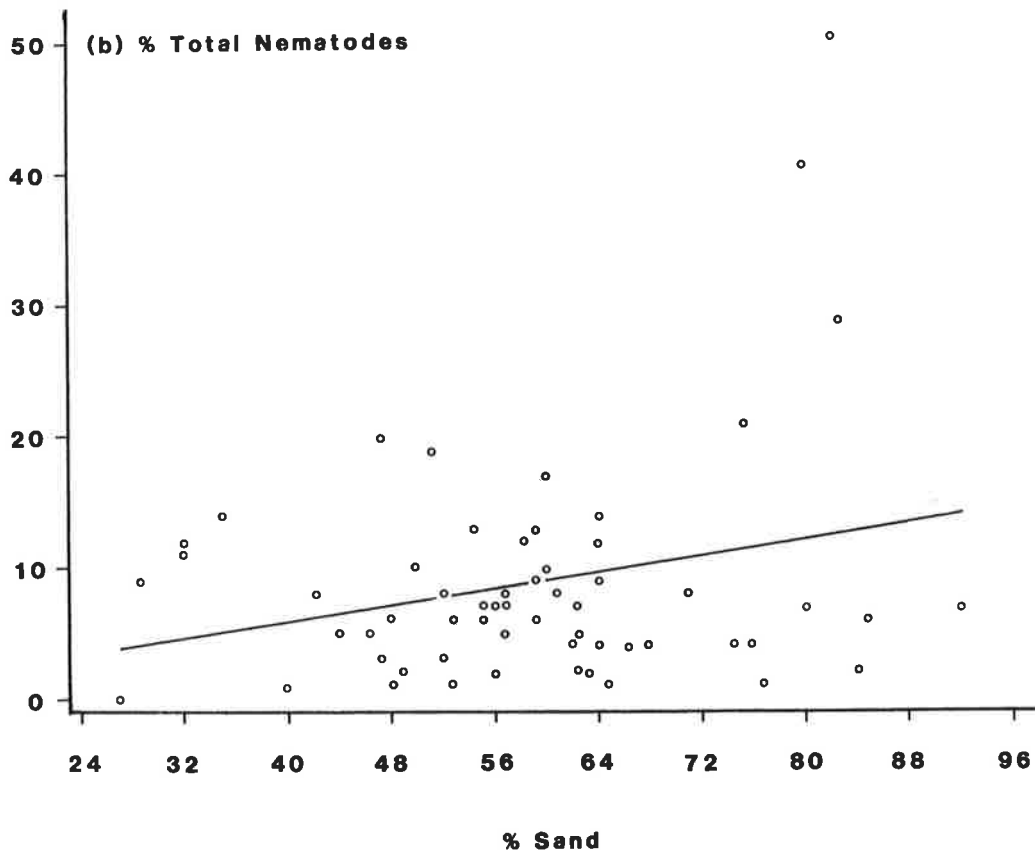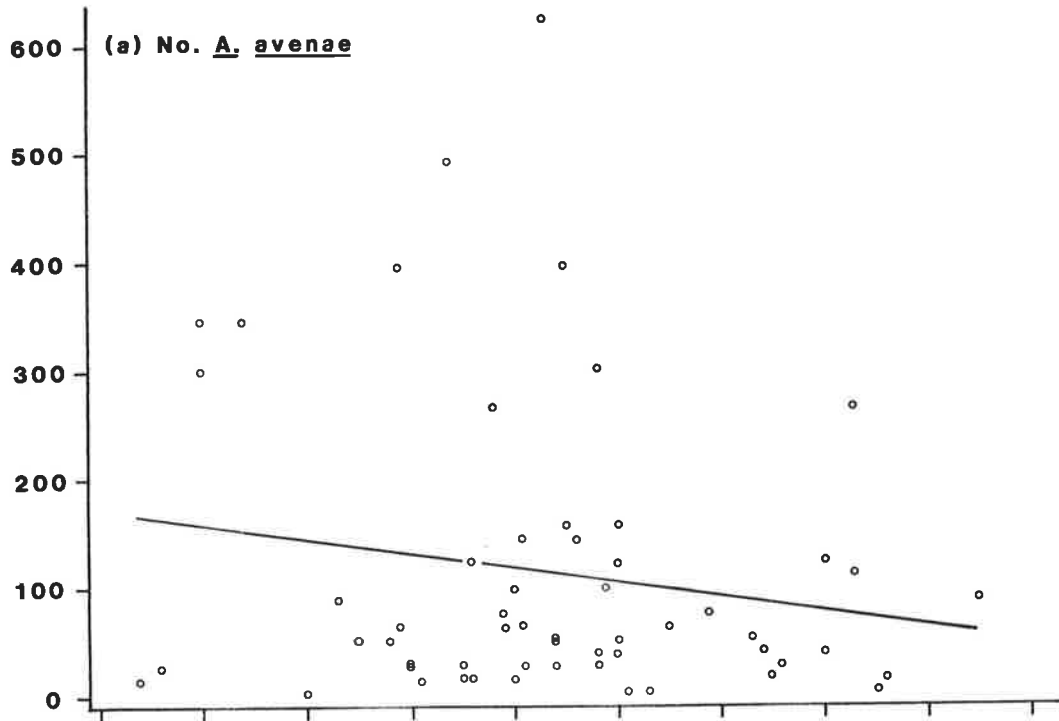
FIG. 7: Fitted regression lines for number of
*A. avenae* per 50 ml soil (a) and as %
of total nematodes (b) on ratio of pre-
cipitation over evaporation for 57
wheat fields from Mid-North Wheatlands
Environmental Region.

(a) No. *A. avenae*

(b) % Total Nematodes

Mean Annual Precipitation / Mean Annual Evaporation (mm)

FIG. 8:  Fitted regression lines for number of

   *A. avenae* per 50 ml soil (a) and as %

   of total nematodes (b) on mean altitude

   for 57 wheat fields from Mid-North

   Wheatlands Environmental Region.

(a) No. _A. avenae_

(b) % Total Nematodes

Mean Altitude (m)
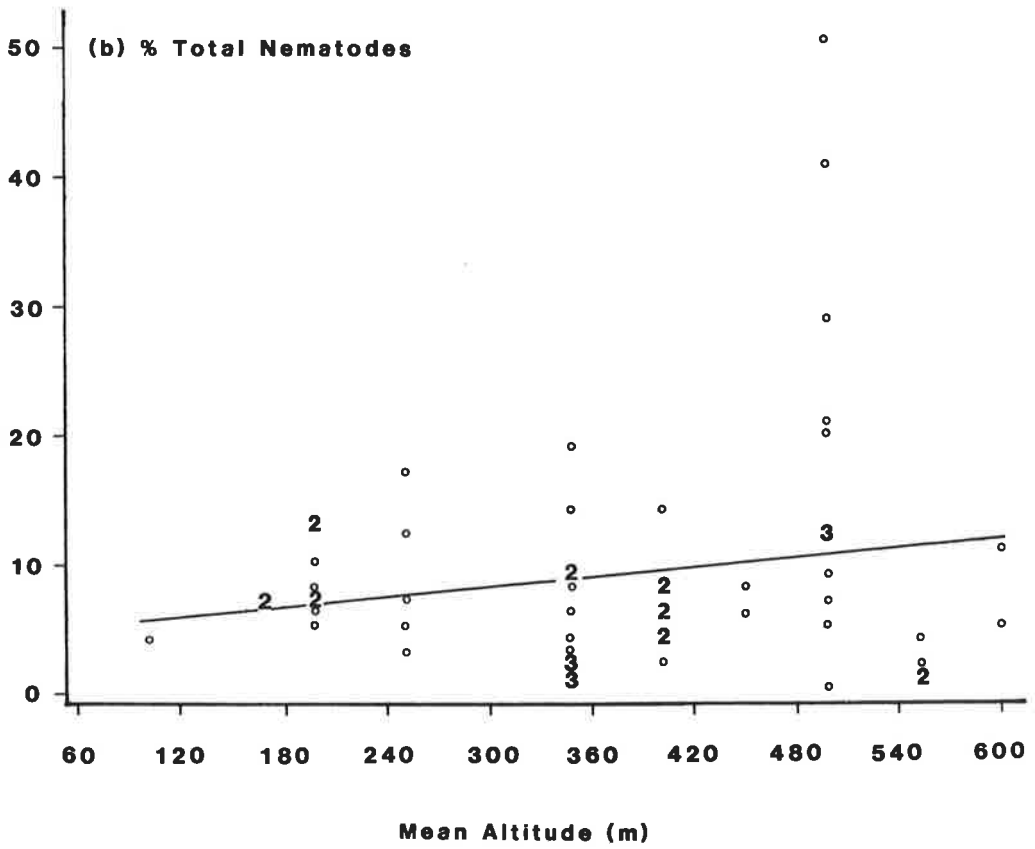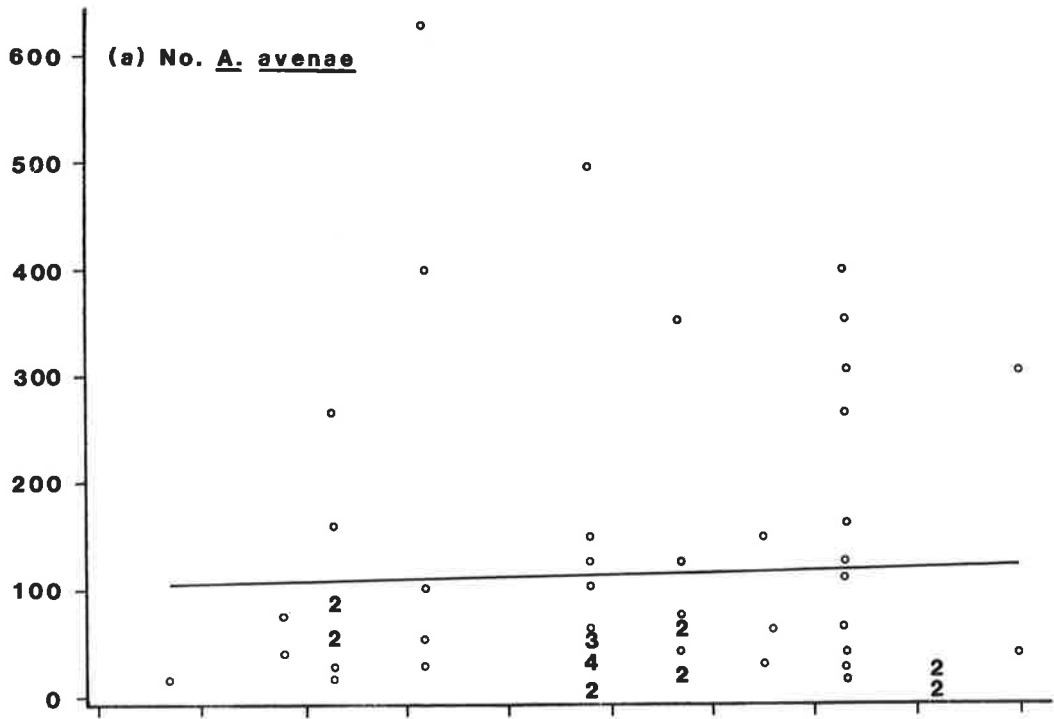
## 3. ABUNDANCE OF *APHELENCHUS AVENAE* IN SALINE SOILS

Since *A. avenae* was found to be relatively more abundant in wheat-field soils with higher levels of soluble salts the distribution of the nematode in saline soils was investigated by sampling along transects on the edge of several saline lagoons. Both lagoons are situated in the Hansen Environmental Association (3.3.11), 25 to 30 km east of Clare (33°50'S, 138°38'E).

### (a) *Black Springs Lagoon Transect*

Soil samples were taken along a transect from the edge of a field under wheat to the shores of the lagoon, 265 m distant (Fig. 9). Wheat (var. Halberd) had been planted for the first time during the year of sampling around the edge of the lagoon and occupied the first 30 m of the transect. The remainder of the transect was uncultivated and was covered by samphire and grasses. Soil samples were taken every 30 m (every 10 m under wheat) with an auger 75 mm in diameter to a depth of 145 mm. Three sub-samples were bulked per sample.

Soil surrounding the lagoon was highly saline; at a mere 65 m from the edge of the wheat-field, electrical conductivities reached levels sufficient to exclude agricultural crops entirely (Bower, 1963). On the edge of the wheat-field nearest the lagoon, EC 1:5 values reached 500 $\mu$ S cm$^{-1}$. Salinity of soil was influenced by topography; increasing in depressions and generally towards the lagoon, but decreasing again on a rim of higher ground near the edge of the lagoon. Soil pH followed a similar trend to EC 1:5 values; the more saline soils being higher in pH. The distribution of *A. avenae* was highly disjunct; the nematode being limited to the area under wheat, suggesting either a sensitivity to increasing salinity or a dependence

FIG 9: Abundance of nematodes and *A. avenae*, and soil characteristics along a transect line at the edge of Black Springs Lagoon, South Australia.

## Black Springs Lagoon Transect

**Height above lagoon (m)**

Wheat

Samphire and grasses
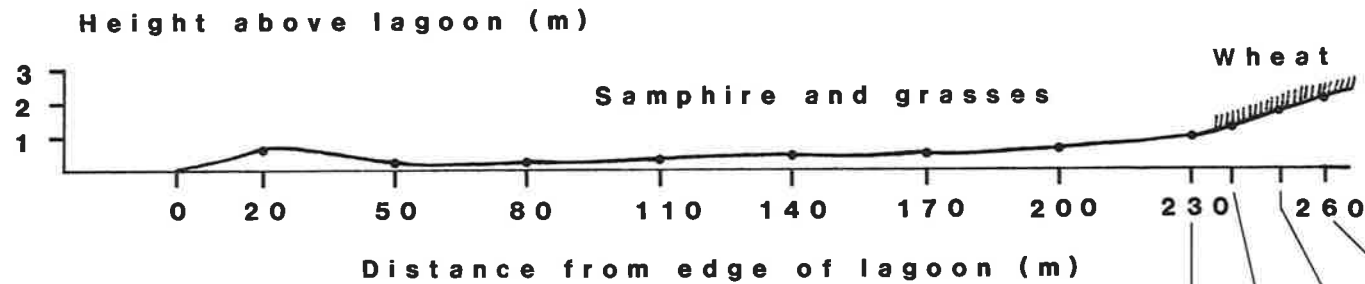
| | 0 | 20 | 50 | 80 | 110 | 140 | 170 | 200 | 230 | | 260 |
|---|---|---|---|---|---|---|---|---|---|---|---|

3
2
1

**Distance from edge of lagoon (m)**

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| EC 1:5 (micro s/cm) | 290 | 8000 | 4500 | 4000 | 8000 | 17000 | 800 | 3400 | 450 | 85 | 110 |
| pH | 7.6 | 7.8 | 7.8 | 7.7 | 7.8 | 8.0 | 7.5 | 7.7 | 7.2 | 6.8 | 7.2 |
| Nematodes/50 ml soil | 646 | 20 | 28 | 125 | 54 | 4 | 67 | 30 | 310 | 440 | 251 |
| No. A. avenae/50 ml soil | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 91 | 224 | 103 |
| % Total nematodes | – | – | – | – | – | – | – | – | 29 | 51 | 41 |

upon food sources associated with wheat. That the latter is the more likely explanation is suggested by the absence of *A. avenae* from soil in the rim of high ground where salinity levels were well within the range found under wheat. Population density of *A. avenae* was very high in the soil under wheat and relative abundance was much higher than generally encountered in wheat-fields elsewhere. This may be related to the fact that wheat had been planted for the first time in this soil. The parthenogenetic mode of reproduction of *A. avenae* (or, at least, of the isolates examined in this locality) makes it ideally suited to colonizing a "new" habitat. Soil newly planted to wheat may be rapidly colonized by fungi associated with wheat and with soil fauna such as *A. avenae*. Rapid build-up of population levels may be possible while fields with longer cropping histories may harbour a greater diversity of mycophagous competitors.

### (b) *Porter Lagoon Transect*

A soil sample taken from under pasture at the edge of this lagoon yielded male *A. avenae* in numbers up to 18% of all adult *A. avenae* extracted. Since males had only rarely been isolated from soil during widespread sampling of wheat-fields, although seen regularly in laboratory cultures in small numbers (cultures established from wheat-field isolates were all found to be parthenogenetic), it was decided to investigate this phenomenon further. Soil samples were taken along a transect from near the edge of the lagoon at 30 m intervals to a point 150 m into a field of unseeded pasture containing rye grass, wild oats and other grasses (Fig. 10). Samples were taken with a spade, 153 mm wide and 225 mm deep.

Laboratory cultures of *A. avenae* from all samples were started using *B. cinerea* as a food source. All cultures were found to be parthenogenetic. Males were found only in soil near the edge of the lagoon and were

FIG. 10:  Abundance of nematodes and *A. avenae*,

and soil characteristics along a tran-

sect line at the edge of Porter Lagoon,

South Australia.

# Porter Lagoon Transect

**Height above lagoon (m)**



**Distance from edge of lagoon (m)**
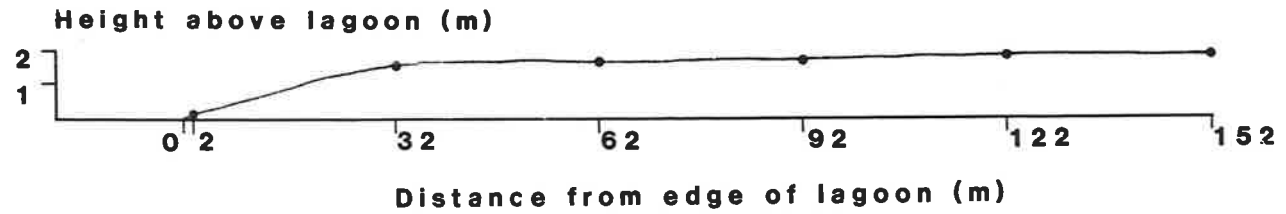
| | 2 | 32 | 62 | 92 | 122 | 152 |
|---|---|---|---|---|---|---|
| EC1:5 (micro s/cm) | 2400 | 310 | 210 | 200 | 160 | 230 |
| pH | 7.4 | 7.5 | 7.4 | 6.6 | 6.6 | 6.6 |
| Nematodes /50 ml soil | 29.5# | 476.5 | 648.5 | 299.5 | 377 | 351 |
| A. avenae/50 ml soil | 0.5# | 17.5 | 4.5 | 9 | 18.5 | 2.5 |
| % Total nematodes | 1.7 | 3.7 | 0.7 | 3.0 | 4.9 | 0.7 |
| Male A. avenae recorded | √ | - | - | - | - | - |

\# per 50g soil (for purposes of comparison, a g of soil can be considered about equivalent to a ml of soil (Oostenbrink et al., 1956)).

not seen in samples from higher ground.    Soil near the lagoon was highly

saline, much more so than soil from Black Springs Lagoon from which

*A. avenae* was found.    Many factors, such as temperature, ethanol, carbon

dioxide and fungi are known to induce the formation of males in various

parthenogenetic strains of *A. avenae* in culture (Hansen, Buecher and Yarwood,

1972, 1973).    It is possible that high salinity levels may operate in this

way in field soils.    However, since the soil from which males were found

at Porter Lagoon was also saturated, it may be that some other factor such

as carbon dioxide level was responsible.    A further indication that the

population was under stress in soil near the edge of the lagoon was the low

density seen here.    Population densities under pasture were generally lower

than those seen under wheat.


## 4.    EFFECTS OF ENVIRONMENTAL VARIABLES ON POPULATION GROWTH OF *APHELENCHUS AVENAE* IN XENIC CULTURE

Since it appeared that certain environmental variables such as

salinity and soil pH were influencing, directly or indirectly, distribution

and abundance of *A. avenae* in the field, it was decided to assess the in-

fluence of these factors on population growth of *A. avenae* in xenic culture

by modifying the culture medium.    Changes to the culture medium will, of

course, influence the host fungus in its growth rate and/or physiology, a

mechanism by which the nematode is most likely to be affected in the soil.

The basic medium used was potato dextrose agar (Difco) containing

100 ppm streptomycin and 100 ppm vancomycin, amended with 1M NaOH to give a

pH of 7.4.    Nine cm Petri dishes containing 25 ml of culture medium were

inoculated with an 11 mm disc of fungus taken with a cork-borer from agar

cultures of either *Botrytis cinerea* or *Rhizoctonia solani*.    Nematodes, 6 L3

per plate and surface - sterilized in 0.5% chlorhexidine gluconate for 5 min,

were inoculated by hand onto plates.    Plates were incubated for 3 weeks at

25°C unless otherwise indicated, the agar removed, diced and nematodes extracted and counted. There were 6 replicates per treatment. The maximum diameters of fungal colonies were measured after successive days to give an indication of growth rate. Although this method does not indicate the actual total production of mycelium it has the advantage of being non-destructive.

### (a) *Salinity*

Potato dextrose agar (PDA) amended with 0.2% NaCl was used to examine the influence of salinity of the culture medium on population growth of the nematode. NaCl adversely affected the linear growth rate of both *Botrytis cinerea* and *Rhizoctonia solani*, during the later stages of growth of the former whilst only early in the mycelial growth of the latter (Table 5). Yield of nematodes was significantly reduced on NaCl-amended plates in the case of *Rhizoctonia solani*.

### (b) *pH*

PDA (pH 5.6) and PDA amended with 1M NaOH to give a pH of 7.4 were used to determine influence of pH of the culture medium on population growth of *A. avenae*. Isolates 37 (from soil of pH 4.8) and 50 (from soil of pH 7.6), as well as an isolate from Brownhill Creek originally cultured by Evans (1968) and since maintained in culture by Dr. J.M. Fisher at the Waite Agricultural Research Institute, were used in these experiments.

The linear growth of *Botrytis cinerea* was significantly higher at the lower pH, as also was *Rhizoctonia solani* but only in the latter stages of growth (Table 6). Most fungi prefer acid conditions (Park, 1968) and further tests showed that the optimum pH for growth of the strain of

TABLE 5: Effect of 0.2% NaCl in agar medium upon radial growth of host fungi and numbers of nematodes produced

| Host Fungus | A. avenae Isolate | | PDA | PDA + NaCl |
|---|---|---|---|---|
| | Isolate #4 | | 257142 ± 54381 (S.E.) | 198479 ± 32295 |
| *Botrytis cinerea* | Diameter | 2 days | 30.5 ± 1.5(S.E.) | 31.2 ± 1.1 |
| | Fungal | 3 days | 46.7 ± 2.8 | 43.0 ± 1.7 |
| | Colony | 4 days | 62.2 ± 4.2 | 54.2 ± 2.8 |
| | (mm)after | 5 days | 76.2 ± 4.1 | 64.0 ± 4.4 |
| | | 6 days | 82.8 ± 1.6 | 69.3 ± 4.2* |
| | Isolate # 7 | | 84610 ± 12324 | 49276 ± 1291* |
| *Rhizoctonia solani* | Diameter | 2 days | 34.2 ± 0.5 | 30.3 ± 0.7* |
| | Fungal | 3 days | 44.8 ± 0.6 | 43.2 ± 0.6 |
| | Colony(mm) | 4 days | 58.5 ± 1.7 | 56.1 ± 1.0 |
| | after | 5 days | 67.9 ± 2.0 | 65.7 ± 1.7 |
| | | 6 days | 77.2 ± 1.9 | 75.3 ± 2.3 |

*Pairs of means for two media significantly different at 5% level.

TABLE 6: Effect of pH of agar medium upon radial growth of host fungi and numbers of nematodes produced

| Host Fungus | A. avenae Isolate | | PDA pH 5.6 | PDA pH 7.4 |
|---|---|---|---|---|
| | Isolate #37 | | 210558 + 70273 (S.E.) | 206518 ± 19080 |
| *Botrytis cinerea* | Diameter | 2 days | 30.8 ± 1.7(S.E.) | 22.5 ± 0.8* |
| | Fungal | 3 days | 55.3 ± 2.1 | 30.8 ± 1.0* |
| | Colony(mm) after | 4 days | 81.3 ± 2.3 | 45.2 ± 3.9* |
| | Isolate #50 | | 283057 ± 41435 | 413985 ± 57580 |
| | Diameter | 2 days | 35.5 ± 1.8 | 22.3 ± 1.7* |
| | Fungal | 3 days | 56.2 ± 2.1 | 31.5 ± 2.4* |
| | Colony(mm) after | 4 days | 81.0 ± 1.7 | 45.2 ± 3.9* |
| | Brownhill Creek Isolate | | – | 443242 ± 24169 |
| *Rhizoctonia solani* | Brownhill Creek Isolate | | 285761 ± 45946 | 58646 ± 3170* |
| | Diameter | 2 days | 29.7 ± 0.3 | 30.7 ± 0.3 |
| | Fungal | 3 days | 42.7 ± 0.3 | 43.8 ± 0.3* |
| | Colony(mm) after | 4 days | 67.7 ± 2.1 | 58.3 ± 0.5* |
| | | 5 days | 76.2 ± 1.1 | 70.5 ± 0.4* |

*Means at different pH's significantly different at 5% level.

*Rhizoctonia* used in these experiments was on the acid side (Table 7).
In the case of the Brownhill Creek isolate on *Rhizoctonia solani*, signifi-
cantly more nematodes were produced in the more acid medium.   No significant
differences between nematode yields could be demonstrated on *Botrytis*
*cinerea* at the two pH levels despite the marked influence of pH on growth
of the fungus.   Intraspecific variation was suggested by the significantly
higher yields (P = 0.05) of the Brownhill Creek and #50 isolates on
*Botrytis cinerea* at pH 7.4 compared with isolate #37.


### (c)  *Temperature*

The temperature response of isolates 13 (taken from latitude
34°29'S) and 57 (latitude 32°47'S) on *Botrytis cinerea* were compared at 20°
and 28°C.

Raising the temperature to 28°C had an adverse effect on the
linear growth of *Botrytis cinerea* but total production of *A. avenae* was
significantly higher at the higher temperature (Table 8).   There were no
significant differences in total production of nematodes of both isolates
at either temperature, but the sex ratio was markedly higher in isolate 57,
especially at 28°C where males outnumbered females.   It is interesting
that despite the abundance of temperature-induced males in this isolate at
28°C, the total production of nematodes was not apparently affected.
Fisher (1972) found that males from an amphimictic population reduced the
number of eggs laid by parthenogenetic *A. avenae* females.


## 5. TEMPERATURE-INDUCED MALES IN PARTHENOGENETIC
ISOLATES OF *APHELENCHUS AVENAE*

Different isolates of *A. avenae* from the Mid-North Wheatlands
Environmental Region responded very differently to increased incubation
temperatures, some producing an abundance of males while in others the sex

TABLE 7: Mean radial growth of *Rhizoctonia solani* on NDY/6 at 25°C on agar media of differing pH (n = 12)

| Diameter of Fungal Colony (mm) | pH 5.3 | pH 7.0 |
|---|---|---|
| After 2 days | 31.8 ± 0.8(S.E.) | 28.7 ± 0.4* |
| 3 days | 48.0 ± 0.5 | 45.7 ± 0.4* |
| 4 days | 63.8 ± 0.4 | 62.6 ± 0.3* |

*Pairs of means at different pH's significantly different at 5% level.

TABLE 8: Effect of incubation temperature on radial growth of *Botrytis cinerea* and numbers of nematodes produced

| A. avenae Isolate | Diameter Fungal Colony (mm) | 20°C | 28°C |
|---|---|---|---|
| | | 14737 ± 5968(S.E.) | 246043 ± 36372* |
| 13 | After 2 days | 23.0 ± 1.5 (S.E.) | 24.3 ± 0.9 |
| | 3 days | 35.5 ± 2.2 | 35.0 ± 1.6 |
| | 4 days | 53.8 ± 3.1 | 47.8 ± 1.8* |
| | 5 days | ·79.5 ± 2.1 | 62.2 ± 1.6* |
| | Sex ratio** | ~0% | 15.0% |
| | | 12544 ± 3036 | 256681 ± 10203* |
| 57 | After 2 days | 23.3 ± 1.9 | 22.8 ± 0.5 |
| | 3 days | 36.7 ± 2.5 | 32.8 ± 1.2* |
| | 4 days | 54.5 ± 3.1 | 46.5 ± 1.2* |
| | 5 days | 79.2 ± 1.7 | 59.3 ± 1.4* |
| | Sex ratio | 0.4% | 57.5% |

*Pairs of means at the two temperatures significantly different at the 5% level.

**Sex ratio = No. adult males/No. adults of both sexes x 100%. No males recorded in isolate 13 at 20°C amongst over 400 adult females counted.

ratio remained essentially stable (Table 9). This response to temperature amongst the different isolates did not appear to follow any pattern, geographic or otherwise, arguing against a direct adaptive function in relation to temperature for this trait. This fact was emphasized by the very different responses from two isolates originating from a pine-forest near Williamstown; the P-isolate showing almost complete sex reversal at 30°C, a temperature which elicited only a marginal increase in frequency of males in the S-isolate (Table 9). The sex ratio tended to increase with age of the culture; thus, the stimulus for production of males may have been associated with overcrowding, shortage of food or "staling" products from the fungus.

Some organisms, such as certain aphids, rotifers and cladocerans exhibit cyclical parthenogenesis (Maynard Smith, 1978) in which the sexual and asexual phases have different ecological roles; the sexual phase commonly occurring during periods of adverse environmental conditions. This, however, is not the case in *A. avenae*. Although temperature-induced males may inseminate both parthenogenetic females – particularly of their own population – and amphimictic females, their spermatozoa are non-functional and actual fertilization has not been observed (Fisher and Triantaphyllou, 1976). Poinar and Hansen (1983) suggested that differences in chromosome number between populations (Triantaphyllou and Fisher, 1976) may have contributed to sperm incompatibility observed between temperature-induced males of a Californian population and amphimictic females of a Western Australian population. However, Fisher and Triantaphyllou (1976) observed the same phenomenon between amphimictic males and parthenogenetic females of an Australian population having the same number of chromosomes.

TABLE 9: Sex ratio of *A. avenae* isolates in monoxenic culture on *Botrytis cinerea* at different temperatures (sex ratio = No. adult males/ No. of adults of both sexes x 100%).

| *A. avenae* Isolate | 20°C | 25°C | 28°C | 30°C | Ambient Temperature** |
|---|---|---|---|---|---|
| 13 (3 wk)* | ~0% | | 15.0% | | |
| 16 (4 wk) | | | | | 7.4% |
| (6 wk) | | ~0% | | | |
| 19 (4 wk) | | | | | 3.8% |
| (6 wk) | | ~0% | | | |
| 37 (3 wk) | | | | | ~0% |
| 42 (3 wk) | | | | | 38.7% |
| (4 wk) | | 10.9% | | | |
| (6 wk) | | 13.8% | | | |
| 50 (2 wk) | | 0.2% | | 0.6% | |
| 52 (3 wk) | | | | | 42.5% |
| 57 (3 wk) | 0.4% | | 57.5% | | 43.8% |
| (7 wk) | | 1.0% | | | |
| W (2 wk) | | 0.4% | | <0.04% | |
| P (2 wk) | | 0.4% | | 89.3% | |
| S (2 wk) | | 0.2% | | 0.5% | |

* Age of culture in weeks in brackets. Williamstown isolates of *A. avenae* denoted by W (wheat-field soil isolate); P (pine-forest soil isolate) and S (isolate from specimen obtained from sporocarp of *Suillus luteus* from pine-forest).

** Cultures kept in a non-refrigerated incubator set to 25°C but exposed to temperatures above 30°C for several days during a heat-wave.

## 6. AMPHIMICTIC AND PARTHENOGENETIC POPULATIONS
## OF *APHELENCHUS AVENAE*

*A. avenae* occurs in both amphimictic and parthenogenetic popu-

lations in Australia (Evans, 1968; Evans and Fisher, 1970) and Fisher (1972)

reported different egg-laying responses by females of an amphimictic and

parthenogenetic population to males of the amphimictic population. Males

reduced the number of eggs deposited by parthenogenetic females while an

increase in density of males sometimes increased and, at other times, de-

creased the number of eggs laid by amphimictic females. All other factors

being equal, the reproductive rate of a parthenogenetic strain which does

not produce males should be twice that of a corresponding sexual strain

(Maynard Smith, 1978). It is of interest to determine whether, in

*A. avenae*, all other factors are in fact equal, and whether the adverse

effect of males noted by Fisher on the egg-laying of parthenogenetic females

could at least partially explain why the amphimictic population is not

selectively displaced by parthenogenetic *A. avenae* in nature. The continued

existence of sexual reproduction in nature and the observed rarity of

parthenogenesis is of course normally explained by the limited ability of

parthenogenetic forms to evolve and their consequent high rate of extinction

(Maynard Smith, 1978).

### (a) *Interactions between amphimictic and parthenogenetic populations of* A. avenae *in monoxenic culture*

Petri plates containing PDA (25 ml per 9 cm plate) pH 5.6 with

100 ppm streptomycin and 100 ppm vancomycin were inoculated with *Botrytis*

*cinerea* as a food source and with adult *A. avenae* of the Western Australian

(WA) and Brownhill Creek (BHC) isolates, surface-sterilized for 5 min in

0.5% chlorhexidine gluconate. Initial densities of males and females were:

1) 20 WA ♂ + 20 WA ♀ + 20 BHC ♀;  2) 6 WA ♂ + 6 WA ♀ + 6 BHC ♀, and

3) WA ♂ + 6 WA ♀ + 6 BHC ♀.  Some plates containing PDA with 0.2% NaCl

were also used in this experiment. There were 6 replicates per treatment and plates were harvested after 3 or 5 weeks incubation at 25°C.

Total production of nematodes after 5 weeks was always significantly higher (P = 0.05) than that after 3 weeks but no significant differences in sex ratio were detected over this time (Table 10). Although sex ratios declined from those at the start of the experiments, no further decline was seen from 3 to 5 weeks and, in fact, mean sex ratios increased over this period of time except in the case of plates where amphimictic females initially outnumbered males 2:1. By about 2 weeks plates had been denuded of aerial mycelium but it is not known if an actual food shortage existed such that amphimictic and parthenogenetic forms were in competition.

The failure to observe a decline in the sex ratio between the two harvests suggests that the amphimictic form was not selectively displaced by the parthenogenetic form under the conditions used. If the trend towards an increased sex ratio with time is real then the opposite may in fact occur. It seems likely that an inhibitory effect of amphimictic males on the egg-laying of parthenogenetic females may be involved in this phenomenon. Whether these results reflect the situation as it occurs in nature is not known, but they suggest a basis by which the amphimictic population could maintain itself in the presence of parthenogenetic competitors. Fisher (1972) suggested that the amphimictic population in Western Australia may be geographically isolated by the Nullabor Plain, however, there is no evidence that parthenogenetic populations do not occur in Western Australia.

### (b) *Rate of egg-laying by amphimictic and parthenogenetic females*

Rate of egg-laying was determined by washing nematodes from monoxenic cultures on *Botrytis cinerea* with sterile water and transferring

TABLE 10: Total production of nematodes on *Botrytis cinerea* with different initial densities of parthenogenetic females (BHC ♀) and amphimictic males (WA ♂ ) and females (WA ♀) at 25°C.   Mean diameters of fungal colonies combine data from plates harvested at both 3 and 5 weeks.   Sex ratios represent numbers of adult males as % of total adults (parthenogenetic and amphimictic females could not be distinguished morphologically)

| | 3 week harvest | | 5 week harvest | |
| --- | --- | --- | --- | --- |
| | PDA | NaCl — PDA | PDA | NaCl — PDA |
| 20 WA ♂ : 20 WA ♀ : 20 BHC ♀ | 242250 ± 10329(S.E.) | — | 330188 ± 27781 | 336375 ± 18355 |
| Mean Sex Ratio (%) | 10.1 ±   1.3(S.E.) | — | 16.4 ±   4.1 | 10.7 ±   2.0 |
| Mean diameter fungal colony (mm) | | | | |
| after 2 days | 45.8 ±   1.1(S.E.) | | | |
| after 3 days | 85.8 ±   0.2(S.E.) | | | |
| | | | | |
| 6 WA ♂ : 6 WA ♀ : 6 BHC ♀ | 211546 ± 20111 | 208667 ± 12054 | 325333 ± 44336 | 410625 ± 28135 |
| Mean Sex Ratio (%) | 15.1 ±   4.2 | 11.5 ±   2.5 | 25.3 ±   5.7 | 19.1 ±   5.2 |
| Mean diameter fungal colony (mm) | | | | |
| after 2 days | 47.5 ±   0.7 | — | | |
| after 3 days | 85.8 ±   0.2 | 65.6 ±   1.5 | | |
| | | | | |
| 3 WA ♂ : 6 WA ♀ : 6 BHC ♀ | 232683 ± 16670 | — | 287500 ± 11369 | — |
| Mean Sex Ratio (%) | 13.0 ±   4.1 | — | 10.3 ±   1.6 | — |
| Mean diameter fungal colony (mm) | | | | |
| after 2 days | 47.0 ±   0.8 | | | |
| after 3 days | 85.8 ±   0.3 | | | |

adult females to glass wells containing sterile water (5-10 ♀ per well)
stored in an incubator and counting number of eggs laid.   Alternatively,
nematodes were placed on the surface of agar (NDY/6, ph 7 containing 100 ppm
vancomycin and 100 ppm neomycin) in 35 mm plastic Petri dishes.

Mean rate of egg-laying by amphimictic (WA) females and partheno-
genetic (BHC)  females was not significantly different, either in sterile
water at 16° or 25°C (Fig.11c) or on agar at 25°C (Fig.11b).   At 30°C,
however, BHC females had a significantly higher rate of egg-laying than WA
females (Fig.11c).   Analysis of variance of the data summarized in Fig.11c
using a split-plot design (Table 11) indicated that incubation temperature,
number of hours incubation and the interaction between these two terms were
significant sources of variation.

On agar, amphimictic males at a ratio of one male to one female
did not significantly depress the rate of egg-laying of amphimictic females
(Fig.11b).   To determine whether heat-induced males in a parthenogenetic
isolate had any effect, two males of isolate #52 were placed with five
females of the same isolate on each of six Petri dishes containing NDY/6,
pH 7.   Rate of egg-laying was not significantly depressed by the addition
of this number of males although the mean rate was significantly below that
of either BHC females or WA females in the absence of males.

Several other parthenogenetic isolates tested (Fig.11a) were
found to have rates of egg-laying significantly less than those of either
#52 or BHC isolates, suggesting intraspecific variation in this character.
After 2 hours incubation at 25°C, females of isolate 19 had a significantly
higher rate of egg-laying than those of isolate 4 (Fig.11a).

FIG.11:  Mean rate of egg-laying by adult female *A. avenae* reared on
*Botrytis cinerea*.

(a)     Mean rates of egg-laying of isolates 4 and 19 in sterile
        water at 25°C.   Bars represent standard errors of means.


(b)     Mean rates of egg-laying of isolates from Brownhill Creek
        (parthenogenetic, with heat-induced males rare), Western
        Australia (amphimictic) and of isolate 52 (parthenogenetic,
        with heat-induced males common) at 25°C on agar.   BHC
        females (represented by squares) incubated without males
        present, WA females (circles) incubated both with (WA) males
        in ratio 1 ♂ : 1 ♀ (circles connected by broken lines) and
        without (circles connected by unbroken lines), and isolate
        52 females (triangles) incubated with heat-induced males in
        ratio 2 ♂ : 5 ♀ (triangles connected by broken lines) and
        without (triangles connected by unbroken lines).


(c)     Mean rate of egg-laying of females of Brownhill Creek (BHC)
        and Western Australian (WA) isolates at 16° (arrowed lines),
        25° (broken lines) and 30°C (unbroken lines) in sterile water.
        Data was analyzed according to a split-plot design and least
        significant differences (at 5% level) are given for comparing
        pairs of means at both differing temperatures and times.

MEAN NO. EGGS LAID/FEMALE/24 HRS. **(A)**

#19

#4

**(B)**

■ BHC

• WA

▼ #52

**(C)**

• BHC

◆ WA

30°

25°   LSD(temp.)

30°

16°   LSD(time)
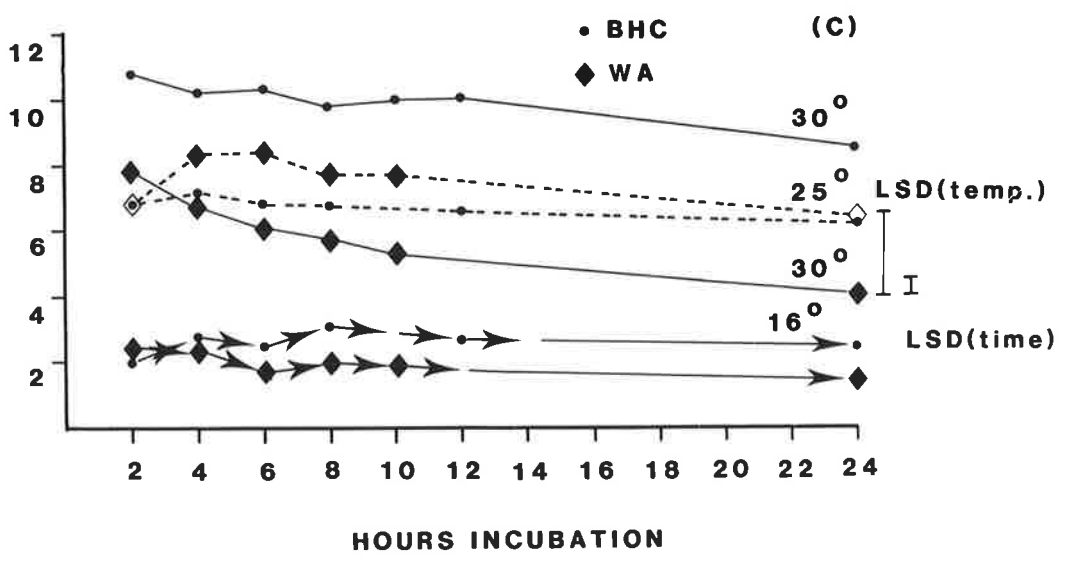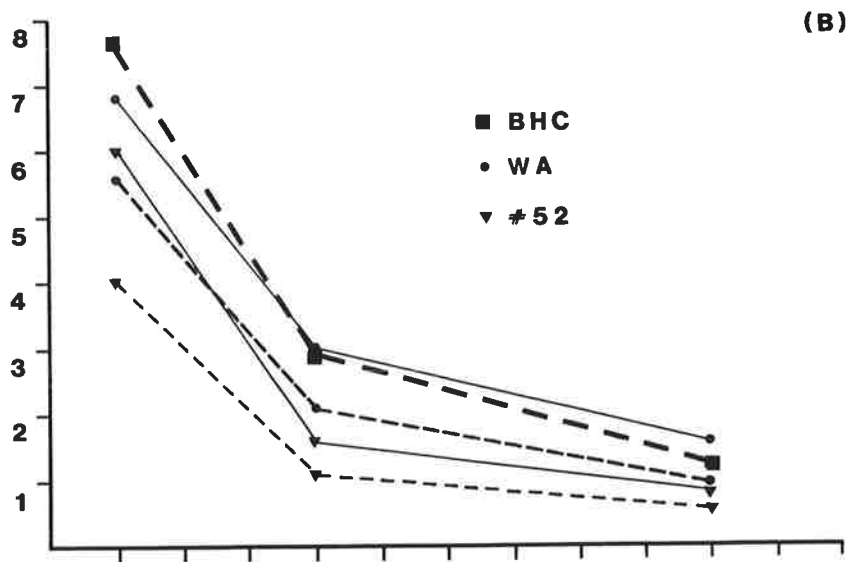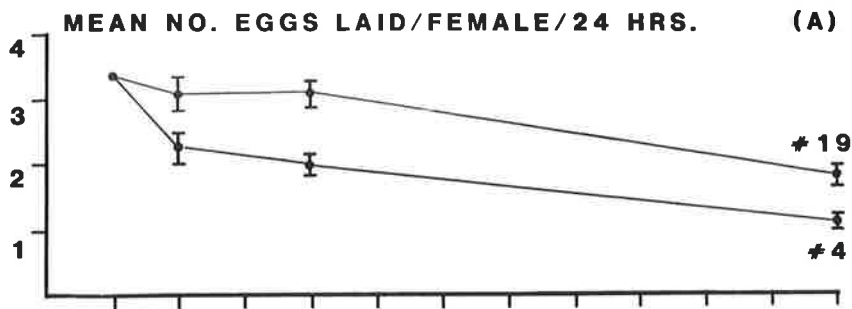
HOURS INCUBATION

TABLE 11: Analysis of variance for rate of egg-laying by females of the parthenogenetic Brownhill Creek population and the amphimictic Western Australian population at three different temperatures (data summarized graphically in Fig. 9c). Since successive measurements were not independent, the data was analyzed using a split-plot design

| Source of variation | df | Sum of squares | Mean square | F |
|---|---|---|---|---|
| Stratum | 5 | 589.41 | | |
| Main plot analysis: | | | | |
| Nematode isolate | 1 | 62.66 | 62.66 | 1.34 N.S. |
| Temperature | 2 | 1148.70 | 574.35 | 12.26 ** |
| Nema x Temp | 2 | 155.25 | 77.62 | 1.66 N.S. |
| Residual | 25 | 1170.94 | 46.84 | |
| Total | 30 | 2537.55 | | |
| Sub-plot analysis: | | | | |
| Time | 4 | 47.49 | 11.87 | 10.04 ** |
| Time x Nema | 4 | 7.84 | 1.96 | 1.66 N.S. |
| Time x Temp | 8 | 44.30 | 5.54 | 4.68 ** |
| Time x Nema x Temp | 8 | 11.02 | 1.38 | 1.17 N.S. |
| Residual | 120 | 141.90 | 1.18 | |
| Total | 144 | 252.55 | | |
| Grand total | 179 | 3379.51 | | |

** Significant at $P = 0.01$;     N.S. = Non-significant.

### (c) *Hatching of eggs of amphimictic and parthenogenetic isolates*

Eggs of the amphimictic (WA) isolate had a higher initial rate of hatch than the parthenogenetic (BHC) isolate (Table 12a) at 25°C in sterile water. A much higher % of eggs of the WA isolate failed to hatch at 30°C than at 25°C, while this increase in temperature failed to affect hatch of BHC eggs (Table 12b). This factor, along with the observation made earlier that an increase in temperature from 25 to 30°C increased the rate of egg-laying by BHC females but decreased it in WA females (Fig. 9c), suggests that the BHC isolate is better adapted to higher temperatures than the WA isolate. It is also interesting that males are still rare in BHC cultures grown at 30°C, such that egg-laying would not be inhibited at this temperature by males. Yet parthenogenetic isolates obtained from localities further north than the BHC isolate and subjected to higher temperatures in the field exhibit marked induction of males at this temperature. Hatching of eggs of both isolates was markedly inhibited at 16°C (Table 12).

It is concluded that, in many important parameters such as rate of egg-laying and hatching of eggs, differences exist between the amphimictic and parthenogenetic populations of *A. avenae* that influence the so-called "two-fold advantage of parthenogenesis" (Maynard Smith, 1978).

## 7. *APHELENCHUS AVENAE* FROM OTHER HABITATS

To study variation between populations of *A. avenae* from other habitats, both natural and agricultural, soil was collected from various locations over a wide area. Nematodes were extracted using a modified Baermann method (see Materials and Methods) unless otherwise indicated.

TABLE 12a: % of eggs hatching with time at 25°C in sterile water of Brownhill Creek (BHC - 596 eggs) and Western Australian (WA - 344 eggs) isolates

|  | Hours Incubation at 25°C | | | | | |
|---|---|---|---|---|---|---|
|  | 48 | 72 | 78 | 96 | 120 | 192 |
| BHC | 1.7 | – | 81.2 | 92.0 | 92.0 | 92.0 |
| WA | 20.1 | 87.8* | 84.0 | 90.1 | 91.3 | – |

*For 156 eggs only examined.

TABLE 12b: % of eggs not hatching after 192 hours incubation at 16°, 25° and 30°C of Brownhill Creek (BHC) and Western Australian (WA isolates

|  | Incubation Temperature (°C) | | |
|---|---|---|---|
|  | 16 | 25 | 30 |
| BHC (No. eggs) | 46.2 (158) | 8.0 (596) | 7.4 (256) |
| WA (No. eggs) | 32.4 (71) | 8.7 (344) | 22.3 (121) |

*(a)  Dangerous Reef, South Australia (34°49'S, 136°12'E)*

This reef, situated in Spencer Gulf, consists of a series of low-lying rocks, the main one of which possesses a thin covering of guano-rich soil supporting a sparse vegetation dominated by *Atriplex muelleri* Benth..    Soil samples were collected here on 28 October 1980, and a nematode, thought to be *A. avenae*, was found at a mean density of 4.8 per 50 ml soil (n = 4 samples), representing 2.8% of total nematodes.    Males were common and no morphological differences were detected between the nematode and *A. avenae* from other populations except that a greater variability in the shape of the female tail was observed.    Females usually had the blunt tail typical of *A. avenae* but some tended towards a more conical shape.    The isolate was cultured readily on *Botrytis cinerea* and the ability of the isolate to reproduce asexually was tested by inoculating 35 mm Petri plates containing PDA seeded with *B. cinerea* with one L2 or L3 larva per plate.    Plates were maintained at 25°C and after 5 weeks nematodes were extracted.    There was no evidence of reproduction although single adult nematodes were still alive;    it was surmised that males and females were necessary for reproduction.

The only other amphimictic population of *A. avenae* known from Australia is in Western Australia (Evans, 1968) and it has been suggested that this population is geographically isolated by the Nullabor Plain (Fisher, 1972).    The Dangerous Reef population is, of course, geographically isolated and it is tempting to speculate that this distribution may represent amphimictic ancestral populations occupying relictual habitats.    It has been commonly observed that some parthenogenetic animals are more widespread in distribution than their sexual progenitors (Cuellar, 1977).

*(b)* <u>*Soil from under permanent pasture, Waite Agricultural*</u>
<u>*Research Institute, collected 23 January 1981*</u>

Two samples consisting of 3 cores each were taken with a 75 mm auger

to a depth of 140 mm from a field plot of permanent pasture.   A total of

700 ml of soil was processed by the centrifugal-flotation technique (Jenkins,

1964), and *A. avenae* was found at a mean density of 12.9 per 50 ml soil,

representing 1.5% of total nematodes.   No male *A. avenae* were seen and the

sex ratio of a monoxenic culture suggested that the population was partheno-

genetic.


*(c)* <u>*Snowy Mountains, New South Wales (soil samples*</u>
<u>*collected by Prof. H.R. Wallace during the southern*</u>
<u>*winter in early May, 1981)*</u>

In soil from under open heath near Kiandra (35°23'S, 148°30'E)

and under pasture near Cooma (36°15'S, 149°07'E) *A. avenae* made up approxi-

mately 2.5 and 0.2% respectively of total nematodes extracted.   The sex

ratio seen in monoxenic cultures of these isolates suggested that the popu-

lations were parthenogenetic.


*(d)* <u>*HayPlains, New South Wales (soil collected*</u>
<u>*by Prof. H.R. Wallace in early May 1981)*</u>

*A. avenae* made up approximately 0.3% of nematodes extracted from

soil near Hay (34°31'S, 144°31'E).   The sex ratio of a monoxenic culture

suggested that the population was parthenogenetic.


*(e)* <u>*Macquarie Island (54°29'S, 158°58'E)*</u>

Soil samples were collected from this sub-Antarctic island

during the southern spring on 28 October 1981, by Messrs. Montgomery and

Cronin of the Tasmanian National Parks and Wildlife Service.   Samples were

taken from under *Poa* grasses *(P. foliosa* and *P. annua), Stilbocarpa polaris*

(Araliaceae) and a moss (*Azorella* sp.) to a depth of 10 cm from the northern end of the island between North Head and the southern end of the Isthmus.

*A. avenae* was not recovered from any of the soil samples and it is interesting that Bunt (1954) failed to record this nematode from 42 different localities sampled on Macquarie Island 30 years prior to this study. It may be that conditions on this island are too harsh for *A. avenae* to survive or that the nematode has not yet reached there.

Large numbers of larvae of a cyst nematode were found in two of the samples. This nematode was identified as *Punctodera matadorensis* Mulvey & Stone, 1976 by Dr. J.M. Fisher; recorded here for the first time in the Southern Hemisphere. It was previously described from natural grasses in Canada (Mulvey & Stone, 1976) and is probably parasitic upon *Poa* grass on Macquarie Island. Bunt (1954) makes no mention of any nematode which might fit the description of *P. matadorensis* in his comprehensive survey of nematodes on Macquarie Island. A possible early source of introduction of the nematode to Macquarie Island was through the many North American sealing vessels which called there shortly after its discovery in 1810.

Total nematodes recovered from Macquarie Island soil ranged from 7 to 947 per 100 ml soil, much lower than those typically recovered from temperate soils. It is curious that Bunt (1954) recorded much higher nematode populations; ranging from 5000 to 17000 per 100 g soil. His method of extraction differed in that much smaller (10 g) samples of soil were extracted using water heated to 40°C and this may have contributed to the wide discrepancy in results.

8. INTRASPECIFIC VARIATION IN KARYOTYPE IN *APHELENCHUS AVENAE*

The haploid chromosome number of *A. avenae* has been reported as either $n = 8$ or $n = 9$ for several populations studied by Triantaphyllou and

TABLE 13: Nematodes extracted from soil under various types of vegetation on Macquarie Island. Counts represent means of 2 replicate 50 ml-samples; figures in brackets give % of total nematodes extracted

| Sample No. Associated vegetation* | 1 P.f. | 2 P.f. | 3 S.p. | 4 P.a. | 5 P.f. | 6 A. |
|---|---|---|---|---|---|---|
| **Stylet-bearing nematodes** | | | | | | |
| *Punctodera matadorensis* | 17.5 (34.3) | – | – | – | – | 321 (80.3) |
| *Aphelenchoides* sp. | 13.5 (26.5) | – | – | – | – | – |
| *Tylenchus* spp. (*sensu lato*) | – | 10 (20.8) | 0.5 (14.3) | 8.5 (4.3) | 246 (52.0) | – |
| Nematodes without stylets (several spp.) | 20 (39.2) | 38 (79.2) | 3 (85.7) | 191.5 (95.7) | 227.5 (48.0) | 79 (19.7) |

*P.f. = *Poa foliosa*;   S.p. = *Stilbocarpa polaris*;   P.a. = *Poa annua*;   A. = *Azorella* sp.

55

Fisher (1976), and it was decided to determine the karyotype of a number of

isolates from the Mid-North Wheatlands Environmental Region to determine the

extent of intraspecific variation in this character.

As noted by Triantaphyllou and Fisher (1976), metaphase chromo-

somes in oogonia were rarely observed and determination of the somatic

chromosome number was often difficult due to fusion of chromosomes.  When

bivalents could be distinguished, 8 or 9 could be seen (Fig. 12).  Trianta-

phyllou and Fisher (1976) reported a haploid chromosome number of n = 8 for

the Brownhill Creek population (B in Fig. 13).  There appeared to be a

pattern in the distribution of the 8 and 9 chromosome populations (Fig. 13);

those with 9 chromosomes being distributed north of about 34°S and those with

8 chromosomes to the south.

## 9.  VARIATION IN PROTEIN PATTERNS BETWEEN *APHELENCHUS AVENAE* POPULATIONS

Denatured proteins from homogenates of various *A. avenae* isolates,

including a series of isolates derived from points along a transect at Porter

Lagoon, were separated by electrophoresis on polyacrylamide gels.  Protein

patterns of all isolates, including the amphimictic isolate from Dangerous

Reef, shared many bands of similar mobility (Fig. 14a).  However, differ-

ences were noticed in protein patterns between isolates, particularly amongst

the less mobile bands or proteins of higher molecular weight.  Some differ-

ences could even be observed in protein patterns of the various isolates

from Porter Lagoon.

Evans (1971) also observed differences in protein patterns and

enzyme polymorphisms in populations of *A. avenae*.  However, as in the

present study, analyses were made on mixtures of nematodes in different

developmental stages.  Enzyme patterns have been shown to vary between stages

in several nematodes (see Hussey, 1979).  Hussey (1979) suggested that some

TABLE 14:   Number of counts of meiotic oocyte chromosomes stained with
            acetic orcein made in determining karyotype of *A. avenae*
            isolates from Mid-North Wheatlands Environmental Region

| *A. avenae* isolate | Haploid chromosome number | No. counts made |
|:---:|:---:|:---:|
| 8 | 8 | 2 |
| 11 | 8 | 1 |
| W | 8 | 27 |
| 44 | 9 | 20 |
| 50 | 9 | 2 |
| 52 | 9 | 3 |
| 54 | 9 | 9 |
| 57 | 9 | 3 |

FIG. 12:   Meiotic chromosomes (metaphase) from oocyte of *A. avenae*

isolate #50, stained with acetic orcein.   The bar

represents 5 μm.
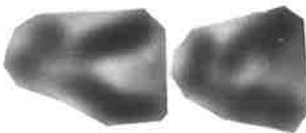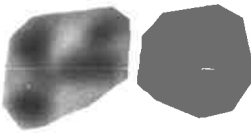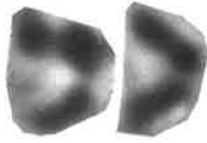
FIG. 13: Distribution of populations of *A. avenae* with n = 8
(diamonds) or 9 (circles) haploid chromosome number.

W = population from Williamstown wheat-field,
B = Brownhill Creek population studied by Triantaphyllou
and Fisher (1976).

Numbers denote isolates from Mid-North Wheatlands
Environmental Region as depicted in Fig. 2.
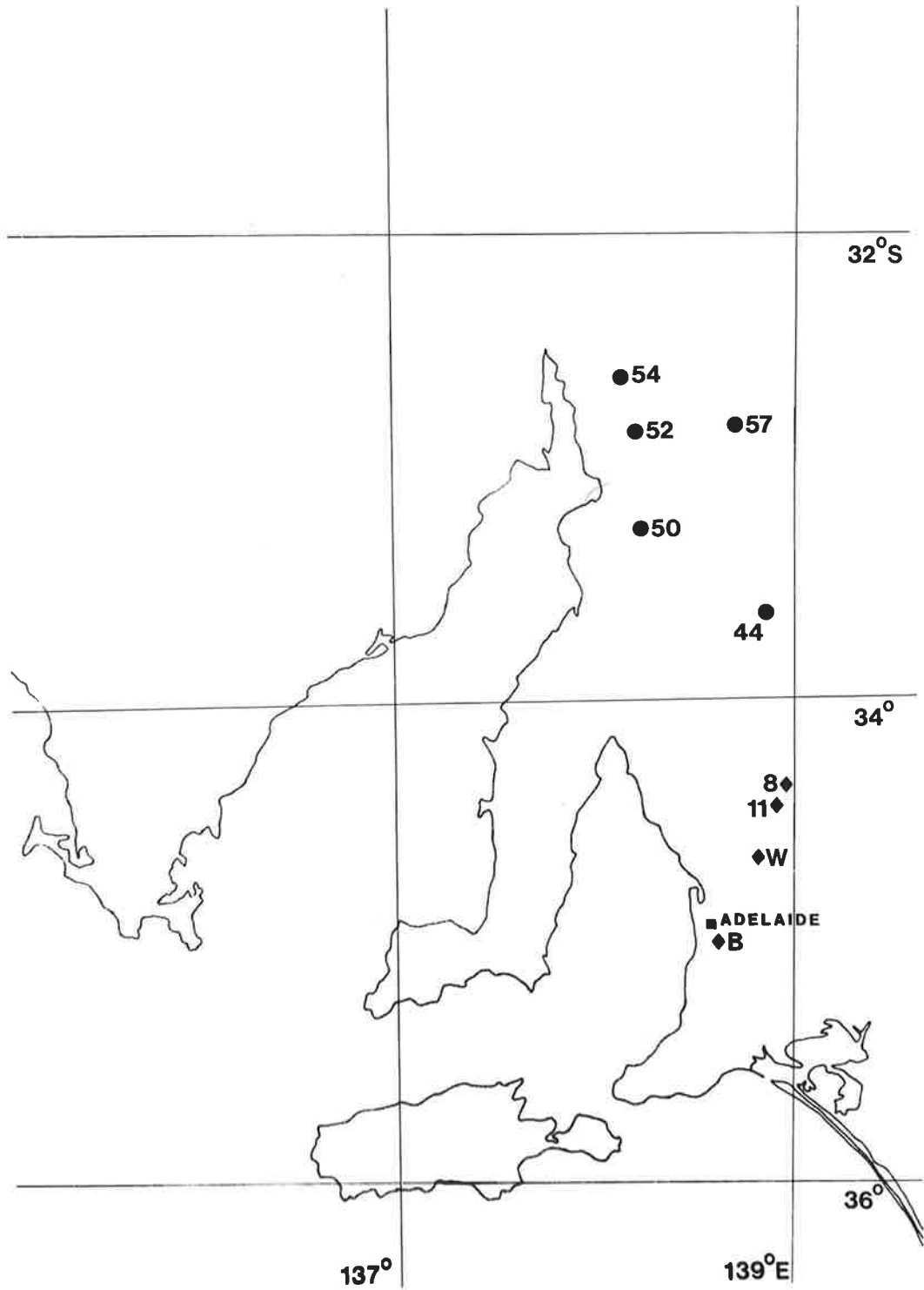
FIG. 14:  Denatured proteins from homogenates of *A. avenae* isolates
separated by electrophoresis on polyacrylamide gels and
stained with Coomassie brilliant blue.   The following
molecular weight markers were used:   bovine serum
albumin (BSA) – 68,000;  glutamate dehydrogenase (GDH) –
53,000;  ovalbumin (Oval) – 43,000;  lysozyme (Lyso) –
14,300;  cytochrome C (Cyto-C) – 12,300, and insulin –
5,700.

*A. avenae* isolates:-

(a)  Isolates from transect at Porter Lagoon (see Fig.10)
derived from soil taken at 32(a), 62(b), 92(c),
122(d) and 152 m(e) respectively from the edge of
the lagoon;  BH = Brownhill Creek isolate;
DH = Dangerous Reef (amphimictic) isolate;  and
G = isolate from wheat-field from Hundred of
Gilbert.   Numbered isolates refer to those from
wheat-fields of Mid-North Wheatlands Environmental
Region.

(b)  Isolates 1 and 52 separated by sieving into groups
a (those nematodes passing through a 45 μm-mesh
sieve),  b (those retained on both 45 and 355 μm-
mesh sieves) and c (those retained on 45 μm-mesh
sieve but passing through 355 μm-mesh sieve).

A

b  DR  G  32  19  13  57  DR  BH  e  d  c  b  a

_BSA
_GDH
_Oval

_Lyso
_Cyto. c

B

_BSA
_GDH
_Oval

_Insulin

L – 52c – ⌐L – 52b – ⌐L – 52a – ⌐L – 1c – ⌐L – 1b – ⌐ 1a
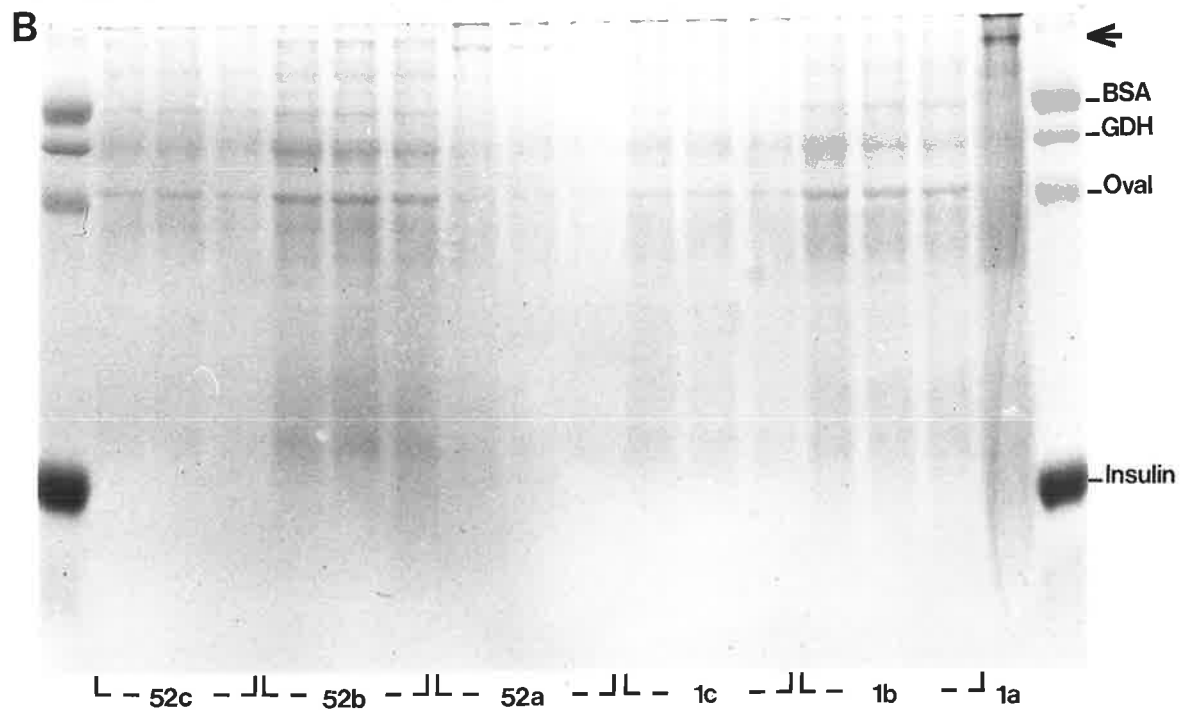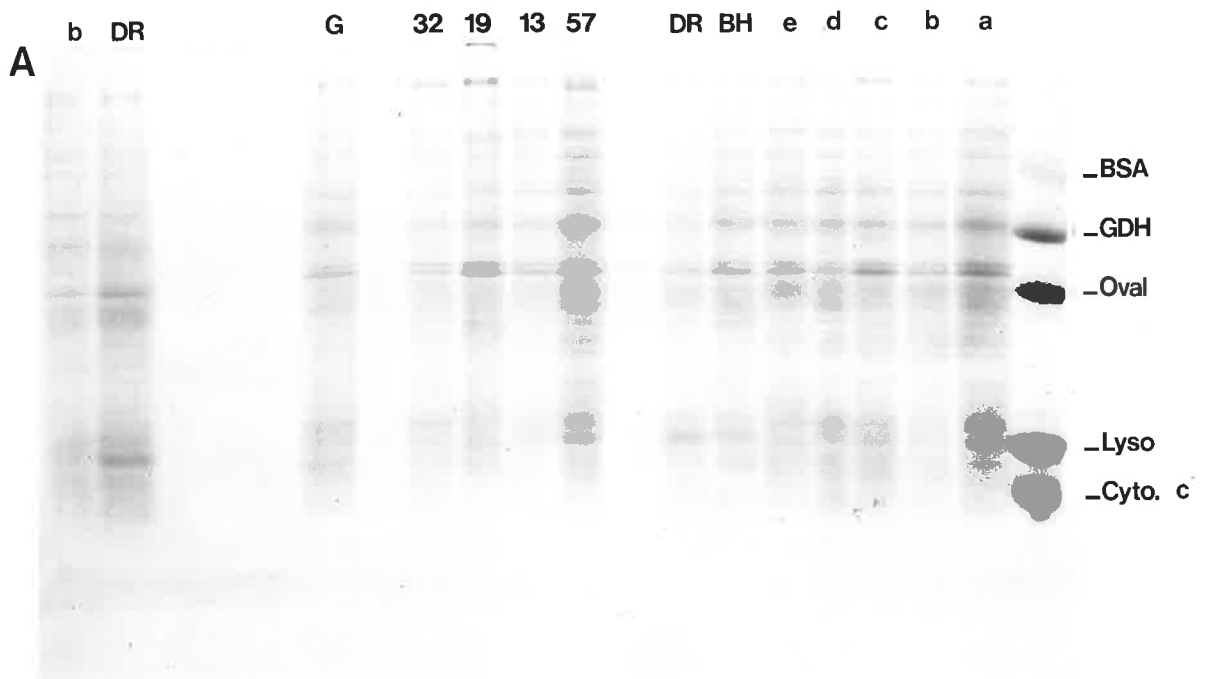
of the variability reported in enzyme patterns of nematodes may have stemmed from the use of mixtures of stages. To determine whether this factor may have been responsible for some of the variability in protein patterns reported in this study, length-classes of several *A. avenae* isolates were separated on sieves of different mesh-sizes and proteins separated by electrophoresis (Fig. 14b). Nematodes from culture jars were placed on a 45 μm-mesh sieve for one minute and those retained on the sieve were placed on a 355 μm-mesh sieve, also for one minute. Thus, nematodes were separated into three groups; those having passed through the 45 μm-mesh sieve (mean length of ten nematodes : 490 ± 56 μm S.E.), those having been retained on the 45 μm-mesh sieve but passing through the 355 μm-mesh sieve (679 ± 58 μm) and those having been retained on both sieves (888 ± 43 μm). There appeared to be differences in protein patterns between the first and last of these groups and these differences were, as before, seen amongst the bands of lower mobility (marked by an arrow-head in Fig. 14b). It was concluded that mixed developmental stages could contribute to variability in protein patterns and that improved methods of separating stages would be needed before electrophoresis could be used with confidence to study intra-specific variation in *A. avenae*.

## IV. THE ASSOCIATON BETWEEN SOIL MYCOFLORA AND ABUNDANCE OF
## APHELENCHUS AVENAE IN A WHEAT-FIELD AND PINE-FOREST

Although correlations between abundance of *A. avenae* and certain physico-chemical properties of soil had been found in a survey of wheat-fields, laboratory studies suggested that these factors were more likely to influence population density through their effects on host fungi. To study the influence of the soil mycoflora on abundance of *A. avenae*, these components of the soil biota were compared in two contrasting habitats; a wheat-field and a pine-forest.

## 1. SOIL CHARACTERISTICS OF THE STUDY SITES

The forest soil was more acidic than the wheat-field soil (Table 15), as would be expected for a mor soil (Griffin, 1972). The higher moisture content of the forest soil was also anticipated as a result of the shading and cover provided by the canopy and surface litter. However, soil texture differed markedly between the two sites; the forest soil being classed as a sandy loam and the wheat-field soil a clay loam on the basis of international particle-size distributions (Table 15). This may suggest a fundamental difference in basal materials between the two sites.

In the wheat-field, a gully ran in an east-westerly direction through quadrats E and I and soil here was noticeably heavier than in the rest of the field. Wheat growing in this gully was stunted compared with plants in the surrounding soil (Fig. 15).

The forest floor was covered by pine-needle litter and where litter had accumulated to a sufficient depth the different layers described by Hesselman (1926) and Kubiena (1953) could be discerned. In places mosses and liverworts formed thick mats and patches of grass occurred also

TABLE 15:   Soil characteristics of the Williamstown wheat-field and pine-forest

| | Mean pH (n = 12) | Mean % moisture ( n = 24) | Mean EC 1:5 $\mu$ Siemens cm$^{-1}$ (n = 24) | % Sand | % Silt | % Clay |
|---|---|---|---|---|---|---|
| Wheat-field | 5.93* | 5.95* | 286 | 48.5 | 24.8 | 26.7 |
| Pine-forest | 5.17 | 7.30 | 251 | 85.2 | 4.9 | 9.9 |

*Means for wheat-field and pine-forest soils significantly different at 5% level.

FIG. 15: Quadrats of Williamstown wheat-field showing
mean heights (from tip to point of attachment
of grain, n = 6) of wheat plants at time of
soil sampling.
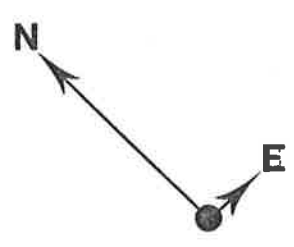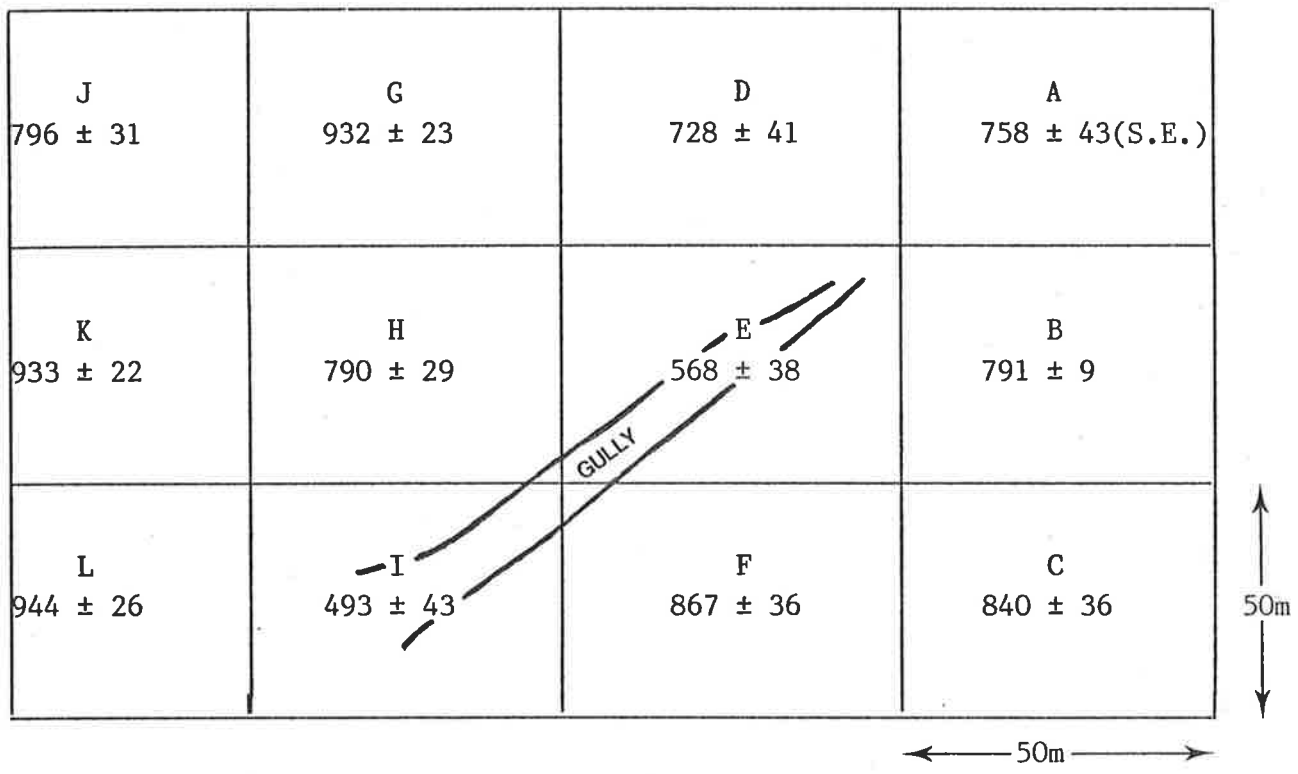
where a break in the canopy permitted sunlight to penetrate to the forest
floor.  Soursobs (*Oxalis pes-caprae* L.) were also common, as were the
fruiting bodies of higher fungi.  Basidiomycete hyphae, especially *Amphinema
byssoides*, formed almost a continuous mat in the pine litter.  The ground
covers at the locations sampled in the 12 quadrats are given below:

Quadrat A:  Almost entirely pine litter with sparse moss and
*Oxalis pes-caprae*

Quadrat B:  Thick moss mat with pine litter and numerous sporo-
carps of *Thelephora terrestris*

Quadrat C:  As for A

Quadrat D:  As for A

Quadrat E:  Pine litter with sparse moss

Quadrat F:  Pine litter with sparse moss and sporocarps of
*Hebeloma* sp.

Quadrat G:  Pine litter, sparse moss and *O. pes-caprae*, and
abundant sporocarps of *Hebeloma* sp.

Quadrat H:  Pine litter with sparse moss, *O. pes-caprae* and sporo-
carps of *Hebeloma* sp. and *Thelephora terrestris*

Quadrat I:  Almost entirely pine litter

Quadrat J:  Pine litter with sparse moss and *O. pes-caprae*

Quadrat K:  Pine litter with sparse moss, liverworts and sporo-
carps of *Hebeloma* sp.

Quadrat L:  Pine litter with sparse moss and *O. pes-caprae*.

2.  ABUNDANCE OF *APHELENCHUS AVENAE* IN WHEAT-FIELD AND PINE-FOREST SOILS

Although nematodes were more abundant in the forest soil,
*A. avenae* was significantly more abundant in the wheat-field soil (Table 16).
*A. avenae* comprised over 10% of all nematodes extracted from wheat-field soil
compared with only 0.25% from pine-forest soil.  A correlate to its low

TABLE 16: Abundance of nematodes and *A. avenae* in Williamstown wheat-field and pine-forest soils (per 50 ml soil, n = 24)

|  | Mean total nematodes | Mean No. *A. avenae* (% total nematodes) |
|---|---|---|
| Wheat-field soil | 113.8*** | 11.4*** (10.04) |
| Pine-forest soil | 201.1 | 0.5 (0.25) |

***Means for wheat-field and pine-forest soils significantly different at 0.1% level.

abundance in the forest soil was the observed patchiness of distribution there (Poisson indices of dispersion 30.1 for the wheat-field and 56.1 for the pine-forest with a critical level of 35.2 at P = 0.05).   *A. avenae* was recovered from only 25% of soil samples from the forest compared with 96% from the wheat-field.   Higher numbers of *A. avenae* than had previously been seen in the pine-forest were found in several soil samples, subsequently taken from areas where sunlight penetrated the canopy and allowed a denser growth of grasses.

*Aphelenchoides* spp., a genus known to include fungivores (Franklin, 1978) were also found in both pine-forest and wheat-field soils at densities of 2.9 and 3.3 per 50 ml soil respectively (n = 12 samples). Thus *A.avenae* was more abundant than total *Aphelenchoides* in wheat-field soil while the reverse was true of forest soil.   Many of the *Aphelenchoides* spp. found were reared successfully on *Botrytis cinerea*, indicating at least partial mycophagy.

## 3.   ABUNDANCE OF NEMATODES IN FOREST LITTER

*A. avenae* was not found in forest litter extracted by the modified Minderman (1956) technique (Table 17d), but its presence was revealed when larger (10 g) samples were processed using a thermal misting apparatus.   In contrast, an *Aphelenchoides* sp. with a tufted mucro which appeared to be closest to *A. coffeae* (Zimmerman, 1898) Filipjev, 1934 (after key of Fortuner, 1970), occurred in all samples of all litter layers by either method. *Aphelenchoides* spp. were most abundant in the F-layers where fungal mycelium was also dense, a fact reflected in the high moisture content of these layers (Table 17a).   These nematodes multiplied readily on fungal cultures suggesting at least some degree of mycophagy.   Thermal misting (of 10 g litter samples) yielded *Aphelenchoides* in numbers up to 80 per g of litter

TABLE 17a: Abundance of *A. avenae* and *Aphelenchoides* in pine-forest litter
(per g litter, means of n = 12 samples)

| Litter | Mean % moisture | Mean total nematodes | Mean no. *A. avenae* | Mean no. *Aphelenchoides* sp. (% total nematodes) |
|---|---|---|---|---|
| L | 48.8 | 7.2 | –* | 0.8 (11.5) |
| $F_1$ | 63.3 | 23.1 | – | 3.6 (15.6) |
| $F_2$ | 70.6 | 65.3 | – | 2.2 (3.4) |
| H, | 53.8 | 59.4 | – | 1.4 (2.4) |

*Dash indicates not recorded at level of sampling intensity used.

TABLE 17b: Nematodes in pine-forest litter other than *A. avenae* and
*Aphelenchoides*. Mean number nematodes per g litter.
Figures in brackets represent % of total nematodes extracted

| Litter-layer | Rhabditids | Dorylaimids | Mononchids | Tylenchids* | Others |
|---|---|---|---|---|---|
| L | 6.2 (84.6%) | – | – | 0.3 (3.9%) | – |
| $F_1$ | 18.8 (81.9) | 0.3 (1.2) | – | – | 0.3 (1.2) |
| $F_2$ | 55.0 (84.4) | 3.3 (0.9) | – | 0.5 (0.1) | 4.7 (1.2) |
| H | 51.7 (86.8) | 1.7 (2.8) | 0.3 (0.5) | – | 4.5 (7.5) |

*Other than *Aphelenchoides*.

from the F₁-layer and comprising 75% of total nematodes extracted, much higher relative numbers than those from 300 mg samples extracted with the Minderman technique.

Nematodes were most abundant in the lower litter-layers ($F_2$ and H), while *Aphelenchoides* were most abundant in the F-layers and reached their highest relative abundance in the upper litter-layers ($F_1$ and L) (Table 17a). Rhabditids were the most numerous nematodes found in litter and reached their highest densities in the lower litter-layers (Table 17b). Rhabditids were also numerous in forest soil, especially *Acrobeles*.

4. NEMATODES FROM FUNGAL SPOROCARPS COLLECTED FROM THE FOREST FLOOR

Sporocarps of 17 species of higher fungi were collected from the forest floor, among them representatives of the genera *Clitocybe*, *Collybia*, *Galerina*, *Hebeloma*, *Laccaria*, *Rhizopogon*, *Suillus* and *Thelephora*. Nematodes were extracted from sporocarp tissue (free of any adhering soil particles) of several of these spp. The most commonly encountered mycophagous nematode was an *Aphelenchoides* sp. with a tufted mucro, apparently the same as that found in litter. This nematode was recovered from fructifications of 5 out of 6 basidiomycete spp. examined, while *A. avenae* was found in only 2 of these species. In *Suillus luteus*, *Aphelenchoides* and *A. avenae* were recovered in numbers up to 3.9 and 3.2 per g fresh weight fructification respectively. Corresponding densities in *Rhizopogon luteolus* reached 2.2 and 0.95 per g respectively. Desiccated nematodes of both species were commonly recovered from fructifications, suggesting that exploitation of these food sources may depend on favourably moist conditions. Rhabditid nematodes were very common on sporocarps. *Ditylenchus* was rarely recorded. *Tylenchus sensu lato* was not recorded from sporocarps although it was common in one sample containing mycelium from the stalks of several

*Suillus* caps and adhering soil.   *Tylenchus* comprised 11.9% of nematodes
extracted from this sample, with the remainder consisting of *Aphelenchoides*
– 9.7%, Doryaimids – 3.8% and Rhabditids – 74.6%).

The ability of *A. avenae* to feed on sporocarp tissue was tested
on tissue of a *Coprinus comatus* cap, selected because thin sections allowed
some passage of light whilst observations were made through a microscope.
Thin sections of tissue from the top of the cap and fragments of gill tissue
were placed in drops of water on a microscope slide.   Adult female
*A. avenae*, surface-sterilized in 0.5% chlorhexidine gluconate, of an isolate
from the pine-forest soil kept in monoxenic culture, were placed on the
surface of the sporocarp tissue, a coverslip applied and the nematodes ob-
served at 420 x magnification.   Feeding was observed on both cap and gill
tissue;   the nematodes punctured cell walls with their stylets and evacuation
of cell protoplasm was accompanied by pulsation of the valve plates in the
median oesophageal bulb.   Feeding was not observed on thin sections of
stalk tissue, perhaps because cell walls here appeared to be thicker.
Surface-sterilized *A. avenae* were also placed in drops of water on the gills
of upturned caps of 5 species collected from the forest and incubated in
sealed plastic jars at 25°C.   However, multiplication did not occur possibly
because caps soon decayed or dried out.

5.  USE OF FUNGAL BAITS TO TRAP MYCOPHAGOUS
    NEMATODES IN PINE-FOREST LITTER AND SOIL

To determine whether potential competitors of *A. avenae* other
than *Aphelenchoides* spp. were present in the pine-forest, fungal baits in
porous bags were used to attract mycophagous nematodes in litter and soil.
Bags, about 2 cm x 2 cm, were made of either silk, with pores up to about
90 x 50 μm, or cotton with pores up to about 950 x 700 μm and were closed
on three sides.   Two *Penicillium* isolates (P86B and P94B) from pine-forest

soil were grown on a 2% solution of malt extract (Difco) in McCartney
bottles, the mat of mycelium removed, washed well under running water and
placed in a bag.   The opening to the bag was sealed with high vacuum grease
and bags containing mycelium were transported to the forest in a container
of water to ensure they did not dry out.   Two sites were selected  at
random for depositing the baits, one site for each fungus.   At each site
a bag of each type was placed at the following levels through the litter and
soil:

       (a)   In the middle of the L litter-layer.

       (b)   At the interface between the $F_1$ and $F_2$ litter-layers.

       (c)   Between the bottom of the H litter-layer and the top

             of the mineral soil,   and

       (d)   At 10 cm below the top of the mineral soil.

The disturbed soil and litter was replaced over the baits and left for 48
hours before removal and extraction of nematodes from mycelium by the modi-
fied Baermann technique.

No nematodes were recovered from baits placed below the surface
of the mineral soil but nematodes were recovered from mycelium which had
been placed in the litter, albeit in small numbers.   The *Aphelenchoides* sp.
with the tufted mucro previously encountered was most commonly recovered,
followed by bacteria-feeding Rhabditid nematodes.   No *A. avenae* were isolated
by this method.   Other mycophagous nematodes may have been present but not
detected by this technique.   The small numbers of nematodes found suggested
that the technique was inefficient.   Different results may have followed
from more extensive sampling or from the use of different baits.

# 6. FUNGI FOUND IN WHEAT-FIELD AND PINE-FOREST SOILS

## (a) Isolation of fungi from soil on dilution and soil plates

Fungal colonies isolated from dilution plates (325 and 468 from wheat-field and pine-forest soils respectively) and soil plates (252 and 234 respectively) were classified according to their morphology on NDY; 166 morphological groups were identified from the wheat-field and 121 from the pine-forest. Lactophenol cotton-blue or acid fuschin mounts were then prepared and isolates identified where possible to at least generic level (see Appendices 3-4) using the keys of Domsch et al. (1980) and Barron (1968). Fungal cultures failing to fruit on NDY were classified as "sterile cultures". A small number of colonies sub-cultured from dilution plates (1.85% of wheat-field soil colonies and 0.21% of pine-forest soil colonies examined) and soil plates (0.79% and 0.43% respectively) failed to grow on NDY and were discarded.

Comparison of the fungal genera and species groups most commonly isolated (comprising more than 1% of either total dilution plate or soil plate cultures) from wheat-field and pine-forest soils revealed markedly different mycofloras in these two soils (Table 18). Penicillium dominated the fungi isolated by both methods from forest soil, whereas a more diverse mycoflora was revealed in wheat-field soil with many genera, commonly recorded from this soil, being either rare (Aspergillus and Fusarium) or not recorded at all (Acremonium, Broomella, Cladosporium, Myrothecium and Torulomyces) from the forest soil. Sterile fungi and Mucorales were more prominently represented in wheat-field soil compared with pine-forest soil while Trichoderma was more frequently recorded from the latter soil. Penicillium isolates were classified according to subgenus after the key of Pitt (1979) and a significant association between habitat and incidence of

TABLE 18: Frequency of fungal genera and species groups commonly isolated from wheat-field and pine-forest soils by dilution and soil plate methods as % of total colonies isolated

| | Dilution plates | | Soil plates | |
|---|---|---|---|---|
| | Wheat-field % | Pine-forest % | Wheat-field % | Pine-forest % |
| *Penicillium* | 33.2 | 90.2 | 34.1 | 86.3 |
| *Aspergillus* | 12.0 | 0.4 | 9.5 | 0.4 |
| Mucorales | | | | |
| (a) Total | 6.5 | 1.7 | 11.5 | 3.4 |
| (b) *Mortierella* | 3.7 | 1.5 | 6.4 | 3.0 |
| (c) *Mucor* | 0.6 | 0.2 | 3.2 | 0.4 |
| *Fusarium* | 14.5 | 1.1 | 15.1 | 3.9 |
| *Broomella* | 10.2 | – * | 6.8 | – |
| *Cladosporium* | 0.6 | – | 3.2 | – |
| *Myrothecium* | 1.9 | – | – | – |
| *Paecilomyces* | 1.9 | 1.5 | 0.4 | 0.9 |
| *Torulomyces* | 1.5 | – | 1.6 | – |
| *Acremonium* | 0.9 | – | 1.6 | – |
| *Trichoderma* | 1.5 | 1.9 | 0.4 | 2.1 |
| Sterile cultures | 8.0 | 0.6 | 9.5 | 1.7 |
| Total | 92.7 | 97.4 | 93.7 | 98.7 |

*Dash indicates fungi not recorded at level of sampling intensity used.

sub-genera was found (Table 19), indicating that the two habitats differed in composition of this component of their mycofloras.

Many genera with a frequency of <1% on dilution or soil plates from wheat-field soil (*Absidia*, *Actinomucor*, *Conidiobolus*, *Coniothyrium*, *Cunninghamella*, *Doratomyces*, *Gliocladium*, *Gongronella*, *Graphium*, *Metarrhizium*, *Phialocephala*, *Rhizopus*, *Stachybotrys*, *Ulocladium* and several unidentified Coelomycetes) were not recorded from pine-forest soil, but very few genera (*Botrytis*, *Verticillium*) were recorded only from the latter. Similarly, many individual species were recorded solely from wheat-field soil whereas few species, other than some *Penicillium* spp, were found only in forest soil (Appendices 3-4). More *Trichoderma* spp. were recorded from pine-forest soil *(T. hamatum, T. harzianum* and *T. koningii)* than from wheat-field soil *(T. harzianum* and *T. viride)*.

Mean propagule counts per g soil of fungal genera and species groups commonly recorded from dilution plates of wheat-field and pine-forest soils are presented in Fig. 16. No significant differences result from converting propagule counts to per unit dry soil (Table 20). Fungal pro-pagules were far more numerous in the forest soil but belonged predominantly to *Penicillium* spp. whereas other genera, apart from *Trichoderma*, made up greater proportions of the total propagule count in wheat-field soil. Propagules of *Fusarium* and sterile fungi were significantly more abundant in wheat-field soil.

### (b) Selective isolation of specific fungi from soil

Certain fungi are only rarely isolated if at all from dilution or soil plates, hence selective isolation methods were used to augment the picture obtained of the mycoflora by the former methods.

TABLE 19: Isolates of *Penicillium* from wheat-field and pine-forest soils classified according to subgenus (after Pitt, 1979)

| | Subgenus | | | | Total |
| | *Aspergilloides* | *Penicillium* / *Biverticillium* | *Furcatum* Section | | |
| | | | *Furcatum* | *Divaricatum* | |
|---|---|---|---|---|---|
| Wheat-field | 19* | 17 | 24 | 11 | 71 |
| Pine-forest | 39 | 10 | 16 | 23 | 88 |
| Total | 58 | 27 | 40 | 34 | 159 |

*There is a significant ($P < 0.01$) association between habitat and incidence of subgenera ($X^2 = 12.9$ with 3 d.f.).

FIG. 16:  Mean propagule counts per g soil of common genera and
species groups of fungi from wheat-field (shaded bars)
and pine-forest (open bars) soils.  Pairs of means
marked with a star are significantly different at the
2% level or better.

FUNGAL PROPAGULES $\times 10^3$ /g SOIL

TOTAL = Total fungal propagules
PEN = Penicillium
ASP = Aspergillus
FUS = Fusarium
TRICH = Trichoderma
MUC = Mucorales
STER = Sterile cultures
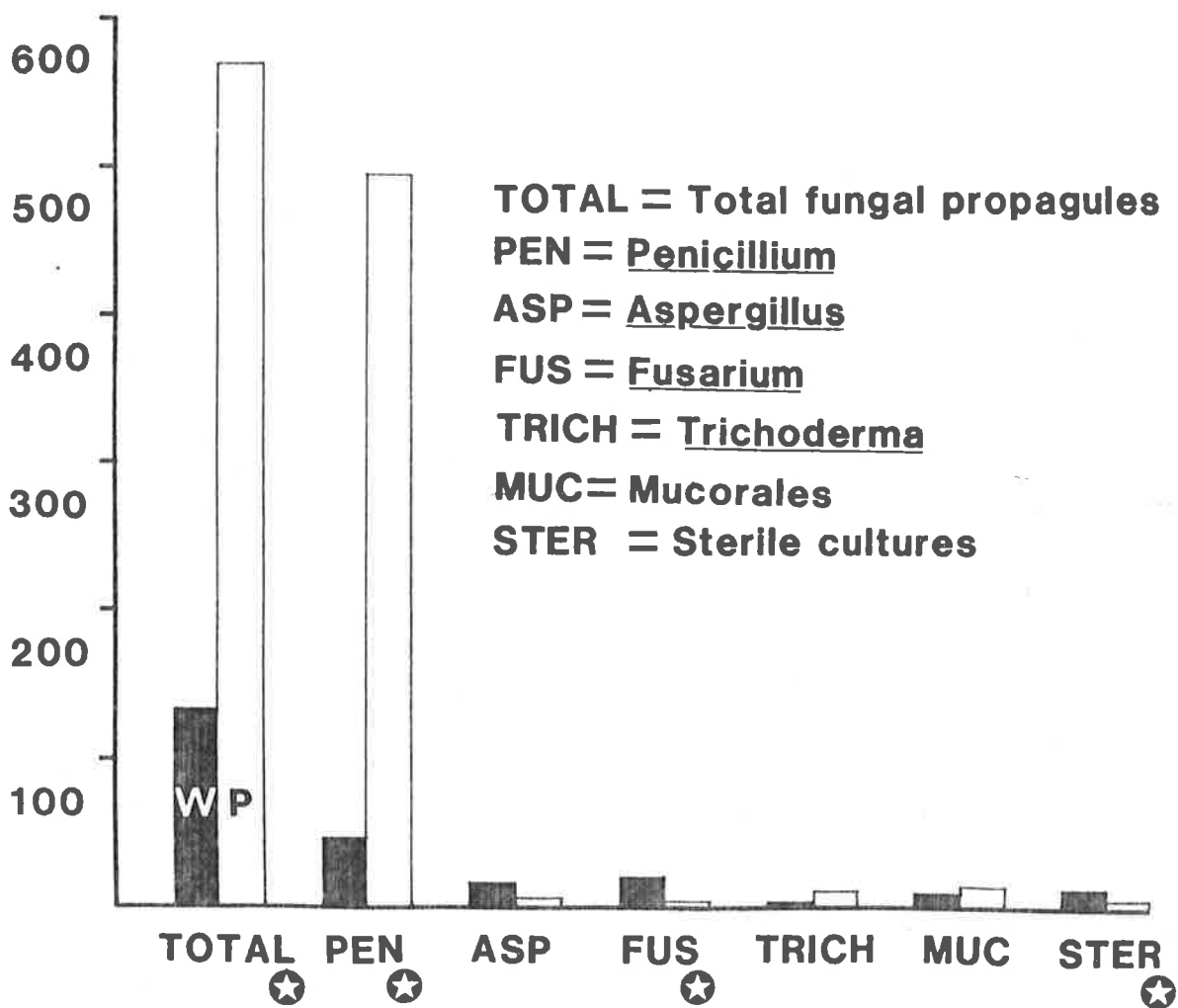
TABLE 20:  Mean propagule counts per g soil (a) and per g dry soil (b) of
common genera and species groups of fungi from wheat-field and
pine-forest soils (n = 24 for total fungal propagules, n = 12
for genera and species groups)

| Propagules x $10^4$ | | Wheat-field soil | Pine-forest soil |
|---|---|---|---|
| Total fungal | (a) | 13.33 ± 1.20(S.E.) | 55.58 ± 6.76*** |
| | (b) | 14.14 ± 1.30 | 59.75 ± 7.30*** |
| *Penicillium* | (a) | 4.50 ± 0.85 | 49.46 ± 7.78*** |
| | (b) | 4.81 ± 0.93 | 53.40 ± 8.45*** |
| *Aspergillus* | (a) | 1.63 ± 0.41 | 0.50 ± 0.42 |
| | (b) | 1.73 ± 0.43 | 0.54 ± 0.45 |
| *Fusarium* | (a) | 1.96 ± 0.33 | 0.26 ± 0.14*** |
| | (b) | 2.08 ± 0.35 | 0.28 ± 0.15*** |
| *Trichoderma* | (a) | 0.21 ± 0.13 | 0.97 ± 0.40 |
| | (b) | 0.23 ± 0.14 | 1.05 ± 0.44 |
| Mucorales | (a) | 0.88 ± 0.18 | 1.35 ± 0.83 |
| | (b) | 0.92 ± 0.18 | 1.46 ± 0.90 |
| Sterile cultures | (a) | 1.08 ± 0.20 | 0.34 ± 0.19** |
| | (b) | 1.16 ± 0.22 | 0.36 ± 0.20** |

Pairs of means for wheat-field and pine-forest soils significantly
different at P = 0.02 (**) or P = 0.001 (***).

(1) *Rhizoctonia solani sensu lato*

(i) Using the selective medium of Ko and Hora (1971):- soil from Quadrat I of the wheat-field (15 x 2 g sub-samples) was mixed into a paste with sterile distilled water and applied in clumps (10 per 2 g sub-sample per plate) to Petri plates containing the selective medium. These were incubated at 28°C for 24 hours and then those hyphae showing the greatest linear growth (greater than 5 mm) away from the edges of the soil clumps were sub-cultured onto NDY for subsequent identification. *Rhizoctonia* was not found using this method, an unidentified hyphomycete being the most common fungus isolated followed by several sterile hyaline fungi.

A modification of Ko and Hora's medium was used incorporating selective agents in place of "Dexon" to suppress the growth of other fungi. The base medium of Ko and Hora, minus "Dexon" and with streptomycin increased to 100 ppm, was amended with "Hymexazol" (50 ppm) and "Ridomil" (10 ppm) and tested as before with 15 x 2 g sub-samples of wheat-field soil. After 24 hours at 28°C, maximum growth away from clumps was lower than on the unmodified medium, ranging from 1.5 to 6 mm compared with 3-9 mm. *Rhizoctonia* was not isolated but the medium did prove selective for *Actinomucor*, 63% of isolates from hyphae 5 mm in length or more after 24 hours belonging to this genus.

Subsequently, *Rhizoctonia* was readily isolated from organic debris particles in wheat-field soil. Ko and Hora (1971) claimed that the dilution plate method was unsuitable for estimating abundance of *R. solani* due to the low population level of this fungus in most field soils and recommended their selective method for this purpose

because of its sensitivity.   The failure of the method here may have

to do with variability amongst isolates;   for example, temperature

requirements of *R. solani* isolates are very variable (Domsch *et al.*,

1980) yet the above isolation method relies upon a high rate of growth

at 28°C.


(ii) Baiting:-  the "infected host method" of Davey and Papavizas

(1962) was tested for isolation of *Rhizoctonia* from wheat-field soil.

Soil from Quadrats G and J was placed in dishes, 60 mm deep, watered

freely with distilled water and covered with about 80 surface-sterilized

wheat (var. Halberd) seeds (5 min in 4% sodium hypochlorite followed

by rinsing in sterile water).   The seeds were then covered in a thin

layer of soil, the dishes sealed in plastic bags and stored in

darkness (to stress the seedlings) at 25°C for 7-10 days.   The root

systems of 35(G) and 50(J) plants were examined for lesions and 138

and 179 root segments respectively plated onto NDY (with 100 ppm

streptomycin and 10 ppm tetracycline) after surface sterilization in

0.5% sodium hypochlorite (30 sec) and washing in sterile water.

*Rhizoctonia* was not detected by this method  suggesting that

pathogenic isolates of this fungus were not common in the soil examined.


(iii)  From the organic debris fraction of soil:-  Boosalis and

Scharen (1959) considered that this fraction was the natural habitat

of *Rhizoctonia* in soil and, indeed, the fungus was readily isolated

from wheat-field soil using a modification of their method.

Soil (100 g) from wheat-field Quadrat K and pine-forest Quadrat I

was suspended in 2.5L of water in a bucket, stirred vigorously and

allowed to settle for 30 sec before the supernatant was passed through

a 250 μm-mesh sieve.   This procedure was repeated 6 times and the

residue on the sieve washed thoroughly  for one minute under running

water whilst agitating the sieve.   The organic debris was further

cleared of soil particles by rubbing with a rubber pipette bulb on

the end of a pencil under running water for another minute.   Petri

plates with 2% water agar pH 7.2 were cleared of excess moisture by

evaporation in a laminar flow and then spotted (4 spots per plate)

with 2 drops of a solution containing 1% of both streptomycin and neo-

mycin.   After the antibiotic solution had been absorbed by the agar,

individual organic particles blotted dry on sterile filter paper, were

placed, one per spot, onto plates.   Some 104 and 100 organic debris

particles from wheat-field and pine-forest soils respectively were

plated and incubated at 25°C.   Hyphal tips were sub-cultured up to

9 days later onto NDY/6 for subsequent identification, although

*Rhizoctonia* could be immediately recognized by its distinctive

characteristics.

Those fungi which remained sterile in culture, especially the

dark forms, constituted the most commonly isolated group of fungi from

wheat-field organic debris (Table 21).   Warcup (1957) obtained a

similar result using the hyphal isolation method on wheat-field soil,

and it is interesting that many of the hyphae isolated by this method

are found to be attached to humus particles (Warcup, 1955).   *Fusarium*

was also more commonly isolated from organic debris particles  than

with dilution and soil plate analyses of wheat-field soil;   *Penicillium*

on the other hand was much reduced in frequency.   A possible *Fusidium*

sp., not otherwise isolated, was common on organic debris particles

and a number of otl_r fungi (for example, *Rhizoctonia* and *Humicola*)

were isolated only from organic debris.   It appeared that the organic

fraction was characterized by a different array of fungi to that found

TABLE 21: Frequency of fungi isolated from washed, organic debris particles as % of total (wheat-field soil n = 116, pine-forest soil n = 55)

| Wheat-field | % | Pine-forest | % |
|---|---|---|---|
| *Fusarium* spp. | 26.7 | *Penicillium* spp. | 47.6 |
| *Fusidium* sp.? | 14.6 | *Trichoderma* spp. | 19.0 |
| *Aspergillus* spp. | 6.9 | *Fusarium* spp. | 14.3 |
| *Humicola* sp. | 2.6 | *Mortierella* spp. | 9.5 |
| *Mortierella* sp. | 1.7 | *Paecilomyces* sp. | 2.4 |
| *Paecilomyces lilacinus* | 1.7 | Dark sterile cultures | 4.8 |
| *Rhizoctonia solani* | 1.7 | Hyaline sterile cultures | 2.4 |
| *Chaetoceratostoma* sp.? | 0.9 | | |
| *Chaetomium indicum* | 0.9 | | |
| *Gliocladium solani* | 0.9 | | |
| *Penicillium* sp. | 0.9 | | |
| Unidentified Coelomycete | 0.9 | | |
| Dark sterile cultures | 28.4 | | |
| Hyaline sterile cultures | 11.2 | | |
| Total | 100.0% | Total | 100.0% |

for soil generally by dilution and soil plate analyses.

Fungi were both more frequently isolated from organic debris particles from wheat-field soil than from pine-forest soil (116 isolations compared with 55) and in greater diversity (Table 21). As in dilution and soil plate analyses of forest soil, *Penicillium* was the most commonly isolated genus from organic debris. *Trichoderma* and *Fusarium* exhibited an increased frequency of isolation by this method. The nature of organic debris in forest soil, being high in phenolics, may dictate a more specialized and limited array of fungi associated with it than in the wheat-field.

## (2) *Pythium* spp.

*Pythium* spp. were rarely found on soil and dilution plates hence the dilution plate technique combined with a selective medium based on the methods of Vaartaja and Bumbieris (1964) and Tsao and Ocana (1969) was used to study their incidence further. The medium consisted of cornmeal agar (Difco) with "Pimaricin" (10 ppm), pentachloronitrobenzene (100 ppm), vancomycin (200 ppm) and (optional) rose bengal (50 ppm). Five 10 g sub-samples of soil from Quadrats I and K of the wheat-field and Quadrats C and I of the pine-forest were serially diluted in sterile distilled water and two dilution plates at a final dilution of 1/100 prepared per sub-sample. Wheat-field sample I and pine-forest sample C were processed using the medium containing rose bengal and due to inhibition of growth, colonies were not counted until after 4 days at 25°C compared with 2 days for the other 2 samples on the medium without rose bengal (Table 22). The first five colonies encountered growing across each plate were sub-cultured onto cornmeal agar (with and without β-sitosterol at 0.01 g per litre medium) for subsequent identification, giving a total of 50 cultures per sample.

TABLE 22: Mean number of fungal propagules per g of soil growing on *Pythium* selective medium with and without rose bengal after 4 and 2 days incubation respectively at 25°C. Means for wheat-field and pine-forest soils on medium with rose bengal significantly different at P = 0.001; on medium without rose bengal at P = 0.02.

| Selective medium | Soil sample | Propagules x $10^2$ per g soil | Propagules x $10^2$ per g dry soil |
|---|---|---|---|
| Selective medium with rose bengal | Wheat-field Sample I | 30.30 ± 2.23(S.E.) | 30.83 ± 2.28 |
| | Pine-forest Sample C | 11.30 ± 0.79 | 12.00 ± 0.84 |
| Selective medium without rose bengal | Wheat-field Sample K | 23.60 ± 1.97 | 24.81 ± 2.07 |
| | Pine-forest Sample I | 16.40 ± 1.71 | 17.77 ± 1.86 |

Mean numbers of fungal propagules per g soil that grew on the selective medium were significantly higher in wheat-field soil compared to pine-forest soil. Although a greater proportion of these propagules on the medium with rose bengal were taken up by *Mortierella* spp. in wheat-field soil (Table 23), *Pythium* propagules were still more abundant than in forest soil. A greater proportion of colonies sub-cultured from the selective medium with rose bengal failed to grow on cornmeal agar compared with that from the medium alone.

A greater diversity of *Pythium* spp. was isolated from wheat-field soil than from pine-forest soil (Table 23). Species lacking oogonia and sporangia on cornmeal agar (although sometimes possessing thick walled chlamydospores) dominated both soil types but were the only ones isolated from forest soil at all. *Pythium acanthicum* was subsequently isolated from pine-forest soil using pine-needles as bait and *P. dissotocum* was isolated from soil on a *Phytophthora* selective medium.

Four isolates of these non-fertile species from both habitats and which were very similar in appearance were tested for rate of growth on cornmeal agar (with 100 ppm vancomycin) at 25°C. Mean linear growth of the pine-forest isolates over 24 hours was 12.1 mm (range 11.5-12.5 mm) compared with 9.1 mm (range 8-10.5 mm) for the wheat-field isolates; suggesting that different species were involved. To induce formation of oogonia and sporangia, agar blocks of the fungi were transferred to water and fungi sub-cultured onto lima bean agar (with and without β-sitosterol) and cornmeal agar (Difco) with fresh grated carrot (15 g/L), soil (1 g/L) and β-sitosterol (0.01 g/L) (Middleton, 1943). Oogonia failed to appear and the isolates (probably heterothallic) were assigned to the *Pythium afertile* species group after Middleton's classification.

TABLE 23: Identity of fungi sub-cultured from *Pythium* selective media onto cornmeal agar from wheat-field and pine-forest soils (% of total cultures examined)

| Selective Medium | With rose bengal | | Without rose bengal | |
|---|---|---|---|---|
| Soil sample | Wheat-field I | Pine-forest C | Wheat-field K | Pine-forest I |
| *Pythium* | | | | |
| acanthicum | 2 | – | 2 | – |
| afertile | 20 | 48 | 62 | 86 |
| irregulare | 6 | – | – | – |
| monospermum | 2 | – | – | – |
| paroecandrum | 6 | – | 30 | – |
| Other fungi* | 42 | 30 | 4 | 2 |
| Fungi failing to grow | 22 | 22 | 2 | 12 |
| Total | 100% | 100% | 100% | 100% |

*Predominantly *Mortierella* spp.

A. *avenae* isolates earlier obtained from a number of wheat-field soils failed to reproduce upon an isolate of *Pythium ultimum* (supplied by Mr. M. Bumbieris), as was also found for the Brownhill Creek population by Evans (1968). It was therefore of interest to determine whether this fungus was present in soil at the study sites, and the selective method of Stanghellini and Hancock (1970) was used for this purpose. Soil (1 g) from wheat-field Quadrats I and K and pine-forest Quadrats C and I was shaken in 99 ml sterile distilled water for 2 min on a test-tube shaker, 1 ml withdrawn from 2 cm below the meniscus and placed drop by drop on the margin of 3-day old water agar (2%) in Petri plates. The suspension was agitated for a further 2 min and another 1 ml sample applied to other plates in the same manner. Plates were incubated at 24°C for 18-24 hours at which time any hyphae growing away from the margins of the drops were sub-cultured onto cornmeal agar for subsequent identification. Only 9 out of 179 drops produced hyphae and none of these was *Pythium ultimum*. It was concluded that this fungus was rare if present at all in the soil examined.

## (3) *Phytophthora* spp.

Selective methods used to study the incidence of *Phytophthora* spp. included pear baiting, and pine-needle baiting (Dance *et al.*, 1975) · combined with the selective medium of Tsao and Guy (1977). This selective medium was also used directly with soil, as recommended by Tsao and Guy (1977).

About 200 g of soil from Quadrats I and C of the forest and Quadrats I and K of the wheat-field was placed in 120 mm-diameter dishes, a clean pear placed on top and rainwater added to several cm above the soil. Lesions on pears were sub-cultured onto cornmeal agar (Difco) over the course of a week. *Phytophthora* spp. were not detected by this method.

In using pine-needles as bait, soil (from forest Quadrats I, B and C and wheat-field Quadrats I and K) was added to dishes as before and covered with either distilled water, autoclaved peptone/soil extract (1 g Bacto-peptone incubated for 2 days with 100 g soil and extracted in 1 L water) or autoclaved pond water/distilled water (1:2). The basal portions of fresh *Pinus radiata* needles (6 per dish) were then floated on the surface of the liquid and dishes incubated at room temperature or 16°C for 3 days. Needles were then surface-sterilized for 30 sec in 0.5% sodium hypochlorite, washed 3 times in sterile distilled water and plated onto the *Phytophthora* selective medium of Tsao and Guy (1977). Plates were incubated at 25°C and fungi sub-cultured onto cornmeal or lima bean agar up to one week later. *Phytophthora* spp. were not isolated by this method and it was concluded that, if present, they were rare in these soils. Of 92 fungi isolated from pine-needles exposed to pine-forest soil, all but one (a *Trichoderma* sp.) proved to be *Pythium acanthicum*, a fungus not isolated from this soil previously on *Pythium* selective media.

Soil (100 mg) from forest Quadrat C and wheat-field Quadrat I was sprinkled evenly over the surface of the selective medium (Tsao and Guy, 1977) in Petri dishes (10 mg of soil per dish) and incubated at 25°C in the dark. Colonies were counted after 72 hours and the first 5 colonies encountered per plate (giving a total of 50 per sample) sub-cultured onto cornmeal agar for identification. After 72 hours the wheat-field soil had produced 109.2 ± 4.7 (S.E.) colonies per plate compared with only 18.7 ± 2.1 (S.E.) for the pine-forest soil. No *Phytophthora* spp. were recovered by this method; the most commonly isolated fungi from forest soil were *Mortierella* spp. (58%) and *Pythium afertile* spp. (36%), while *Gongronella butleri* (68%) and *Mortierella* spp. (20%) were most commonly isolated from wheat-field soil.

## (4) *Botrytis* spp.

A *Botrytis* sp. had been isolated from pine-forest soil from dilution plates and the selective medium of Kritzman and Netzer (1978) was used to further study its incidence.

Soil (10 g) from forest Quadrat C and wheat-field Quadrat I was serially diluted in sterile distilled water to give 5 plates at a final dilution of 1/100 and one plate at a dilution of 1/10 per sample. Plates were poured with the selective medium and after 48 hours at 25°C brown-pigmented colonies were counted and sub-cultured onto NDY for identification.

Most colonies so isolated proved to be *Fusarium*, *Phoma* or *Stemphylium* spp.. No *Botrytis* spp. were isolated, suggesting that they were rare in these soils.

## 7. FUNGI ISOLATED FROM ROOTS OF WHEAT AND *PINUS*

*Penicillium* and *Trichoderma* spp. were the dominant fungi isolated from *Pinus* roots, while wheat roots yielded a greater diversity of fungi (Tables 24, 25). The composition of the mycoflora from *Pinus* roots was generally similar to that found for organic debris from pine-forest soil but differed from that of soil. In particular, the frequency of *Trichoderma* (especially *T. koningii*) was higher than that for soil. Wheat roots exhibited a higher incidence of dark sterile fungi and a reduced frequency of *Penicillium* and *Aspergillus* spp. compared with soil. Data for sodium hypochlorite-treated wheat roots are not given (Table 25) due to destruction of cultures by mites. Of 20 cultures not destroyed, 75% were of dark sterile fungi, suggesting a similar picture to that found for streptomycin-treated roots.

TABLE 24: Frequency of fungi isolated from streptomycin-treated root
segments as % of total (wheat n = 80, *Pinus* n = 95)

| Wheat roots | % | *Pinus* roots | % |
|---|---|---|---|
| *Paecilomyces lilacinus* | 7.5 | *Penicillium* spp. | 52.6 |
| *Aspergillus* spp. | 3.8 | *Trichoderma koningii* | 29.5 |
| *Penicillium* spp. | 3.8 | *T. harzianum* · | 2.1 |
| *Phoma* spp. | 3.8 | *Mortierella* spp. | 6.3 |
| *Mortierella* spp. | 3.8 | Hyaline sterile cultures | 8.4 |
| *Phialocephala* sp. | 2.5 | Dark sterile cultures | 1.1 |
| *Fusarium roseum* sp. gr. | 2.5 | | |
| *F. solani* | 1.2 | | |
| *Fusarium* sp. | 1.2 | | |
| *Broomella* sp. | 1.2 | | |
| *Cochliobolus sativus* | 1.2 | | |
| *Myrothecium verrucaria* | 1.2 | | |
| *Periconia macrospinosa* | 1.2 | | |
| Hyaline sterile cultures | 3.8 | | |
| Dark sterile cultures | 61.3 | | |
| Total | 100.0% | Total | 100.0% |

TABLE 25: Frequency of fungi isolated from sodium
hypochlorite-treated *Pinus* roots (n = 54)

|  | *Pinus* roots |
| --- | --- |
| *Penicillium* spp. | 35.2 |
| *Trichoderma* | |
|   *koningii* | 24.1 |
|   *harzianum* | 5.5 |
| *Pythium* spp. | 13.0 |
| *Fusarium* spp. | 9.3 |
| *Mortierella* spp. | 9.3 |
| *Phoma eupyrena* | 3.6 |
| Total | 100.0% |

# 8. ACTINOMYCETES AND BACTERIA IN WHEAT-FIELD AND PINE-FOREST SOILS

Actinomycetes and bacteria were extracted from soil samples from wheat-field Quadrat I and pine-forest Quadrat C using a dilution plate technique (Lingappa and Lockwood, 1962). Total available propagules of both actinomycetes and bacteria were significantly higher in wheat-field soil compared with pine-forest soil (Table 26). This may be related in part to the preference by these organisms for neutral-alkaline conditions (Griffin, 1972).

TABLE 26: Mean numbers of actinomycete and bacterial propagules per g of wheat-field and pine-forest soil (n = 5). Numbers in brackets represent mean numbers of propagules per g of dry soil

|  | Wheat-field soil | Pine-forest soil |
| --- | --- | --- |
| Actinomycetes | 10 460 000*** (10 641 960***) | 812 000 (862 510) |
| Bacteria | 8 796 000*** (8 948 170***) | 2 062 000 (2 190 260) |

***Means for wheat-field and pine-forest soils significantly different at 0.01% level.

## V. SOIL FUNGI, BACTERIA AND ACTINOMYCETES AS FOOD RESOURCES OF *APHELENCHUS AVENAE* AND OTHER NEMATODES

It had been established that *A. avenae* was significantly less abundant in the pine-forest soil compared with the wheat-field soil and that these two soils possessed different mycofloras. To test the hypothesis that this difference in abundance may have resulted from differences in the suitability of these mycofloras as food sources of *A. avenae*, feeding trials between the nematode and fungi from the two soils were conducted. To determine whether differences existed in rates of reproduction achieved on given fungi by *A. avenae* from the wheat-field and pine-forest populations, isolates of both populations were tested on fungi from both soils. Several isolates from the same nematode population were also tested to determine the level of intra-population variability in reproduction rates on different fungi. Lastly, other presumed mycophagous nematodes from wheat-field and pine-forest soils were tested on fungi also obtained from these soils to determine if resource overlap in food occurred between them and *A. avenae*. Such resource overlap would be a pre-requisite to establishing the existence of competition for food between these nematodes; a possible alternative hypothesis in explaining differences in abundance of *A. avenae* between the two sites. In this regard it should be noted that the nematodes tested here are most certainly not the only mycophagous organisms (or, indeed, nematodes) present in these soils.

Tikyani and Khera (1969) reported that an isolate of *A. avenae* failed to reproduce on the bacterium *Bacillus megaterium* but was "cultivated on an unidentified bacterium when transferred in masses". Feeding trials between *A. avenae* and various cultures of soil bacteria were conducted to determine whether bacteria could be significant food resources for this nematode. Although actinomycetes are abundant in soil they have not previously been tested as food sources for *A. avenae*.

Fungi, bacteria and actinomycetes isolated from wheat-field and pine-forest soils were tested as food sources for *A. avenae* and other nematodes isolated from the same soils and maintained in monoxenic culture on *Botrytis cinerea*.

## 1. BACTERIA AND ACTINOMYCETES

Three randomly selected bacterial isolates from each soil, four actinomycetes from wheat-field soil and three actinomycetes from pine-forest soil were tested as food sources for *A. avenae* isolated from soil of Quadrat A of both sites.

*A. avenae* failed to reproduce above those numbers on uninoculated agar when placed on cultures of bacteria from either soil (Table 27). It was concluded that *A. avenae* was not able to utilize these bacteria as food sources.

Actinomycetes on which *A. avenae* were tested were also found to be unsuitable as hosts, and although several yielded numbers slightly in excess of controls (Table 27) they were very small when compared with yields achieved on fungal hosts, which may exceed hundreds of thousands. Numbers of adults recovered from plates did not exceed the initial inoculum and the small increases in numbers presumably resulted from hatching of eggs laid by females. Females transferred from a suitable fungal host will lay a small number of eggs without any further feeding, however, the larvae which hatch from these eggs require a suitable food source to reach maturity.

It therefore appeared unlikely that *A. avenae* utilized bacteria or actinomycetes as food sources in the soils tested.

TABLE 27:   Mean numbers of *A. avenae* (wheat-field and pine-forest cultures)
reared on cultures of bacteria and actinomycetes from wheat-
field and pine-forest soils.   Controls refer to plates inocu-
lated with nematodes alone

| | Nutrient agar | | | | Krainsky's medium | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Control | Bacteria | | | Control | Actinomycetes | | | |
| | | 1 | 2 | 3 | | 1 | 2 | 3 | 4 |
| Wheat-field | 0.8 | 1.0 | 0.6 | 1.0 | 1.8 | 7.4 | 4.0 | 2.4 | 2.0 |
| Pine-forest | 0.8 | 0 | 0.8 | 0 | 0.4 | 2.8 | 7.2 | 3.4 | − |

## 2. FUNGI

### (a) *Description of Nematode Isolates Tested on Fungi*

Various isolates of *A. avenae* and *Aphelenchoides* spp.
originating from the two sites were used in feeding trials with fungi from
pine-forest and wheat-field soils, *viz.*:

*A. avenae* -

(1) *Pine-forest*

> (i) isolate from pine-forest soil, Quadrat A.

> (ii) isolate from stalk of *Suillus luteus* sporocarp
> from pine-forest.

(2) *Wheat-field*

> (i) isolate from wheat-field soil, Quadrat A.

*Aphelenchoides* spp. -

(1) *Pine-forest*

> (i) isolate from L-litter layer of pine-forest, appearing to
> be closest to *A. coffeae* (Zimmerman, 1898) Filipjev, 1934
> (after key of Fortuner, 1970). Adult females 734.5 ±
> 22.7 μm (S.E.) in length (mean 20 specimens, range 508-874
> μm), with four incisures in lateral field, oocytes in a
> single row and bearing a tufted mucro on the tip of the tail.
> (All measurements from specimens from two-week old cultures
> on *Botrytis cinerea* incubated at 25°C). Males not seen;
> asexual reproduction (apparently by parthenogenesis) con-
> firmed by starting cultures with single second-stage larvae.

> (ii) isolate from fruiting body of *Rhizopogon luteolus*, apparent-
> ly belonging to the same species as the isolate from
> L-litter layer.

(iii) isolate from pine-forest soil, Quaddrat C.  Adult females
597 ± 15.4 μm (S.E.) in length (mean 10 specimens, range
543-689 μm), with three incisures in the lateral field, and
bearing a simple mucro on the tip of the tail.  Stylet 11-12 μm
in length.  Sex ratio of males to females 1:19, asexual
reproduction (apparently by parthenogenesis) confirmed.
Adult males 568.8 ± 16.5 μm (S.E.) in length (mean 10 speci-
mens, range 441-639 μm), curved ventrally when killed by
heat, spicules paired, cuniform, with prominent apex and
rostrum and measuring 20.7 ± 0.7 μm (S.E.) around the arc
of the dorsal limb (mean of 5 specimens, range 18.6-22.6 μm).
Mail tail without bursa or gubernaculum but with three pairs
of papillae.  Tail of female more bluntly rounded than de-
picted for *A. composticola* by Franklin (1957) and also
differing from this species by the presence of annules in
the head region.

(2)  _Wheat-field_

(i)  isolate from wheat-field soil, Quadrat B, and similar in
appearance to the isolate from L-litter layer of the pine-
forest.  Adult females 696.5 ± 14.9 μm (S.E.) in length
(mean 21 specimens, range 568-804 μm) and bearing a tufted
mucro on the tip of the tail.  Males absent, asexual re-
production (parthenogenetic) confirmed.

(ii)  isolate from wheat-field soil, Quadrat H.  Adult females
597.5 ± 15.4 μm (S.E.) in length (mean 20 specimens, range
499-739 μm), with three incisures in lateral field and tail
without a mucro.  Males absent, asexual reproduction
(parthenogenetic) confirmed.

In these feeding trials "Hibitane" (chlorhexidine gluconate), an agent that is both bacteriocidal and fungicidal, was at first used to free nematodes of surface contaminants prior to inoculation.   Peacock (1959) recommended an immersion time of 15 min for treating *Meloidogyne* egg-masses. In the feeding trials an immersion time of 10 min was initially used and was subsequently decreased to 5 min and then to 2 min.   Although no immediate mortality resulted from treatment with "Hibitane", toxic effects became evident when nematodes were observed over several days.   Consequently, this agent was replaced by a mixture of antibiotics (penicillin, streptomycin and tetracycline) which was found to give better survival of nematodes and reduce variability in the results, but to lead to more plates being discarded due to contamination by fungi.   The two sets of results (from nematodes treated with "Hibitane" or antibiotics) are analyzed separately, data from the latter being subjected to an analysis of variance.

### (b)  Results of Feeding Trials on Fungi

Evans (1968) found that the population (on a log. scale) of *A. avenae* reared on a fungus in culture followed a sigmoid curve at temperatures between 20°C and 30°C.   From several fungi he tested, highest numbers of nematodes were produced on an isolate of *Rhizoctonia solani* and after fourteen days at 25°C the population was nearing the end of the log. phase of growth and was approaching a plateau.   A similar result was indicated in the present study on *Botrytis cinerea*, the fungus used to maintain cultures of the nematode.   Given a suitable host fungus, the conditions used in this study – fourteen days incubation at 25°C – were sufficient to allow build-up of large nematode poulations.   However, Evans (1968) pointed out that interpretation of results showing different populations on different host fungi at a single harvest was difficult unless it is known at which phase in the growth curve the harvest is made.   In this study, fungal groups

involving many isolates rather than individual fungi were compared.

Control plates in which nematodes were inoculated onto agar without fungi did not support any population increase. Production of the various isolates of *A. avenae* and *Aphelenchoides* spp. on genera and species groups of fungi from wheat-field and pine-forest soils are summarized in Tables 28a and 29a respectively. A log transformation [$y = \log_e$ (total nematodes + 1] was applied to this data and analyses of variance performed both for individual fungal genera (Appendices 5a-v and 6a-1) and for the data overall (Tables 28b and 29b).

Variation in numbers of nematodes produced between both nematode isolates and fungal groups was highly significant (P = 0.001; Tables 28b and 29b). These two variables were clearly not independent, as the inter-action between them was found to be highly significant (P = 0.001; Tables 28b and 29b). It was concluded that the nematode isolates differed in their rate of population growth on fungi, that numbers of a given nematode isolate produced on some fungal groups were higher than on others, and that the suitability of different fungal groups as food-hosts tended to follow a consistent pattern across nematode isolates (that is, fungi that were "poor" food-hosts for one nematode isolate tended to be poor hosts for other isolates).

Overall, the *A. avenae* isolates produced higher numbers on fungi from both habitats compared with any of the *Aphelenchoides* isolates (Figs. 17-18, Tables 28a and 29a). Since all of the *Aphelenchoides* isolates used were smaller in body length than *A. avenae* and probably smaller in volume, the above finding suggests that the rate of assimilation of fungal protoplasm and conversion to biomass was considerably higher in *A. avenae*. This may indicate a higher degree of specilization towards mycophagy by *A. avenae*, it being possible that some or all of the. *Aphelenchoides* spp. were only facultative fungal feeders. Yields from *Aphelenchoides* isolates C (pine-

TABLE 28a:   Table of means for production of nematodes/fungal genera and species groups from wheat-field soil.   *A. avenae* isolates:  P - pine-forest soil;  W - wheat-field soil.  *Aphelenchoides* isolates:  pine-forest - L (litter);  C (soil);  wheat-field soil - B,H.

| Fungi | *A. avenae* | | *Aphelenchoides* isolates | | | | Total |
|---|---|---|---|---|---|---|---|
| | P | W | L | C | B | H | |
| *Penicillium* | 1942.9 | 5965.7 | - | 3.8 | 1068.0 | 364.6 | 2642.7 |
| *Fusarium* | 10216.7 | 16599.9 | 2621.8 | 1432.6 | 2803.1 | 528.6 | 8077.9 |
| *Trichoderma* | 1305.0 | 2447.3 | 5775.0 | 2602.5 | 7177.5 | - | 3457.4 |
| *Mortierella* | 12135.0 | 12843.9 | - | - | 9143.3 | 1305.0 | 10825.6 |
| Mucorales* | 7023.8 | 16577.0 | 1236.3 | 1035.0 | 1271.7 | 257.5 | 6409.7 |
| *Aspergillus* | 73.6 | 320.0 | - | - | 51.5 | 332.5 | 121.6 |
| *Metarrhizium* | 3312.5 | 8375.0 | - | - | - | - | 5843.8 |
| *Cladosporium* | 1485.0 | 6800.0 | - | - | - | - | 4142.5 |
| *Paecilomyces* | 3960.0 | 17812.5 | - | - | - | - | 11875.7 |
| *Acremonium* | 630.0 | 31968.8 | - | 0.5 | 1.5 | 201.3 | 9665.7 |
| *Gliocladium* | 265.0 | 662.5 | - | 15.5 | 0.5 | 232.5 | 235.2 |
| *Graphium* | 8925.0 | 17375.0 | - | 1176.0 | 205.0 | - | 7740.9 |
| *Broomella* | 9875.0 | 32500.0 | 1267.3 | 335.0 | 865.3 | 12.5 | 7655.0 |
| *Phoma* | 11929.4 | 24861.5 | 1507.1 | 939.0 | 1240.0 | 1085.0 | 10286.5 |
| *Cochliobolus* | 10000.0 | 25375.0 | - | - | - | - | 20250.0 |
| *Myrothecium* | 1509.7 | 4691.9 | - | 5.4 | 693.7 | 190.0 | 1610.7 |
| *Torulomyces* | 9410.0 | 30531.3 | - | - | - | - | 19970.6 |
| *Doratomyces* | 485.0 | 14093.8 | - | - | 75.0 | 2100.0 | 6169.5 |
| *Coniothyrium* | 1940.0 | 2730.0 | - | - | 69.8 | - | 1867.4 |
| *Periconia* | 15458.3 | 20562.5 | - | - | - | - | 17500.0 |
| *Ulocladium* | 9266.7 | 12481.3 | 29.5 | - | - | 19.0 | 6728.6 |
| Sterile fungi | 6966.4 | 16324.6 | 7990.8 | 229.0 | 5827.5 | 542.5 | 7255.7 |
| Total | 7462.8 | 14237.6 | 3609.2 | 595.8 | 2636.2 | 511.2 | 6777.5 |

*Other than *Mortierella* (*Mucor*, *Gongronella* and *Cunninghamella*).

TABLE 28b:   Analysis of variance of data as summarized in Table 28a.
Before analysis a log. transformation ($y = \log_e$ (total
no. nematodes + 1)) was applied to the data.

Significance levels for variance ratios:
P = 0.001 (***);   P = 0.01 (**);   P = 0.05 (*);
N.S. = non-significant.

| Source of variation | df | Sum of squares | Mean square | F |
|---|---|---|---|---|
| Fungal genera | 21 | 1942.90 | 92.52 | 35.58 *** |
| Nematode isolates | 5 | 3267.47 | 653.50 | 251.29 *** |
| Interaction | 66 | 1066.51 | 16.16 | 6.21 *** |
| Residual | 1111 | 2889.17 | 2.60 | |
| Total | 1203 | 9166.05 | | |

TABLE 29a: Table of means for production of nematodes on fungal genera and species groups from pine-forest soil. Nematode isolates as given in legend to Table 28a, except for *A. avenae* isolate S from sporocarp of *Suillus luteus* collected in pine-forest

| Fungi | *A. avenae* | | | *Aphelenchoides* isolates | | | | Total |
| | P | W | S | L | C | B | H | |
|---|---|---|---|---|---|---|---|---|
| *Penicillium* | 1982.5 | 10536.3 | 15117.7 | 2523.8 | 12.6 | 1.0 | – | 4474.8 |
| *Paecilomyces* | 3110.3 | 14012.5 | – | 1600.0 | 3247.5 | 285.0 | – | 6411.5 |
| *Trichoderma* | 13337.5 | 17109.4 | – | 915.0 | 864.4 | 1311.3 | – | 9906.8 |
| *Mortierella* | 12277.3 | 14168.8 | 15657.1 | – | 1170.6 | 2924.0 | – | 9303.7 |
| *Mucor* | 7400.0 | 4808.8 | – | – | – | – | – | 6620.0 |
| *Fusarium* | 4668.2 | 16357.6 | 9500.0 | 1631.1 | 366.6 | 2553.8 | – | 7888.4 |
| *Verticillium* | 3481.5 | 8609.1 | – | 2370.0 | 2.1 | 4287.5 | – | 4220.6 |
| *Pestalotia* | 7946.3 | 28041.7 | – | 15600.0 | 877.5 | – | 27.5 | 13171.2 |
| *Botrytis* | 20550.0 | 39625.0 | – | – | – | – | 13.0 | 26265.9 |
| *Chaetomium* | 6425.0 | 8366.7 | – | – | – | – | – | 7257.1 |
| Sterile fungi | 5164.5 | 8085.2 | 7708.3 | 1031.2 | 237.9 | 22877.5 | – | 6899.1 |
| P16* | 4245.6 | 11612.5 | 15675.0 | – | 140.0 | – | – | 7554.5 |
| Total | 4286.6 | 14170.3 | 13874.4 | 2731.2 | 372.3 | 6767.0 | 20.3 | 6770.3 |

*Unknown Hyphomycete bearing conidia.

TABLE 29b: Analysis of variance of data as summarized in Table 29a. Before analysis a log. transformation ($y = \log_e$ (total no. nematodes + 1)) was applied to the data.

| Source of variation | df | Sum of squares | Mean square | F |
|---|---|---|---|---|
| Fungal genera | 11 | 751.46 | 68.31 | 25.45 *** |
| Nematode isolates | 6 | 3082.11 | 513.69 | 191.38 *** |
| Interaction | 36 | 383.77 | 10.66 | 3.97 *** |
| Residual | 728 | 1954.01 | 2.68 | |
| Total | 781 | 6171.35 | | |

*** F-value significant at $P = 0.001$.

FIG. 17:   Mean production of antibiotic-treated nematodes on
          genera and species groups of fungi from wheat-field
          soil.


(a)   *A. avenae*:
      shaded bars – wheat-field soil isolate;
      unshaded bars – pine-forest soil isolate.


(b)   Pine-forest *Aphelenchoides* isolates:
      shaded bars – isolate C from soil;
      unshaded bars – isolate L from L-litter layer.


(c)   Wheat-field *Aphelenchoides* isolates:
      shaded bars – isolate H from soil;
      unshaded bars – isolate B from soil.
      (question marks indicate isolates not tested
      on those fungal groups).


PEN = *Penicillium*;   PAE = *Paecilomyces*;   MOR =
*Mortierella*;   MUC = Mucorales other than *Mortierella*
(*Mucor*, *Gongronella* and *Cunninghamella*);   TRI =
*Trichoderma*;   FUS = *Fusarium*;   ASP = *Aspergillus*,
MET = *Metarrhizium*;   CLA = *Cladosporium*;   ACR =
*Acremonium*;   GLI = *Gliocladium*;   GRA = *Graphium*;
BRO = *Broomella*;   PHO = *Phoma*;   COC = *Cochliobolus*;
MYR = *Myrothecium*;   TOR = *Torulomyces*;   DOR =
*Doratomyces*;   CON = *Coniothyrium*;   PER = *Periconia*;
ULO = *Ulocladium*;   STE = sterile cultures.

(a)

NO. NEMATODES x 10$^3$

(b)

(c)

PEN   PAE   MOR   MUC   TRI   FUS   ASP   MET   CLA   ACR   GLI   GRA   BRO   PHO   COC   MYR   TOR   DOR   CON   PER   ULO   STE
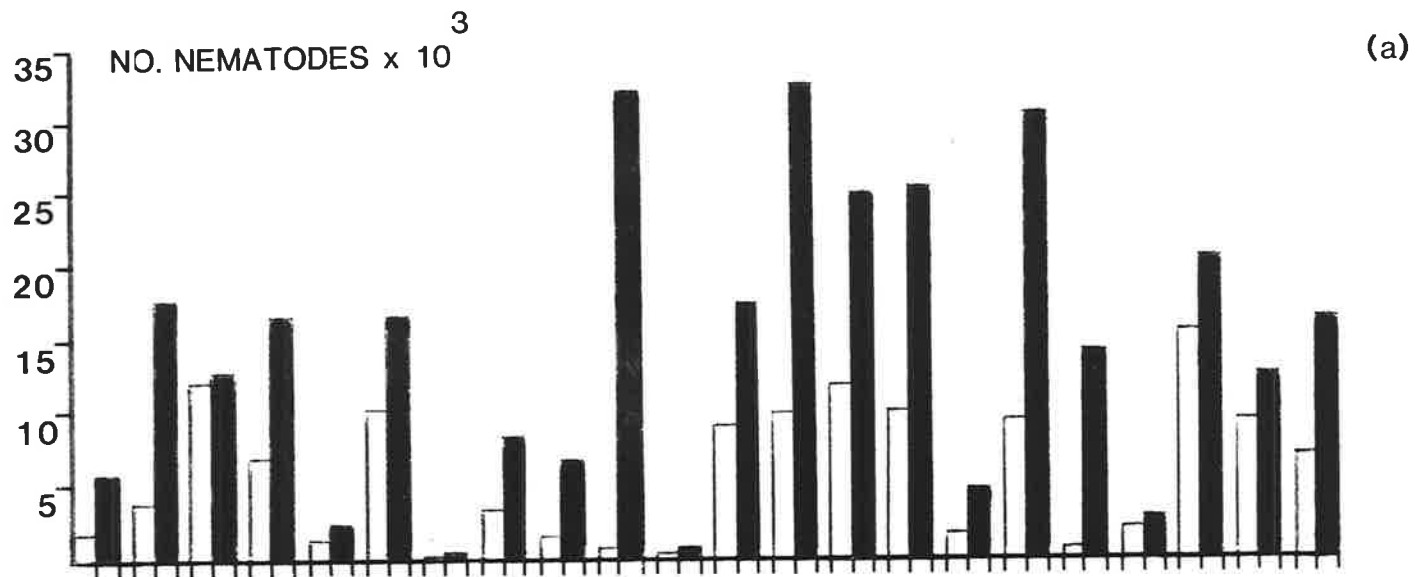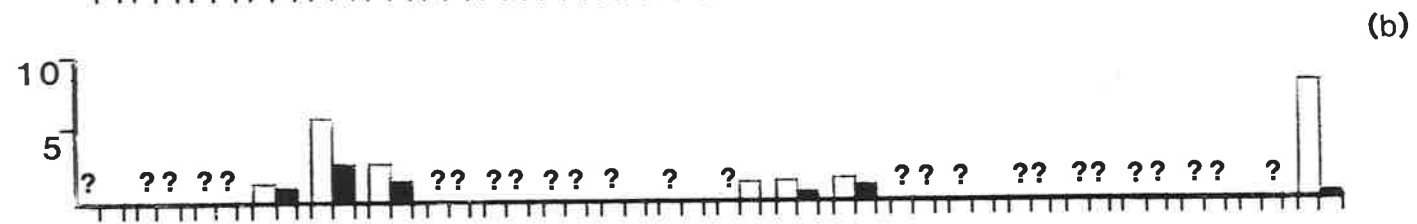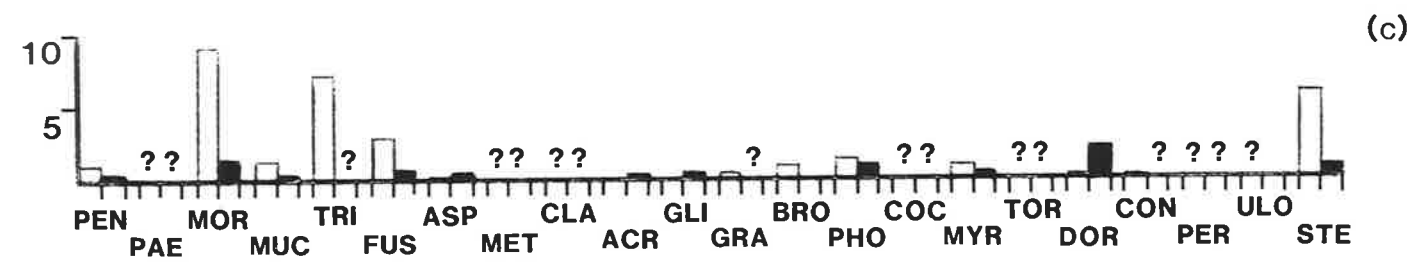
FIG. 18: Mean production of antibiotic-treated nematodes on genera and species groups of fungi from pine-forest soil.

(a) *A. avenae*:
shaded bars - isolate from *Suillus luteus* sporocarp from pine-forest;
partially shaded bars - isolate from wheat-field soil;
unshaded bars - isolate from pine-forest soil.

(b) Pine-forest *Aphelenchoides* isolates:
shaded bars - isolate C from soil;
unshaded bars - isolate L from L-litter layer.

(c) Wheat-field *Aphelenchoides* isolates:
shaded bars - isolate H from soil;
unshaded bars - isolate B from soil.

PEN = *Penicillium*; PAE = *Paecilomyces*; MOR = *Mortierella*; MUC = *Mucor*; TRI = *Trichoderma*; FUS = *Fusarium*; VER = *Verticillium*; PES = *Pestalotia*; BOT = *Botrytis*; CHA = *Chaetomium*; STE = sterile cultures; P16 = unknown Hyphomycete bearing conidia.
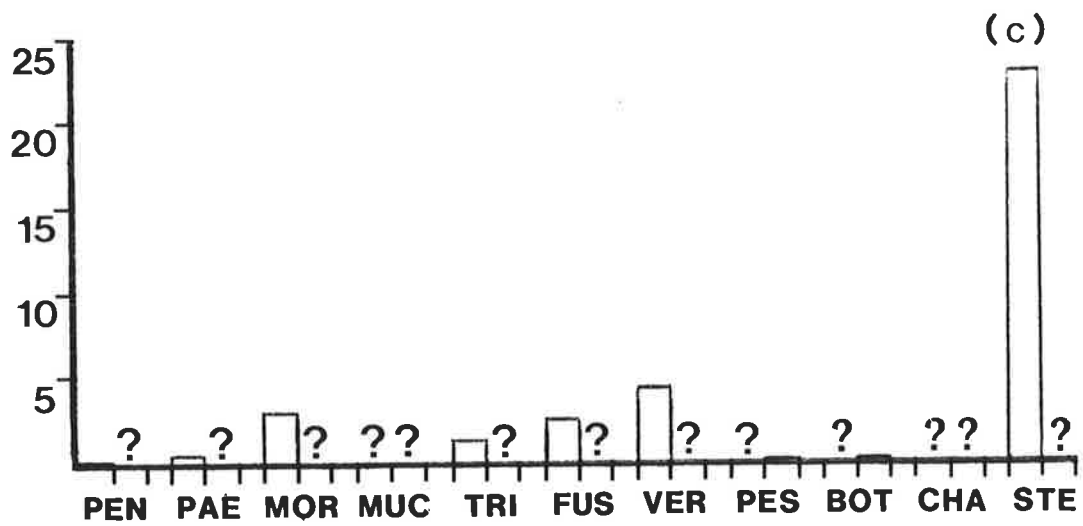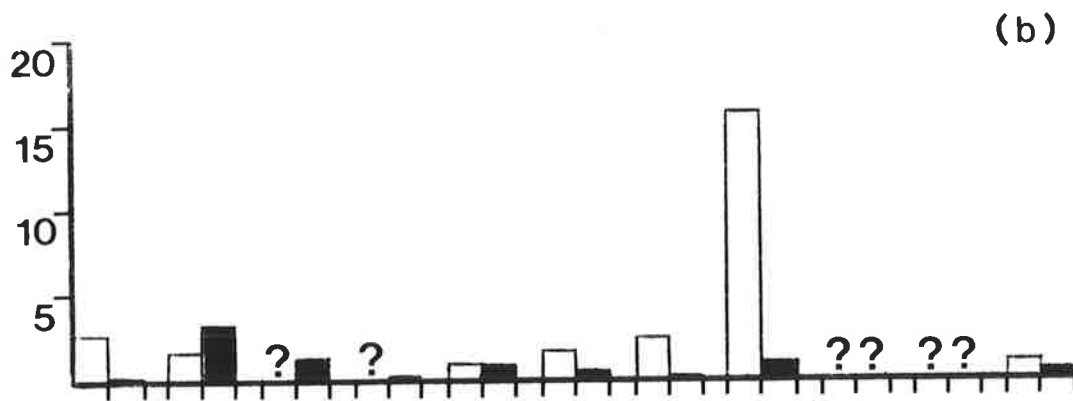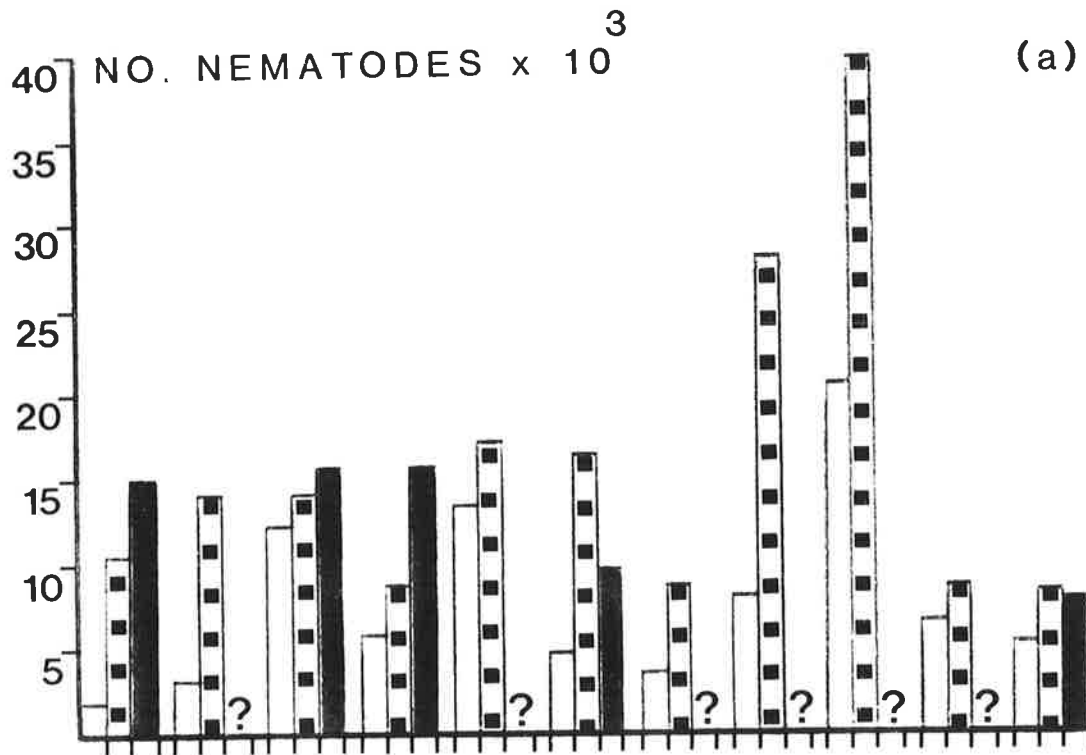
forest) and H (wheat-field) were particularly low compared with *A. avenae*.
Yields of isolates L (pine-forest) and B (wheat-field) were similar for many
groups of fungi. The similarity in morphology between these two
*Aphelenchoides* isolates was noted earlier. Overall yields of *Aphelenchoides*
isolates from the pine-forest were not markedly different from those from
the wheat-field.

The *A. avenae* isolate from wheat-field soil generally yielded
higher mean populations on fungal genera and species groups from both wheat-
field and pine-forest soils compared with the isolate from pine-forest soil
(Figs. 17a, 18a, and 19-20; Tables 28a and 29a). However, it became
apparent that this result could not be used to account for the higher density
of *A. avenae* in wheat-field soil compared with pine-forest soil. Thus,it
was found that isolates of *A. avenae* from the same habitat could vary as
much in their rates of population growth in monoxenic culture as between
isolates from different habitats. This was demonstrated by a pine-forest
isolate of *A. avenae* originating from a *Suillus luteus* sporocarp which, like
the wheat-field soil isolate, also produced higher populations than the
pine-forest soil isolate (Fig. 18a). It appeared that within the 3-hectare
area of forest sampled there co-existed *A. avenae* with substantially differ-
ing intrinsic rates of population growth in monoxenic culture. This
further suggested an underlying genetic diversity, possibly in the form of
distinct (parthenogenetic) clones. There is no reason to believe that this
situation would not apply equally to the wheat-field or any other habitat.

Mean production of *A. avenae* isolates over the range of fungi
tested from wheat-field soil was not markedly different from that of pine-
forest soil (see total means Tables 28a and 29a), although the total mean
for the pine-forest isolate was somewhat higher on the wheat-field fungi.
However, different fungal genera and species groups varied markedly in their
capacities to support population growth of *A. avenae* and, as was noted

FIG. 19: Mean numbers of pine-forest soil (shaded bars) and
wheat-field soil (unshaded bars) isolates of *A. avenae*
produced on some common fungal genera and species
groups from both wheat-field and pine-forest soils.

Means for genera were obtained by averaging means
for the individual isolates belonging to a genus and
were determined for both nematodes treated with
chlorhexidine gluconate (a) and antibiotics (b)
prior to inoculation.

Number of isolates tested are given below the bars.

PEN = *Penicillium*;  ASP = *Aspergillus*;   MUC =
Mucorales;  STER = sterile cultures.

NO. NEMATODES x $10^3$ (a)

(b)

PEN    ASP    FUS    TRICH    MUC    STER
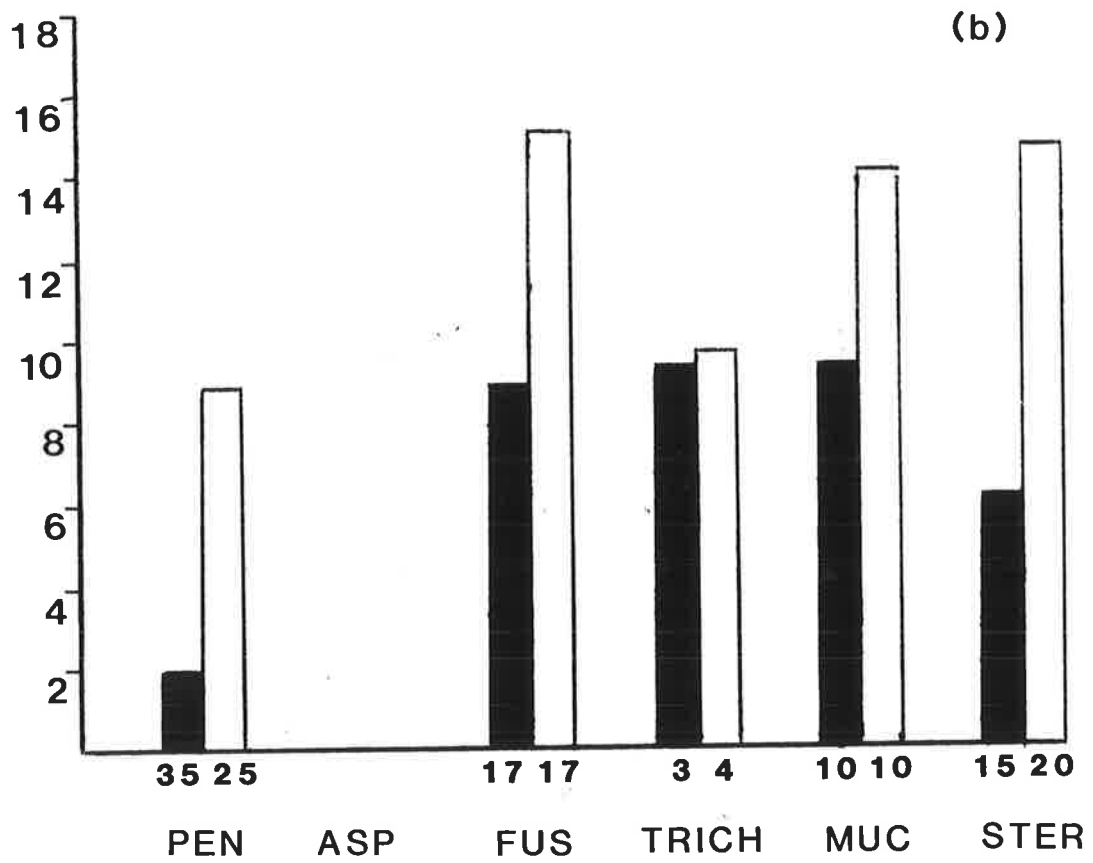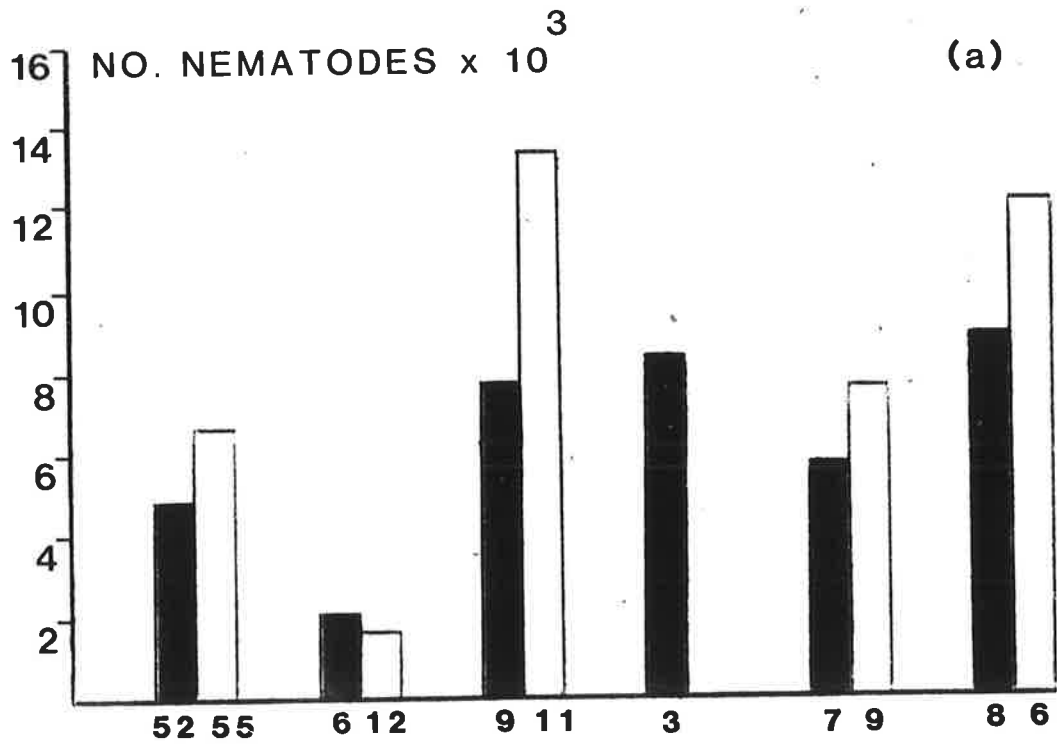
FIG. 20: Mean numbers of pine-forest soil (shaded bars) and
wheat-field soil (unshaded bars) isolates of
*A. avenae* on common fungal genera and species groups
from wheat-field soil. (Nematodes treated with
chlorhexidine gluconate (a) and antibiotics (b)).

NO. NEMATODES x $10^3$

(a)

16
14
12
10
8
6
4
2

15 27    4 10    6 9    1    6 8    4 5

(b)

18
16
14
12
10
8
6
4
2

3 10    13 13    1 2    7 7    11 16

PEN    ASP    FUS    TRICH    MUC    STER
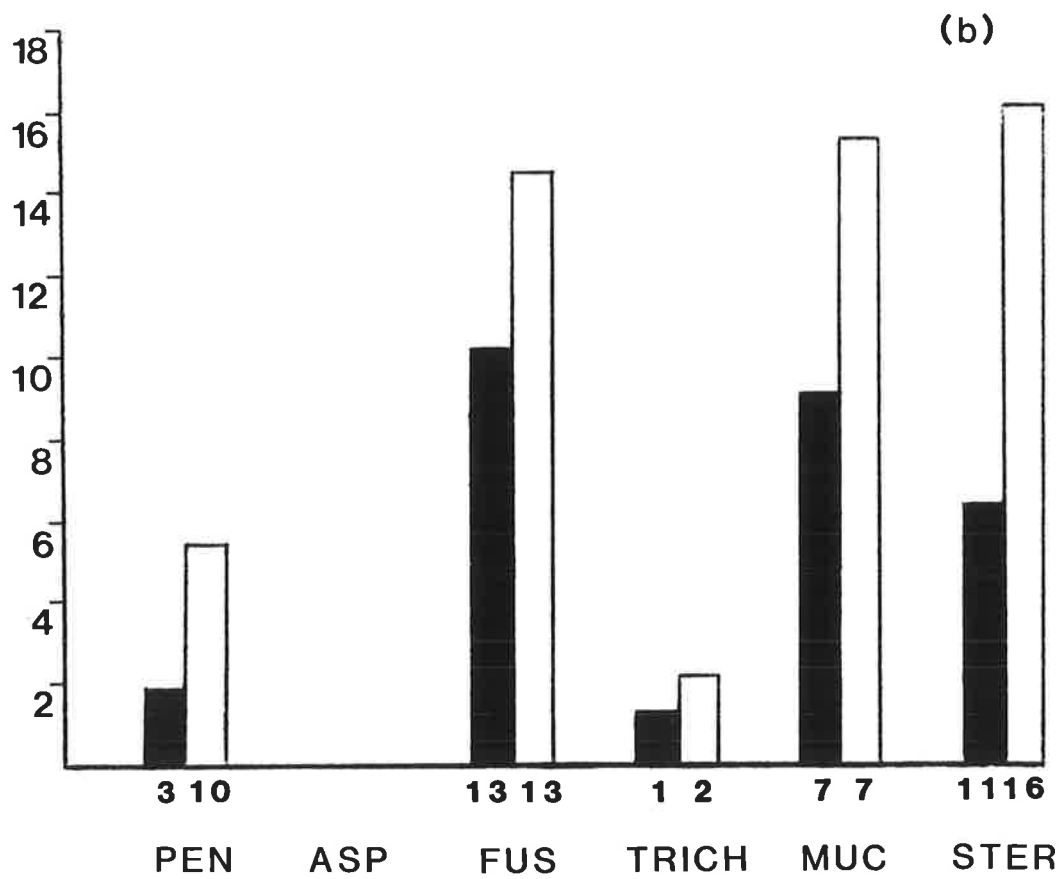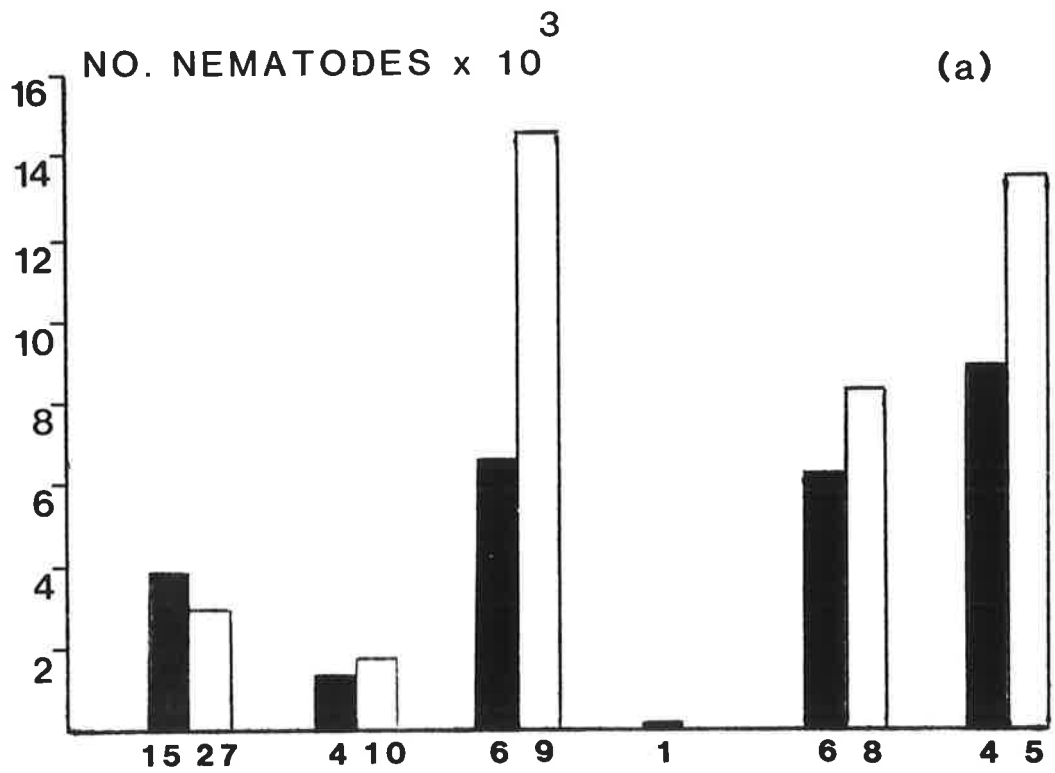
earlier, the wheat-field and pine-forest soils differed in the frequency
with which many of these genera could be isolated by various methods. In
particular, it appeared that *Penicillium* spp. were especially abundant in
pine-forest soil compared with wheat-field soil. Mean rate of reproduction
of *A. avenae* and, indeed, of all the nematodes on *Penicillium* isolates was
comparatively low (Tables 28a and 29a). It appeared that *Penicillium*
spp. were generally poor food-hosts of *A. avenae*. Other fungi which fell
into this category were *Aspergillus*, *Gliocladium*, *Coniothyrium* and
*Myrothecium*.

In contrast, those fungal groups which were isolated in signifi-
cantly greater frequency from wheat-field soil - *Fusarium* and sterile fungi -
tended to be more productive food-hosts of *A. avenae*. Other "good" hosts
of the nematode included:

(a)     from pine-forest soil; *Botrytis, Mortierella, Paecilomyces,*
        *Pestalotia* and *Trichoderma,*

(b)     from wheat-field soil; *Acremonium, Broomella, Cochliobolus,*
        *Doratomyces, Graphium, Mortierella* and other Mucorales,
        *Paecilomyces, Periconia, Phoma, Torulomyces* and *Ulocladium*
        (Tables 28a and 29a). Concomitant, then, with the greater
        diversity of fungi found in wheat-field soil was a larger number
        of good food-hosts in that soil compared with the pine-forest
        soil. Mankau and Mankau (1963) and Townshend (1964) concluded
        that *A. avenae* exhibited a distinct preference for plant para-
        sitic fungi but, as can be seen from the above, fungi which
        are presumed to be saprophytic (such as *Doratomyces, Graphium,*
        *Mortierella* and other Mucorales, *Paecilomyces, Periconia,*
        *Torulomyces* and *Trichoderma*) can serve adequately as hosts for

this nematode.   Pine-forest *Trichoderma* isolates appeared to
be more productive food-hosts for *A. avenae* than those from the
wheat-field.

For many individual fungal genera and species groups, particularly
those such as *Penicillium* in which it was possible to test a large number of
isolates, variation in numbers of nematodes produced between both nematode
isolates and fungal isolates was highly significant (Appendices 5 and 6).
The interaction between the latter two terms was also often highly signifi-
cant.   It was concluded that within these fungal groups the nematode
isolates differed in their rate of population growth, that some of the fungal
isolates were better food-hosts for a given nematode than others and these
also tended to be the same isolates that were better hosts for the other
nematodes.   Thus, fungal groups contained as much variability within them-
selves as between different groups in regard to suitability as food-hosts
for these nematodes.   This suggests that host suitability may depend  on
some property, such as some chemical factor, which varies below the generic
and specific levels.

A similar pattern was seen with *A. avenae* treated with "Hibitane";
with the wheat-field soil isolate generally reaching higher populations than
the pine-forest soil isolate and fungi such as *Penicillium* and *Aspergillus*
being poor food-hosts in comparison with others such as *Fusarium* and sterile
cultures (Figs. 19-21).   Some apparent exceptions are seen in the case of
certain fungi (other than *Penicillium*) from pine-forest soil (Fig. 21a),
probably due to an insufficient number of isolates being tested.   Populations
of the *A. avenae* isolate from the *Suillus luteus* sporocarp were at least
equal and, often, greater than those of the wheat-field soil isolate (Fig. 23a).
The very low populations of the former isolate recorded on *Penicillium* and

FIG. 21: Mean numbers of pine-forest soil (shaded bars) and wheat-field soil (unshaded bars) isolates of *A. avenae* on common fungal genera and species groups from pine-forest soil. (Nematodes treated with chlorhexidine gluconate (a) and antibiotics (b)).

NO. NEMATODES x $10^3$

(a)

16

14

12

10

8

6

4

2

37 28    2 2    3 2    2    1 1    4 1

(b)

18

16

14

12

10

8

6

4

2

32 15    4 4    2 2    3 3    4 4

PEN    ASP    FUS    TRICH    MUC    STER
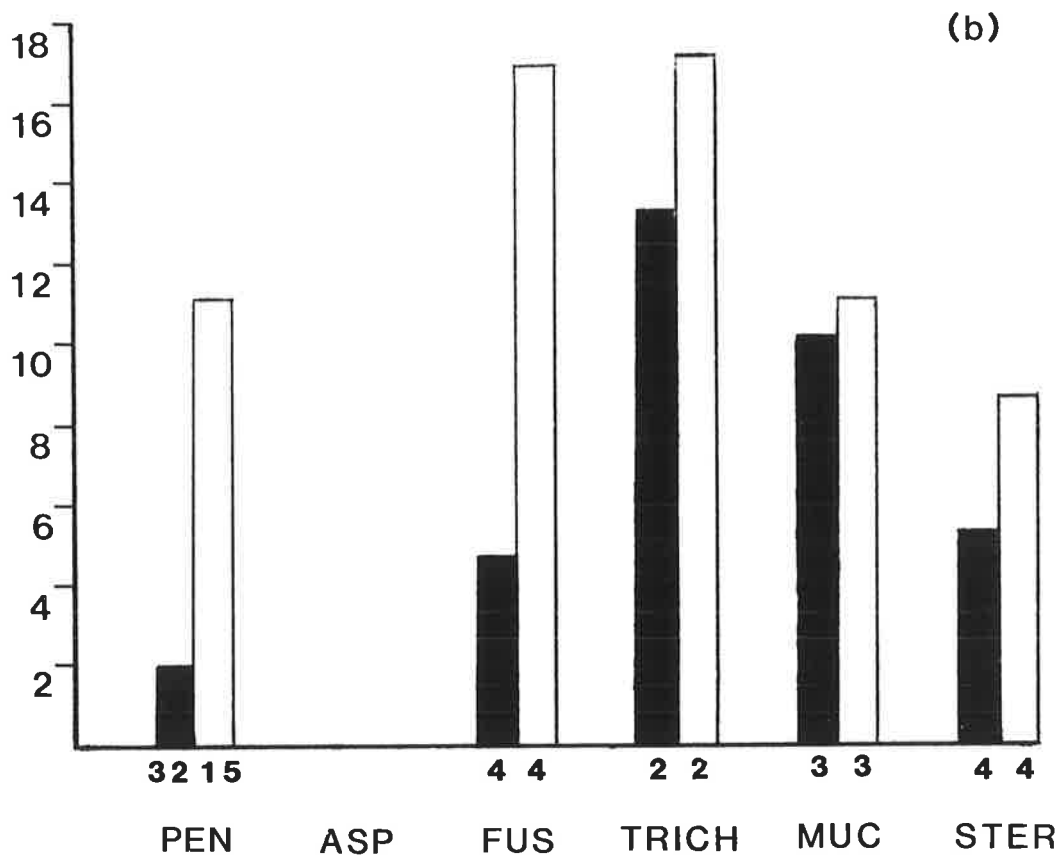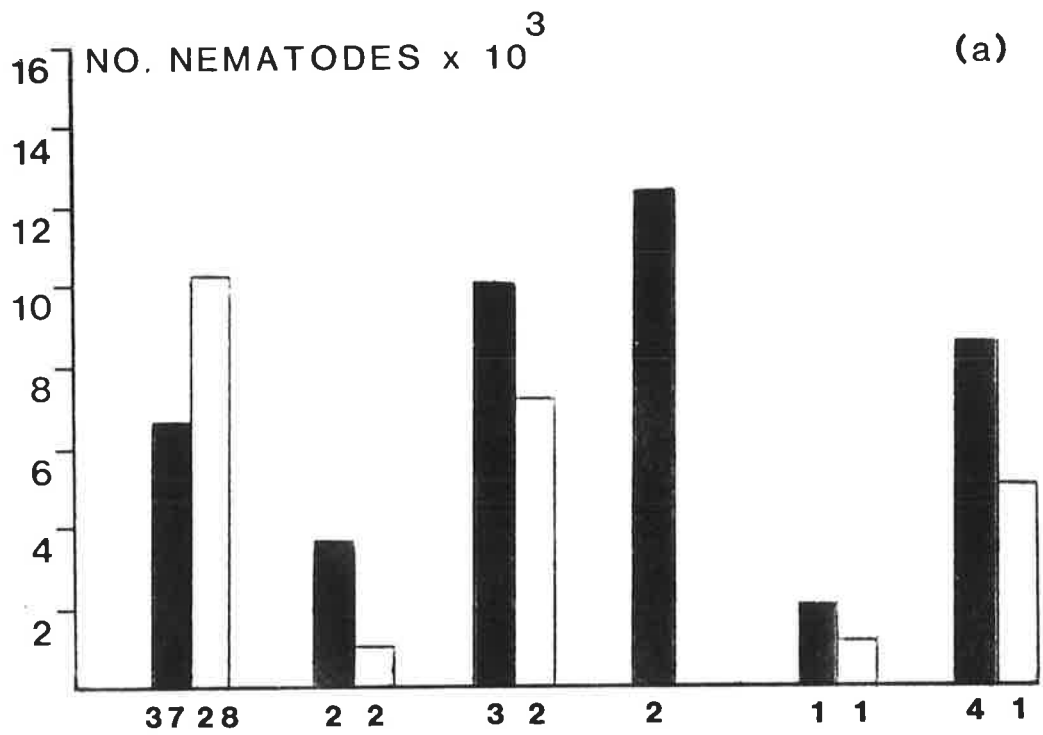
Mucorales reflect the fact that this isolate was tested upon only one isolate from each of these groups. With certain exceptions – *Aphelenchoides* isolates L and B on *Chaetomium* and *Sporotrichum (?)*, and on *Broomella* respectively – the *Aphelenchoides* isolates produced lower numbers than *A. avenae* on fungi from both wheat-field and pine-forest soils (Figs. 22, 23b). The pattern of host suitability observed for the *Aphelenchoides* isolates was similar to that seen for *A. avenae*. Thus, *Penicillium* and *Aspergillus* were also poor food-hosts for the *Aphelenchoides* isolates while *Fusarium* and sterile cultures were more productive hosts (Fig. 23b). The most productive hosts for *A. avenae* were, firstly from pine-forest soil: *Botrytis, Fusarium, Pestalotia, Trichoderma* and *Verticillium* (Fig. 22a), and, secondly, from wheat-field soil: *Fusarium, Mortierella* and other Mucorales, *Phoma*, sterile cultures and *Ulocladium* (Fig. 22b). The mean population of the pine-forest soil isolate of *A. avenae* on five basidiomycetes from the pine-forest was comparatively low (Fig. 22a). Of these, *Suillus luteus* was by far the most productive host, yielding a mean population of 10,549 per Petri dish. Numbers of the *Aphelenchoides* isolate from the L-litter layer produced on these basidiomycetes, apart from *Suillus luteus* (mean population 13,075), were also very low.

Comparison of results with those of previous studies is frequently not possible as different conditions were used as well as different nematode and fungal isolates. Evans (1968) used an initial inoculum of five adult female *A. avenae* and media which were similarly "rich" in nutrients as the one used in this study. He obtained highest numbers of nematodes, 14,000 to 21,000 after two weeks at 25°C, with an isolate of *Rhizoctonia solani*. The isolate of *R. solani sensu lato* used in the present study was found to be a poor host for *A. avenae*, but marked differences in the suitability of

FIG. 22:

(a) Mean numbers of pine-forest soil *A. avenae* (shaded bars) and *Aphelenchoides* from L-litter layer (unshaded bars) on fungal genera and species groups from pine-forest soil. Initial inoculum treated with chlorhexidine gluconate.

PEN = *Penicillium*; PAE = *Paecilomyces*; ASP = *Aspergillus*; FUS = *Fusarium*; TRI = *Trichoderma*; VER = *Verticillium*; BOT = *Botrytis*; MUC = *Mucor*; PES = *Pestalotia*; P16 = unknown Hyphomycete bearing conidia; BAS = Basidiomycetes; CHA = *Chaetomium*; SPO = *Sporotrichum* (?); PYT = *Pythium*; STE = sterile cultures; TOT = total.

(b) Mean number of wheat-field soil *A. avenae* (shaded bars) and *Aphelenchoides* isolate from wheat-field soil, Quadrat B (unshaded bars) on fungal genera and species groups from wheat-field soil. Initial inoculum treated with chlorhexidine gluconate.

Fungal groups as above except for: MUC - Mucorales other than *Mortierella*; MOR = *Mortierella*; GLI = *Gliocladium*; CLA = *Cladosporium*; PHO = *Phoma*; ULO = *Ulocladium*; BRO = *Broomella*; TOR = *Torulomyces*; MYR = *Myrothecium*; MET = *Metarrhizium*; PHI = *Phialocephala*; ACR = *Acremonium*; RHI = *Rhizoctonia*; ALT = *Alternaria*.

Question marks indicate isolates not tested on those fungal groups.

**NO. NEMATODES X $10^3$**

(a)

(b)
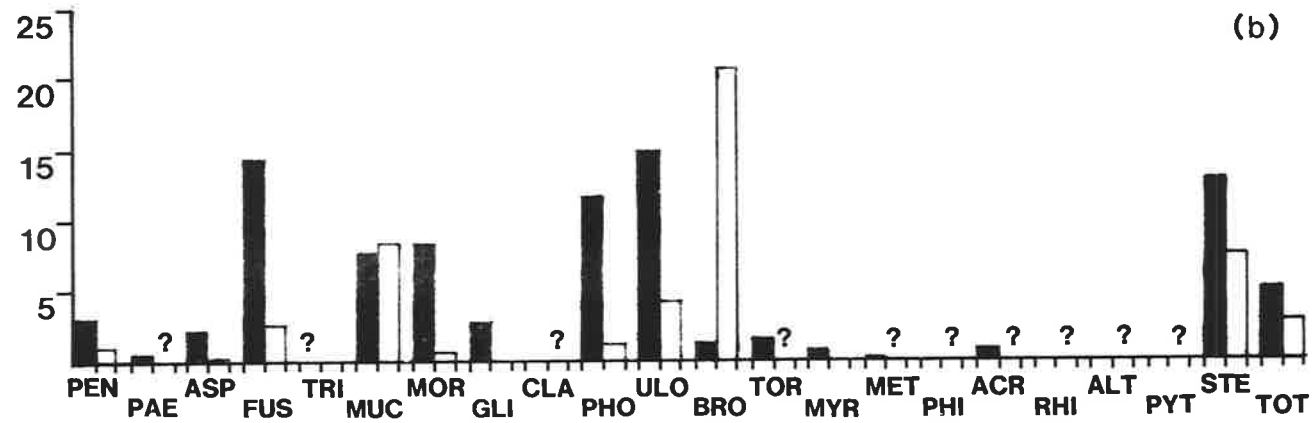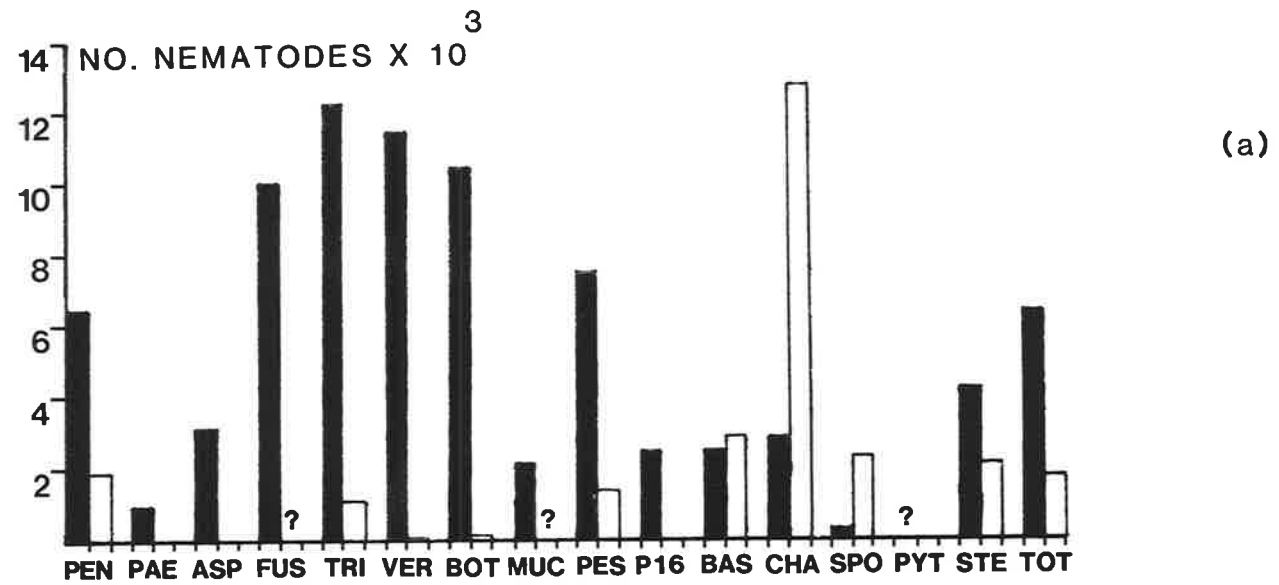
FIG. 23:

    (a)    Mean numbers of wheat-field soil *A. avenae* (shaded bars) and *A. avenae* isolate from *Suillus luteus* sporocarp from pine-forest (unshaded bars) on wheat-field soil fungi.  Initial inoculum treated with chlorhexidine gluconate.

    (b)    Mean numbers of *Aphelenchoides* isolates on wheat-field soil fungi.  Initial inoculum treated with chlorhexidine gluconate.

Shaded bars = L-litter layer isolate;  unshaded bars = pine-forest soil,  Quadrat C isolate;  bars with shaded squares = isolate from *Rhizopogon luteolus* sporocarp from pine-forest;  bars with cross-hatching = isolate from wheat-field soil, Quadrat B.

Fungal groups for both Figs. as in Fig. 22b.
(Note:  MUC = Mucorales).

**(a)**

NO. NEMATODES x 10$^3$
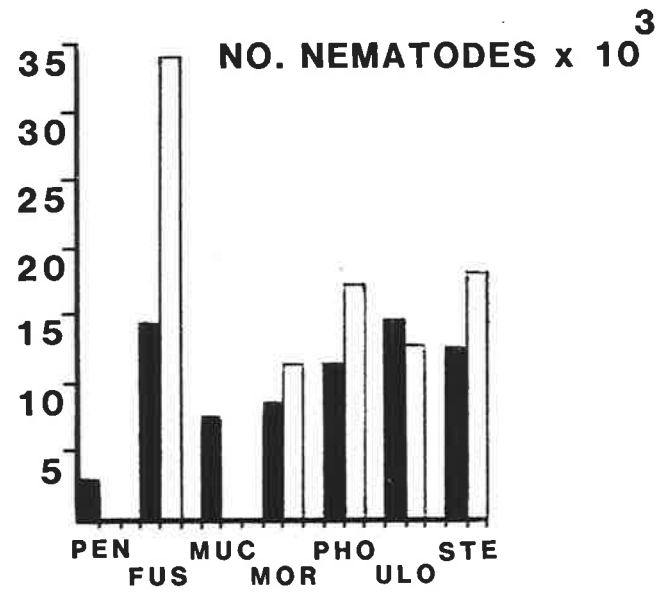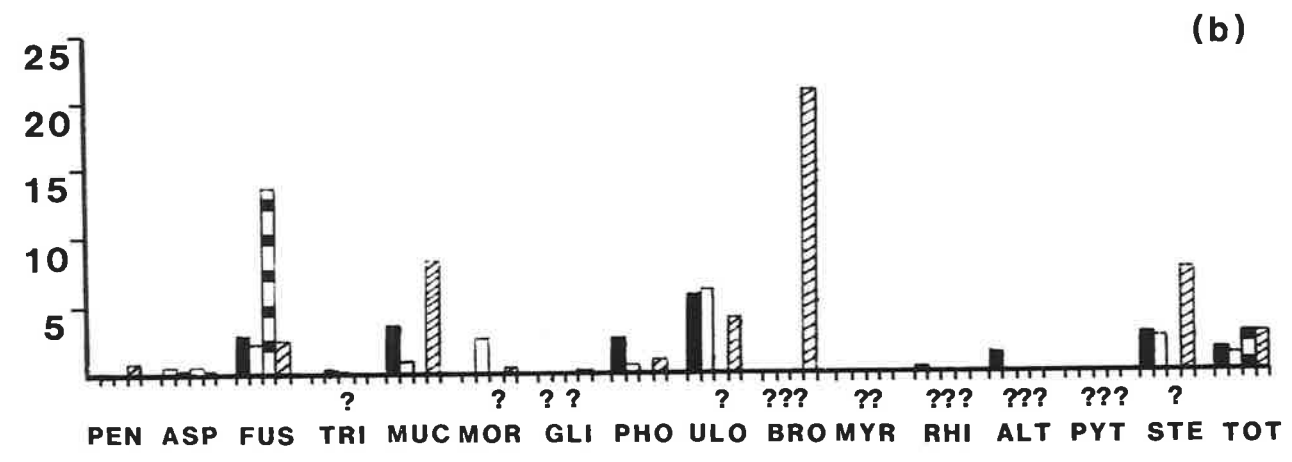
**(b)**

*R. solani* isolates as hosts for *A. avenae* have been noted previously (Barker, 1964). Numbers of *A. avenae* on certain other fungi in this study matched and exceeded those observed by Evans (1968).

Isolates of the *Aspergillus niger* species group from both wheat-field and pine-forest did not support any population growth of either *A. avenae* or any of the *Aphelenchoides* isolates tested and few living nematodes were recovered from such cultures. Mankau (1969a,b) found that an isolate of this fungus was toxic to *A. avenae* and determined that this toxicity was due to oxalic acid produced by the fungus. Results reported here suggest that such toxicity may be widespread amongst isolates of these fungi.

Mankau and Mankau (1963) found that the pythiaceous fungi they tested were poor hosts for *A. avenae*. *Pythium* spp. (*P. acanthicum*, *P. afertile* species group, *P. irregulare*, *P. monospermum* and *P. paroecandrum)* tested here were similarly poor hosts for *A. avenae*. However, the large numbers of nematodes produced on many isolates of *Mortierella* demonstrated that not all pythiaceous fungi are such poor hosts.

Highest numbers of *A. avenae* were produced on a *Botrytis* sp. isolated from pine-forest soil. Of the fungi used to rear *A. avenae* by Townshend (1964), highest numbers were also produced on *Botrytis* spp..

Evans (1968) observed that the ratio of adults to larvae of *A. avenae* in culture underwent periodic fluctuations over time and interpreted this periodicity as reflecting the generation time of the nematode under the conditions given. He also noted significant variation in the adult/larvae ratio of *A. avenae* reared on several different host fungi and, in particular, observed the lowest ratio from the host which produced the highest numbers of nematodes. It was therefore of interest to determine

whether the adult/larvae ratio of the various nematodes here used varied significantly between host fungi and whether a relationship existed between the ratio and host suitability over the much larger number of fungi from the present study.

For this purpose, the data for antibiotic-treated nematodes reared on pine-forest fungi were chosen as a representative sample. The parameter analysed was the percentage of the population made up by adult nematodes at harvest (number of adult nematodes/total number of nematodes x 100%). An angular transformation was applied to this data and analyses of variance performed both for individual fungal groups (Appendix 7a-1) and for the data overall (Tables 30, 31).

Variation in % adults produced between both nematode isolates and fungal groups was highly significant, as was the interaction between the latter two variables (P = 0.001; Table 31). It was concluded that there was significant variation in % adults produced both between nematode isolates and between fungal groups and that fungi which produced high (or low) % adults for one nematode tended also to produce high (or low) % adults for the other nematodes. Analyses of data for individual fungal groups showed that these sources of variation were equally significant for many groups between different fungal isolates (Appendix 7). *Penicillium* and *Verticillium* had the highest mean values of % adults over all nematode isolates. Mean % adults over all fungi was particularly high for the *Aphelenchoides* isolate from Quadrat C of the pine-forest (Table 30), a result which receives comment in the regression analysis below.

To determine whether a relationship existed between % adults and size of the population on different fungi, regression analysis was applied to (untransformed) data for several antibiotic-treated nematodes on pine-forest fungi. In all cases, there appeared to be a significant inverse

TABLE 30:  Mean % adults of nematode isolates at harvest on fungal genera and species groups from pine-forest soil

| Fungi | A. avenae | | | Aphelenchoides isolates | | | | Total |
|---|---|---|---|---|---|---|---|---|
| | P | W | S | L | C | B | H | |
| Penicillium | 25.57 | 19.78 | 22.28 | 32.64 | 76.03 | 100.00 | – | 31.45 |
| Paecilomyces | 18.62 | 13.95 | – | 32.17 | 13.39 | 28.88 | – | 18.76 |
| Trichoderma | 7.60 | 17.92 | – | 25.07 | 14.49 | 15.51 | – | 15.64 |
| Mortierella | 5.86 | 13.77 | 12.56 | – | 48.62 | 23.59 | – | 19.31 |
| Mucor | 7.78 | 14.17 | – | – | – | – | – | 9.70 |
| Fusarium | 16.18 | 15.50 | 38.33 | 19.85 | 28.80 | 17.96 | – | 18.95 |
| Verticillium | 22.14 | 25.84 | – | 18.92 | 100.00 | 41.13 | – | 38.45 |
| Pestalotia | 10.26 | 17.03 | – | 23.18 | 38.12 | – | 71.42 | 26.42 |
| Botrytis | 10.05 | 14.56 | – | – | – | – | 55.94 | 22.09 |
| Chaetomium | 8.64 | 7.34 | – | – | – | – | – | 8.08 |
| Sterile fungi | 15.69 | 19.53 | 25.14 | 31.54 | 60.91 | 10.38 | – | 25.31 |
| P16* | 13.03 | 7.51 | 9.95 | – | 100.00 | – | – | 24.95 |
| Total | 19.93 | 17.69 | 21.55 | 29.93 | 58.49 | 23.18 | 63.68 | 26.67 |

* Unknown Hyphomycete bearing conidia.

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TABLE 31:   Analysis of variance of data as summarized in Table 30.
Before analysis an angular transformation was applied to
the data

| Source of variation | df | Sum of squares | Mean square | F |
|---|---|---|---|---|
| Fungal genera | 11 | 19830.7 | 1802.8 | 12.25 *** |
| Nematode isolates | 6 | 85153.9 | 14192.3 | 96.41 *** |
| Interaction | 36 | 37190.2 | 1033.1 | 7.02 *** |
| Residual | 703 | 103484.4 | 147.2 | |
| Total | 756 | 245659.2 | | |

***F-value significant at P = 0.001.

relationship between the size of the nematode population achieved on different fungi in culture and the proportion of that population made up by adults (Table 32). The regression coefficient for the *Aphelenchoides* isolate from Quadrat C of the pine-forest was significantly different from those of all other nematodes examined (Table 32). The value of a (where the regression equation is in the form y = a + bx) for this nematode was also much higher than for the others, reflecting the many fungal isolates upon which little or no reproduction of this nematode occurred such that the % adults approached the initial value (100%). On other fungi, reproduction was comparatively rapid and many larvae were produced; these factors combined to produce a significantly higher negative regression coefficient for this nematode. This result suggests that the *Aphelenchoides* sp. in question is comparatively more specialized in the range of fungal hosts it utilizes than either the other *Aphelenchoides* sp. from pine-litter or *A. avenae*. This apparent restriction in "niche breadth" could also be associated with utilization of food resources other than fungi by the particular *Aphelenchoides* sp.. That is, in comparison with the other nematodes, this species may be a facultative fungal feeder, utilizing other food resources such as plant roots while remaining only partially adapted to mycophagy upon a limited range of fungal hosts. This hypothesis will require further testing, in particular, the elucidation of alternative food sources.

Regression coefficients for the pine-forest and wheat-field soil isolates of *A. avenae* were not significantly different but the a-value was somewhat higher for the wheat-field isolate. This probably reflects the higher mean populations observed for this isolate as % adults for the two isolates were comparable (Table 30).

TABLE 32: Fitted regression lines for % adults on total population of various nematodes reared in agar cultures on (n) fungal isolates from pine-forest soil

| Nematode isolate | n | Fitted Regression Line | Regression Coefficient ± S.E. | |
|---|---|---|---|---|
| *A. avenae:* | | | | |
| Pine-forest soil | 54 | $y = 27.06 - 0.0016\,x$ | $-0.00158^a \pm 0.00023$ | *** |
| Wheat-field soil | 38 | $y = 35.19 - 0.0013\,x$ | $-0.00134^a \pm 0.00019$ | *** |
| *Aphelenchoides:* | | | | |
| L-litter layer | 29 | $y = 37.82 - 0.0020\,x$ | $-0.00196^a \pm 0.00506$ | *** |
| Pine-forest soil (Quadrat C) | 32 | $y = 77.71 - 0.0412\,x$ | $-0.04124^b \pm 0.00538$ | *** |

[a,b] Regression coefficients with different letters are significantly different at P = 0.001. Statistical methods as used by Bailey (1959); t-test with pooled sums of squares used where n<30 except when variance ratio significant at P = 0.05.

*** Regression coefficient significantly different from zero at P = 0.001.

The finding of periodic fluctuations in the ratio of adults to larvae of *A. avenae* reared on fungi by Evans (1968) suggests particular caution needs to be taken in comparing results for different fungi at a single harvest. However, it appears from the present study that results for different fungal groups are sufficiently consistent for valid comparisons to be made.

# VI. DISCUSSION AND CONCLUSIONS

Intraspecific variation between parthenogenetic populations of
*A. avenae* from South Australian wheat-field soils was observed in karyotype
and in the frequency with which males are produced at high temperatures.
There appeared to be a distinct geographical distribution of populations
with n = 8 and n = 9 chromosomes whereas the distribution of populations
producing numerous males at high temperatures appeared to be haphazard;  popu-
lations (and, perhaps, individuals within those populations) varied markedly
in this capacity over the course of a few kilometres.   Triantaphyllou and
Fisher (1976) noted that the Californian population they examined with n = 9
chromosomes produced numerous males at high temperatures whereas an
Australian population with n = 8 chromosomes did not.   Results presented
here suggest that these two traits are not causally related (that is, popu-
lations with n = 9 chromosomes may or may not produce numerous males at
high temperatures).   The adaptive significance, if any, of these differences
in karyotype and propensity to produce males, is not clear and such differ-
ences do not appear to be correlated with any obvious environmental
variables.   Gradual increases in chromosome numbers are thought to have taken
place in other genera of plant parasitic nematodes through fragmentation of
chromosomes or addition of whole chromosomes (Triantaphyllou and Hirschmann,
1980).

Intraspecific variation was also observed in rates of egg-laying
and in rates of population growth on fungi in monoxenic cultures.   Pheno-
typic differences observed between individuals of parthenogenetic animals
are usually interpreted as indicating an underlying genetic diversity in the
form of distinct clones which may or may not be adapted to different environ-
ments (for example, in earthworms - Jaenike *et al.*, 1980;  spear-winged flies
- Ochman *et al.*, 1980;  and in the hybridogenetic fish *Poeciliopsis* -

Angus, 1980). Results presented here for *A. avenae* collected from a pine-forest indicate that major differences in phenotype (in rates of reproduction on fungi in monoxenic culture) may occur between individuals from within a three-hectare area. This suggests that such an area may encompass several clones or that several clones may co-exist at the one site, the clonal composition and frequency with which individual clones occur perhaps varying between sites as has been found for other parthenogenetic animals (Angus, 1980; Jaenike *et al.*, 1980; Ochman *et al.*, 1980). However, some pheno-typic variation may possibly result from other mechanisms. In particular, the apparently haphazard distribution of populations and/or individuals with a propensity to produce males at high temperatures could conceivably arise through the action of transposable elements (that is, segments of deoxyribonucleic acid which can shift between *loci* within the genome and affect the expression of neighbouring structural genes). It has been suggested that unstable mutants observed in some eukaryotes may result from the action of such elements (Calos and Miller, 1980).

Evolutionary development, then, in *A. avenae* has not been brought to a standstill by the adoption of parthenogenesis as a mode of reproduction. Parthenogenesis in this nematode is automictic, that is, meiosis is retained (Triantaphyllou and Fisher, 1976). The genetic consequences of automixis depend upon the manner in which diploidy is restored and the pattern of chiasma localization (White, 1973; Maynard Smith, 1978). In *A. avenae* the second reduction division is suppressed such that a second polar body is not formed and it appears that diploidy may be restored by inclusion of both groups of chromosomes at telophase II in the same egg nucleus (Triantaphyllou and Fisher, 1976). Such a restitution nucleus would be formed by duplication of the chromatids which have separated in the egg cell,

a process genetically equivalent to fusion of sister pronuclei and expected to produce homozygosity for all *loci* between the centromere and the first chiasma of each chromosome (White, 1973; Maynard Smith, 1978). Trianta- phyllou and Fisher (1976) found no evidence of centromeres on *A. avenae* chromosomes and indicated that a diffuse-kinetochore activity along the entire central euchromatic region of the chromosomes was possible. Such a modification could act to limit the tendency towards homozygosity, preserve existing heterozygosity over much of the length of the chromosomes and facilitate the genetic diversity apparent in this study generated by new mutations.

At 25°C, rates of egg-laying by parthenogenetic females of the Brownhill Creek isolate were equal to those of amphimictic females. Thus, a twofold advantage in reproductive rate (Maynard Smith, 1978) might be anticipated for the parthenogenetic isolate, although this would be partially offset by the higher initial rate of hatch of eggs observed for the amphi- mictic isolate at this temperature. However, the amphimictic isolate was not selectively displaced by the parthenogenetic isolate when inoculated together onto cultures. That is, a net advantage in reproductive rate was not observed for the parthenogenetic isolate in the presence of the amphi- mictic isolate. This may have been due to a reduction in fecundity and longevity of parthenogenetic females in the presence of amphimictic males (Fisher, 1972) or other factors (such as differences in ages of maturation of females between the two isolates) may have acted to obscure any potential differences in reproductive rate. In any case, these results suggest that the amphimictic form of *A. avenae* may be able to maintain itself in nature in the presence of parthenogenetic competitors.

The question then arises as to the reasons for the more wide-spread distribution of parthenogenetic compared with amphimictic forms of *A. avenae*. Parthenogenetic animals have often been observed to be more widespread in distribution than their sexual progenitors (Cuellar, 1977; Suomalainen *et al.*, 1979). Triantaphyllou and Hirschmann (1980) noted this in the case of certain plant parasitic nematodes, especially root-knot nematodes and believed that it reflected adaptation to environments of continuous monoculture of susceptible crop plants. Parthenogenetic animals are also widely known to be associated with newly created or disturbed habitats (Cuellar, 1977). In this study the parthenogenetic form of *A. avenae* was found to be abundant in soil under wheat in fields given over to rotation cereal cultivation. Significantly, the highest abundance of the nematode was recorded from a wheat-field which had been put under cultivation for the first time. *A. avenae* was far more abundant in these wheat-fields than has been found in less disturbed agricultural habitats such as permanent pasture (for example, the Waite permanent pasture in this study and pastures studied by Yeates (1981)) or the pine-forest of this study. Disturbed agricultural habitats are likely to be characterized by sudden declines in food resources and those organisms which utilize them. For example, in South Australia following harvest of wheat the soil remains fallow during the hot, dry summer and fungal activity - that is, abundance of viable hyphae and spores - declines markedly (Warcup, 1957). An organism such as *A. avenae* which depends upon fungal protoplasm from living hyphae will then face a food shortage if it is not limited before by the lack of soil water. A proportion of the population will survive over summer in a quiescent anhydrobiotic state (De Meure *et al.*, 1978) but we would expect the surviving population to be comparatively sparse on arrival of suitable conditions - rain and the planting of another crop - for population growth.

Under these conditions the ability of a parthenogenetic organism to establish a population from a single individual will be important. For *A. avenae* this is more likely since many soil fungi (particularly members of the Deuter-mycotina) appear to be active in soil over very short periods in restricted areas (Warcup, 1957). The preference of this nematode for plant parasitic over saprophytic fungi (Mankau and Mankau, 1963; Townshend, 1964) may reflect a partial specialization towards fungi which, through their parasitic mode of nutrition, have longer periods of activity in the mycelial state in the soil. However, soil fungi known to have long-lived mycelium in soil (Burges, 1960) such as the basidiomycetes tested as food sources for *A. avenae* in this study did not appear to be particularly favoured hosts for the nematode. An ability to establish a population from a single in-dividual would also be important for the spread of an organism which is dispersed passively by wind, particularly in an agricultural environment. Viglierchio and Schmitt (1981), in examining the nematodes recovered from dust raised by agricultural implements traversing dry fields and further carried by wind, found that *A. avenae* comprised over 29% on average of all living nematodes from such dust. The ability of *A. avenae* to undergo anhydrobiosis and adopt a tightly coiled form of decreased weight undoubtedly assists with this dispersal.

Gerritsen (1980) considered the problem of sexual reproduction in sparse populations entailed in finding a mate and developed a model to predict the critical density for successful sexual reproduction (that is, that required to sustain the population) in zooplankton. He was able to make a number of predictions from this model, certain of which can be tested against the data available for plant parasitic nematodes. Thus, encounter probability (between mates) is correlated with size of the organism and an

inverse relationship between size and critical density is predicted such that there may be a minimum size for obligate outbreeders. Using data published by the Commonwealth Institute of Helminthology (1972-77), plant parasitic nematodes can be classified according to maximum length of adult females and to breeding system (Table 33). Nematodes for which insufficient information were available were not included, as were those species whose adult females are sedentary since the model assumes both sexes are vagile. There is a significant association between these classifications and sexual reproduction is less common than expected due to chance amongst the smaller nematodes (Table 33). Of the species listed by the Commonwealth Institute of Helminthology with maximum length of adult females less than or equal to 800 μm, obligate amphimicts comprised only 33% while parthenogenetic species made up 61%. Thus, plant parasitic nematodes appear to conform to the predictions of the above model, lending support to the hypothesis that parthenogenesis is advantageous to nematodes in disturbed habitats where the problems associated with sparse populations periodically occur. Unfortunately, not enough is known regarding the ecological correlates of different breeding systems in *A. avenae* to determine whether the amphimictic form tends to be more commonly found in less disturbed habitats than the parthenogenetic form. Certainly, the amphimictic population from Dangerous Reef occurred in a natural environment.

In wheat-field soil, abundance of *A. avenae* appeared to be correlated with a number of physico-chemical properties of the soil. For example, the nematode tended to be more abundant in more alkaline soils. Tests to examine the influence of these factors on population growth of *A. avenae* in culture revealed nothing of the nature of these correlations. Thus, higher populations of the nematode were produced on the more acid media which

TABLE 33: Association between size of plant parasitic nematodes and breeding system ($\chi^2 = 6.96$, significant at P = 0.05). Data from Commonwealth Institute of Helminthology (1972-77). Expected frequences in brackets.

| Breeding System | 200-600µm | 600-1000µm | >1000µm | Total |
|---|---|---|---|---|
| Parthenogenetic (obligate and facultative) | 11 (7.09) | 16 (16.36) | 9 (12.55) | 36 |
| Amphimictic | 2 (5.91) | 14 (13.64) | 14 (10.46) | 30 |
| Total | 13 | 30 | 23 | 66 |

supported a higher rate of growth of the host fungus.    Although *A. avenae*

tended to be relatively more abundant in more saline soils, in culture

small increases in salinity of the culture medium tended to reduce the rate

of growth of both the host fungus and the nematode population.    Changes to

composition of the culture medium appeared to affect population growth of

the nematode through the host fungus.    As expected, temperature appeared

to exert a direct effect on the reproductive rate of the nematode in culture.

These results, then, seem to point to marked differences  between the soil

environment and that provided in monoxenic cultures.    In addition to the

greater uniformity of the latter environment, in the soil physico-chemical

factors could influence and be influenced by abundance of fungi and other

biota such as predators and competitors of *A. avenae.*

In the pine-forest here studied, *A. avenae* was rarely found in

soil.    Other studies on the soil nematodes of coniferous forests have either

not recorded *A. avenae* at all or only rarely (Bassus, 1962;   Riffle, 1968;

Boag, 1974;   Sohlenius *et al.*, 1977;   Magnusson, 1983a,b).    In the

Williamstown pine-forest a higher abundance of *A. avenae* was observed in

certain more densely grassed areas, suggesting that the rarity of the nema-

tode was more to do with a lack of suitable food sources – perhaps fungi

associated with graminaceous plants – than with some other aspect of this

environment such as the acid conditions which characterize coniferous forest

soils.    Yeates (1979) noted that these acid conditions were inimical to

certain organisms such as lumbricid earthworms, millipedes and woodlice,

but that fungal-feeding Tylenchida flourished in coniferous forest soils.

Thus, nematodes which were, at least partially mycophagous and belonging

to a closely related genus – *Aphelenchoides* – were comparatively abundant

in the pine-forest, particularly in litter.    Bassus (1962), Riffle (1968),

Boag (1974), Sohlenius *et al.* (1977) and Magnusson (1983a,b) also found *Aphelenchoides* spp. to be abundant in the coniferous forests they studied. These findings suggest the possibility of host specialization or competitive interactions between *A. avenae* and these nematodes.

Soils of the two study sites - the wheat-field and the pine-forest - differed markedly in texture, that of the wheat-field being classed as a clay-loam while that of the pine-forest being a sandy-loam. Correlations between soil type or texture and abundance of various nematodes have often been suggested by nematologists (see Wallace, 1973; Norton, 1978). Norton *et al.* (1971) found that *A. avenae* made up a higher proportion of the total nematode population and was more abundant in sandy-loam than in clay-loam soils, while Geraert (1967) concluded that it showed no preference for any soil type (sandy *vs.* heavy soils). It appears unlikely that the differences between the two study sites in soil texture were themselves responsible for the marked difference in abundance of *A. avenae*, particularly since the highest abundance was observed in the clay-loam soil. Of more potential importance to population densities of *A. avenae* between the two sites are differences in management practices and of rates of decay of organic material. Wallwork (1976) noted that absence of permanent plant cover or leaf litter (as in a field in fallow) and mechanical disturbance of the substratum caused by ploughing exposes the soil to marked fluctuations in temperature and moisture, producing high mortality among soil animals and leading to a reduction in species diversity. He observed that Collembola and Acari were particularly reduced in densities by such disturbance. Many collembolans and oribatid mites are known to feed on soil fungi (Griffin, 1972), and certain mites also feed on nematodes including *A. avenae* (Imbriani and Mankau, 1983). Thus, disturbed soil, such as that of the wheat-field, may harbour smaller and less diverse populations of

of important competitors and predators of *A. avenae* than pine-forest soil. Crop rotations also decrease species diversity of soil fauna (Wallwork, 1976). In comparing forest and grassland ecosystems, Wallwork (1976) observed that the latter was characterized by *in situ* decomposition of root systems and by higher rates of energy turn-over and breakdown of organic material. Mor humus, because of its acidity and high content of lignin, is particularly slow to break down. The higher rate of breakdown of organic material in a wheat-field compared with a pine-forest could be important for both saprophytic fungi and plant parasitic fungi in the saprophytic phase of their life cycles. Thus, many important wheat pathogens such as *Gaeumannomyces graminis* and *Rhizoctonia solani* are often found associated with organic fragments in the soil (Griffin, 1972). As against these factors is the observation that the acid conditions prevailing in coniferous forest soils promote the growth of soil fungi, leading to a proliferation of fungal-feeding Tylenchida (Yeates, 1979). From the present study, results with monoxenic cultures indicated that more acid conditions which favoured the growth of the host fungus could result in a higher rate of population growth of *A. avenae*. Hence it is by no means clear, on a *priori* grounds, why *A. avenae* should be comparatively rare in pine-forest soil.

Results presented for fungi isolated from wheat-field and pine-forest soils using a variety of methods indicated that these soils possessed characteristic and different mycofloras. Although dilution and soil plate methods of fungal isolation mainly record species present in the soil as spores (Warcup, 1957), a similar picture emerged with isolations by selective methods and from roots and organic debris. The pine-forest soil was dominated by *Penicillium* spp. and *Pinus* roots and organic debris were also dominated by these fungi and *Trichoderma* spp.. The wheat-field soil was

characterized by a more diverse mycoflora. The frequency with which
*Penicillium* and *Trichoderma* spp. are isolated from coniferous forest litter
and soil by various methods has often been remarked upon (Kendrick, 1958;
Simpson, 1967; Widden and Parkinson, 1973; Widden, 1979; Nelson, 1982).
These fungi are heavy sporulators and the fact of their high incidence –
on dilution plates, for example, in the case of *Penicillium* spp. – is in-
dicative of fungal activity mainly in that spores are a product of past
active growth (Nelson, 1982). Nevertheless, the qualitative differences
between the mycofloras of the two soils are clear. The positive correla-
tion between abundance of *A. avenae* and diversity of the soil mycoflora in
the two habitats suggests that composition of the mycoflora is an important
influence on abundance of this nematode. Basidiomycete hyphae were
abundant in pine litter as were mycophagous *Aphelenchoides*, but *A. avenae*
was correspondingly rare, suggesting possible competitive exclusion or host
specialization between these nematodes.

The soil bacteria and actinomycetes tested in this study were
found not to be significant as food sources for *A. avenae* and it appears
likely that the nematode is unable to utilize them as such. The stylet
lumens of tylenchid nematodes are usually less than 1 μm in diameter and
are regarded as bacterial filters (Bird, 1971). Scanning electron micro-
graphs of the head region of *A. avenae* show that the oral aperture, through
which the stylet passes, is about 0.3 to 0.4 μm in diameter (Hooper and
Clark, 1980). The meaning of Tikyani and Khera's (1969) observation that
*A. avenae* "cultivated on an unidentified bacterium when transferred in
masses" is not clear. In the case of actinomycete hyphae, which are usually
1 μm or less in diameter (Waksman, 1950) it is difficult to see how the
nematode could maintain contact with a hypha to facilitate feeding. Feed-
ing on fungal hyphae by *A. avenae* appears to require sustained contact by

body pressure as the lips of the nematode are pressed against the cell wall (Fisher and Evans, 1967).

The results of feeding trials with fungi from both soils showed that different fungi differed markedly in their suitability as hosts for *A. avenae* as indicated by the nematode's rate of population growth. *Penicillium* spp. - those fungi which had been found to dominate pine-forest soil - were comparatively poor hosts. A greater range of more productive hosts were available for mycophagous nematodes among the more diverse myco-flora of the wheat-field soil than from the pine-forest soil. It is suggested that this is a major factor in determining the higher population density of *A. avenae* in wheat-field soil. Other possible factors, such as different and/or more numerous predators and competitors for fungi in pine-forest soil can not, of course, be entirely discounted. Since many soil fungi, particularly members of the Deuteromycotina, are active in soil for only short periods (Warcup, 1957), a greater diversity of suitable hosts would provide for a more constant supply of food across space and time.

Fungi that were good hosts for *A. avenae* also tended to be good hosts for the *Aphelenchoides* spp. from this study. Thus, it appeared that little host specialization had taken place between these nematodes to pre-clude the possibility of competition for food resources. The observed rarity of *A. avenae* in pine litter compared with mycophagous *Aphelenchoides* may have more to do with the nature of this habitat than the fungi present. For example, the thin water-films which surround needles in the litter may favour movement of the smaller-sized *Aphelenchoides* as against *A. avenae*. Different isolates of fungi belonging to the same genus varied markedly in their capacities to support population growth of mycophagous nematodes, supporting the suggestion (Mankau and Mankau, 1963; Townshend, 1964) that host suitability may be determined by some specific factor such as compo-

sition of protoplasm or production of antibiotics.   Such factors would
explain the similarity in response of the different nematode species to
different fungi.   However, *A. avenae* appeared to be more efficient at
converting fungal protoplasm into biomass than any of the *Aphelenchoides*
isolates.

Evans and Fisher (1970) ascribed differences observed in re-
production rates of isolates of *A. avenae* cultured on fungi to metabolic
differences inherent in the nematodes.   This conclusion is supported by
results presented here which show that even within a comparatively small
area there exist *A. avenae* with markedly different reproduction rates.
Evidently, mutation rates and the automictic mode of reproduction of
*A. avenae* allow for some degree of genetic flexibility such that consider-
able genetic diversity can exist in a parameter as important for survival
as reproduction rate.   The extent of genetic diversity displayed by
*A. avenae* suggests that conclusions regarding ecological differences between
populations of parthenogenetic nematodes which have been based on observa-
tions on experimental populations derived from single individuals be treated
with caution.   A number of plant parasitic nematodes have automictic modes
of reproduction, including certain *Meloidogyne* spp. (Triantaphyllou and
Hirschmann, 1980) - although parthenogenesis is not obligatory in this genus
- and may also possess mechanisms to preserve heterozygosity.   Further work
on the clonal structure of parthenogenetic populations of *A. avenae* will
be needed to establish the spatial and temporal dimensions of such clones.

## VII. APPENDICES

APPENDIX 1:

Formulae for media

### NDY (Warcup, 1955)

| | |
|---|---|
| NaNO$_3$ | 2.0 g |
| KH$_2$PO$_4$ | 1.0 g |
| MgSO$_4$.7H$_2$O | 0.5 g |
| KCl | 0.5 g |
| FeSO$_4$.7H$_2$O | 0.01 g |
| Yeast extract (Difco) | 0.5 g |
| Sucrose | 30.0 g |
| Agar | 15.0 g |
| Distilled water | 1 L |

(NDY/6 consists of these ingredients in amounts
one-sixth of those given above except for agar
and water which remain unchanged)

### Krainsky's Medium ("Plant Pathologist's Pocketbook". Commonwealth Mycological Institute, 1968)

| | |
|---|---|
| Glucose | 10.0 g |
| Asparagin | 0.5 g |
| K$_2$HPO$_4$ | 0.5 g |
| Agar | 15.0 g |
| Distilled water | 1 L |

### Nutrient Agar (based on formula from "Plant Pathologist's Pocketbook", Commonwealth Mycological Institute, 1968)

| | |
|---|---|
| Nutrient broth (Bacto) | 8.0 g |
| Yeast extract (Difco) | 2.0 g |
| Peptone (Bacto) | 5.0 g |
| NaCl | 5.0 g |
| Agar (Bacto) | 15.0 g |
| Distilled water | 1 L |

## 2% Malt Extract Agar

| | |
|---|---|
| Malt extract (Difco) | 20 g |
| Agar | 15 g |
| Distilled water | 1 L |

Proprietary media (Potato dextrose agar, cornmeal agar, lima bean agar) were prepared according to instructions given by the manufacturer (Difco).

APPENDIX 2: Size classes of *A. avenae* separated on sieves of various mesh sizes. Mean lengths are given for ten randomly selected nematodes from amongst those passing through and retained by sieves after various periods of time

| *A. avenae* isolate (age of culture) | Nemas/trial | Width of openings (μm) | Time (min) | Mean length of nemas (μm) ± S.E. | |
|---|---|---|---|---|---|
| | | | | Passed | Retained |
| Isolate 34 (6 wks) | 52500 | 45 | 1 | 241 ± 7 | 371 ± 52 |
| | | | 2 | 287 ± 34 | 692 ± 84 |
| | | | 3 | 281 ± 30 | 613 ± 85 |
| | | | 5 | 281 ± 20 | 536 ± 87 |
| Nemas retained on 45 μm-mesh after 1 min. | 18600 | 150 | 1 | 359 ± 45 | 702 ± 100 |
| | | | 2 | 323 ± 25 | 824 ± 51 |
| | | | 3 | 294 ± 25 | 1063 ± 126 |
| | | | 5 | 613 ± 83 | 744 ± 87 |
| | | 250 | 3 | 369 ± 50 | 719 ± 100 |
| Isolate 52 (8 wks) | 73000 | 355 | 1 | 652 ± 56 | 979 ± 49 |
| | | | 3 | 967 ± 84 | 1055 ± 84 |
| | | 450 | 1 | 814 ± 94 | 999 ± 35 |
| | | 45 | 1 | 490 ± 56 | — |
| Nemas retained on 45 μm-mesh after 1 min. | 73000 | 355 | 1 | 679 ± 58 | 888 ± 43 |

APPENDIX 3: Fungi isolated from wheat-field soil on dilution plates (dp) and soil plates (sp). Isolations recorded for Quadrats A-L; multiple isolations denoted by figures in brackets

| Isolate No. | Fungus | dp | sp |
|---|---|---|---|
| **Fusarium isolates** | | | |
| W1 | *F. roseum* sp. gr. | H,J(2) | A,F,G(2),I,J,K |
| W3 | *F. roseum* sp. gr. | | K |
| W33 | | A,B,E(3),F(2),G(3), J,L(3) | G,J,L(2),A(2), E(2),F |
| W55 | | A(2),B,H(2),L(2) | A,G,I,J(2) |
| W64 | | G | E(2) |
| W84 | *F. solani sensu lato* | B(2),D,L(4) | C,D,F,K |
| W85 | | A,D,F,G,I,K(2) | A,E,H(2),K |
| W90 | | F,G,H | K |
| W93 | | A | H |
| W94 | | | E |
| W112 | *F. merismoides* | F | |
| W121 | | D | |
| W125 | | | H |
| W126 | | C | |
| W127 | | | C |
| W129 | *F. oxysporum sensu lato* | F | |
| **Mucorales** | | | |
| W11 | *Rhizopus (oryzae?)* | L(2) | |
| W21 | *Mucor* | A,C | H,I(5) |
| W61 | *Mortierella* | | G(5),L |
| W62 | *Mortierella* | K | G(2),K(4) |
| W65 | *Mortierella* | I | A,D,J |
| W66 | *Mortierella* | I | |
| W67 | *Mortierella* | A,D,F(2),G,I(2), J,K(2) | B,C,H,L |
| W86 | *Mucor (globosum?)* | | I |
| W88 | *Gongronella butleri* | L | I |
| W89 | *Actinomucor elegans* | J | I |
| W105 | *Absidia spinosa* | C | |
| W130 | *Cunninghamella (elegans?)* | B | G |
| W182 | *\*Mortierella* | | |
| **Trichoderma isolates** | | | |
| W51 | *T. harzianum* | D(3),L | B |
| W83 | *T. viride* | I | |

APPENDIX 3/continued

| Isolate No. | Fungus | dp | sp |
|---|---|---|---|
| *Aspergillus* isolates | | | |
| W3 | | C,F | |
| W6 | *A. niger* sp. gr. | D | D(9) |
| W8 | | | L(2) |
| W15 | *A. terreus* | D(2) | |
| W35 | | B(3),E,F(2),H(2) J(6),K(3) | B(2),H,J(2),K |
| W36 | | I | |
| W37 | | | A |
| W38 | | A,B(2),D(2),F,J(3), K | D,J,K(2) |
| W40 | | | B |
| W71 | | C | |
| W91 | | C | |
| W101 | | B | |
| W157 | | G | |
| W158 | | | F |
| W167 | | J | |
| W172 | | H | |
| W189 | * | | |
| *Penicillium* isolates | | | |
| W4 | +Fd | B,F,K | C,E,F(2) |
| W5 | Bs | A,D,E,F(2) | F(3) |
| W7 | Pp | D(3),G(2) | E,I |
| W23 | Ae | A,B,J(2) | B,D(4),J |
| W24 | Ff | D,J | A,B,C,L(5) |
| W25 | Ff | B(2),C(4),D,J | D,J |
| W26 | Ff | | B |
| W27 | Ae | C | |
| W28 | Ff | | C(5) |
| W29 | Ae | | D |
| W30 | Ae | | A |
| W31 | Ff | | C |
| W32 | Ff | A(2),C | |
| W41 | Pp | A(2),D,F(12),H,J(3) K(4) | A(2),D(3),H(2), J,K(3) |
| W42 | Pp | | H |
| W43 | Ff | I | |
| W44 | Fd | A | |
| W45 | Fd | | F |
| W46 | Fd | D | |
| W47 | Fd | | I |
| W48 | Ff | B,C(2),F,J | A,C,J |
| W56 | Ff | | F |
| W69 | Fd | D,F(3),H(2) | D,F(3),K(2) |
| W70 | Bs | C,H,J | H,J |
| W72 | Ff | G(2) | |
| W73 | Ff | B,D | E |
| W74 | Bs | A | |
| W75 | Ae | L | |
| W76 | Ff | L | |

APPENDIX 3/continued

| Isolate No. | Fungus | dp | sp |
|---|---|---|---|
| W77 | Ff | | C,I |
| W78 | Aa | F,G | F,J |
| W79 | Ae | | L(4) |
| W102 | Ff | | I |
| W108 | Bs | | A |
| W109 | Bs | | L |
| W113 | Ae | I | |
| W114 | Ae | | H |
| W115 | Ff | | I |
| W116 | Bs | | K |
| W117 | Pp | A | |
| W118 | Ff | B | |
| W119 | Bs | | J |
| W122 | Bs | I | |
| W123 | Bs | K | |
| W124 | Pp | | E |
| W128 | Fd | | G(2) |
| W137 | Ae | B,F,J(2) | A,B |
| W138 | Pp | | C |
| W139 | Fd | D | |
| W140 | Ff | | C |
| W141 | Fd | | C |
| W142 | Aa | B | |
| W144 | Ff | | C |
| W145 | Ff | I | |
| W146 | Ff | I | |
| W147 | Ff | I | |
| W148 | Ff | J | |
| W149 | Fd | C | |
| W150 | Ae | | I |
| W151 | Ae | B | |
| W152 | Ae | | K |
| W153 | Bs | J | |
| W154 | Aa | D,J | |
| W163 | Bs | F | |
| W166 | Ae | G | |
| W168 | Ff | D | |
| W169 | Fd | D | |
| W170 | Ae | J(2) | |
| W171 | Ae | L | |
| W185 | *Ae | | |
| W188 | *Ff | | |

| W10,W82 | *Cladosporium cladosporioides* | G,L | C,H(5),I,L |

| W13 | *Metarrhizium anisopliae* var. *anisopliae* | | C,E,J(2) |

APPENDIX 3/continued

| Isolate No. | Fungus | dp | sp |
|---|---|---|---|
| *Myrothecium* isolates | | | |
| W14,W92 | *M. verrucaria* | J,L(3) | |
| W95 | *M. cinctum* | B | |
| W133 | *M. roridum* | G | |
| W16 | *Paecilomyces lilacinus* | E(2),G,I(2),K | B |
| *Torulomyces* isolates | | | |
| W17 | | A,J | A,J(2) |
| W18 | | B,K | |
| W19 | | C | B |
| W20 | *Phialocephala* | C,E | |
| *Acremonium* isolates | | | |
| W22 | | D(2),J | A(3) |
| W155 | | | J |
| W159 | | B | |
| *Gliocladium* isolates | | | |
| W34 | *G. catenulatum* | B(3) | L |
| W173 | *G. roseum* | | I |
| *Phoma* isolates | | | |
| W57 | | J | |
| W58 | | | A |
| W104 | *P. eupyrena* | A | |
| W181 | * | | |
| W187 | * | | |
| W60 | *Ulocladium* | | C,G |
| W64a | *Pythium* | G | E |
| W68 | *Broomella* | A(6),B(8),C(4), F(7),G(2),H(2), I,J(2) | A(4),B(3),C(3), E(2),F(2),H,K, L |
| W100 | *Broomella* | J | |
| W131 | *Pestalotia sensu lato* | | E |

APPENDIX 3/continued

| Isolate No. | Fungus | dp | sp |
|---|---|---|---|
| W107 | *Graphium (bulbicola?)* | I | I |
| W110 | *Chaetomium indicum* | B | |
| W111 | *Stachybotrys* | F | |
| W162 | *Conidiobolus* | I | |
| W164 | *Coniothyrium (?)* | E | |
| W165 | *Doratomyces* | | G |
| W179 | *\*Cochliobolus sativus* | | |
| W193 | *\*Periconia macrospinosa* | | |

Sterile cultures

| | | dp | sp |
|---|---|---|---|
| W49 | | D(2),H,I | A,D,L(2) |
| W50 | | F,K | B,F,G(2),H(3) |
| W52 | | C,D | |
| W53 | | | A(2) |
| W54 | | | G |
| W59 | | A,E | D(2) |
| W80 | | | F |
| W81 | | I | |
| W87 | | | G |
| W97 | | B | |
| W98 | | A | |
| W99 | | | C |
| W103 | | D,E(2),G,H(2),K(2) L | |
| W106 | | | A |
| W120 | | D | |
| W132 | | .H | |
| W134 | | | E |
| W135 | | | A |
| W136 | | A | |
| W143 | | | E |
| W156 | | B | |
| W161 | | | C |
| W174 | * | | |
| W175 | * | | |
| W176 | * | | |

APPENDIX 3:/continued

| | |
|---|---|
| W177 | * |
| W178 | * |
| W180 | * |
| W183 | * |
| W184 | * |
| W186 | * |
| W190 | * |
| W191 | * |
| W192 | * |
| W194 | * |
| W195 | * |
| W196 | * |

<u>Unidentified hyphomycetes</u>

| | |
|---|---|
| W9 | I(3),L |
| W160 | I |

| | | |
|---|---|---|
| W12 | Coelomycete (unidentified) | L(2) |

*Isolated from wheat roots
+Sub-generic classifications of *Penicillium* isolates after
 Pitt (1979). Subgenus *Aspergilloides*: Section *Aspergilloides*
 (Aa), Section *Exilicaulis* (Ae); subgenus *Penicillium*,
 Section *Penicillium* (Pp); subgenus *Biverticillium*,
 Section *Simplicia* (Bs); subgenus *Furcatum*,
 Section *Furcatum* (Ff), Section *Divaricatum* (Fd).

APPENDIX 4:   Fungi isolated from pine-forest soil on dilution plates (dp)
and soil plates (sp).   Isolations recorded for Quadrats A-L;
multiple isolations denoted by figures in brackets

| Isolate No. | Fungus | dp | sp |
|---|---|---|---|
| *Fusarium* isolates | | | |
| P16 | | E | |
| P20 | | | C |
| P22 | *F. solani sensu lato* | | |
| P23 | *F. oxysporum sensu lato* | B(2),H | B,K(2) |
| P24 | | | A |
| P25 | | | A |
| Mucorales | | | |
| P13 | *Mortierella* | | E |
| P26 | *Mucor plumbeus* | F | H |
| P122 | *Mortierella* | A,H | B,E,I,K |
| P123 | *Mortierella* | D,F,H,J | K,L |
| P124 | *Mortierella* | J | |
| *Trichoderma* isolates | | | |
| P5 | *T. hamatum* | A,L | C |
| P21 | *T. koningii* | B,G | G,L |
| P115 | *T. harzianum* | A,E,H,I | H(2) |
| *Aspergillus* isolates | | | |
| P3 | *A. niger* sp. gr. | E | |
| P32 | | A | |
| P117 | | | A |
| *Penicillium* isolates | | | |
| P2 | +Fd | K | |
| P6 | Ae | H | |
| P9 | Ae | | I |
| P29 | Bs | B | |
| P30 | Ae | D | |
| P31 | Aa | J | |
| P33 | Ae | | A(2) |
| P34 | Fd | B | |
| P35 | Ae | | J |
| P36 | Ff | | B |
| P37 | Ae | D,L | |
| P38 | Fd | B,L | L |
| P39 | Bs | J | |
| P40 | Ae | B | |

APPENDIX 4/...

| Isolate No. | Fungus | dp | sp |
|---|---|---|---|
| P41 | Ff | | B,C |
| P42 | Ae | | G,I |
| P43 | Bs | | A |
| P45 | Pp | B | |
| P46 | Aa | F | |
| P47 | Bs | J | |
| P48 | Bs | A(3),B(2),G,H,K | |
| P49 | Bs | A,B | |
| P50 | Bs | | A(2) |
| P51 | Ae | D | |
| P52 | Ae | F | |
| P53 | Ff | H | |
| P54 | Ff | I | |
| P55 | Aa | H(2) | |
| P56 | Fd | | A |
| P57 | Fd | D | |
| P58 | Ae | A(2),C | |
| P59 | Ae | L | |
| P60 | Fd | | G |
| P61 | Fd | | E |
| P62 | Ff | B(4),E | |
| P63 | Fd | H | |
| P64 | Fd | D,G(2),H(2),I(2),J(3),K,L(2) | H(2),L |
| P65 | Ae | H | |
| P66 | Ae | D | |
| P67 | Ae | | C |
| P68 | Ae | D | |
| P69 | Ae | D | |
| P70 | Ae | | C |
| P71 | Aa | K | |
| P72 | Ae | | A,B |
| P75 | Aa | E,F,G(5),I,J(2),L | E,F(2),H,B,C,D(4) |
| P77 | Ff | A,D | |
| P78 | Ae | | E |
| P79 | Fd | | L |
| P80 | Ff | D | C |
| P81 | Fd | | D |
| P82 | Ae | D | |
| P83 | Ae | D | |
| P84 | Ae | D | |
| P85 | Aa | A(3),B,C(2),D(26),E(5),F,G(3),I(6),J(4),K(7),L(5) | A,C(2),D(12),E,F(6),G,I,J(6),K,L(3) |
| P86 | Fd | A,B(2),D,E,F,H(2),I(2),J(2),L(2) | G(2),H(2),I,J(2),K,L(2) |
| P87 | Ff | B | |
| P88 | Ae | D | D |
| P89 | Ae | D,F,G(5),H,I(11),J(3),K(9),L(4) | G,I(2),L(2) |
| P90 | Ae | D | |

APPENDIX 4/...

| Isolate No. | Fungus | dp | sp |
|---|---|---|---|
| P91 | Fd | A,B,E | B(2) |
| P92 | Ae | A(6),B(3),C(4), D(7),E(2),F(2), G(4),H(3),I(6), J(2),K(5),L(4) | F(5),G(1),H(6), I(6),K(5) |
| P93 | Ae | A(4),B(3),C(2), D,E(2),F(6),G(3), H(7), I(6),J, K(6),L(2) | G(4),H(2),I(2), J(5),K,L(3) |
| P94 | Fd | A(3),B,D(4),E(2), H,J(3) | C,D,F |
| P95 | Ae | A(2),B(2),C,H(2), J(3),L | B,G,H,I(5),J |
| P96 | Ff | I | |
| P98 | Fd | A(2),C,H,I,J,K,L | H,L |
| P99 | Ae | I | |
| P100 | Aa | J,K | E,F,G,K |
| P101 | Fd | D | |
| P103 | Fd | A(7),B(4),C(9),D(8), F(2),G(9),H(5),I, J(2),K(4),L(6) | B,C,E,F(2),G(5) H(2),I,J(3),K, L(3) |
| P104 | Ff | A,B,D | |
| P105 | Ff | L | A(2),B(4),C(5), E(3) |
| P106 | Ff | B(3),C,D(2),E,G(2), K | A(5),B(4),C,D, E(7) |
| P107 | Ff | E | |
| P108 | Fd | | E |
| P109 | Ff | | B |
| P110 | Fd | B | B |
| P111 | Ff | D | |
| P112 | Fd | D | |
| P113 | Ff | | A |
| P114 | Ae | F(2),G(3) | |
| P116 | Ae | E | |
| P118 | Fd | | F |
| P119 | Fd | A | |
| P120 | Fd | I | |
| P121 | Bs | A(5),B(2),C(2), D,E(2) | |
| P125 | Bs | L | |

*Paecilmyces* isolates

| | | | |
|---|---|---|---|
| P1 | *P. lilacinus* | B,H,J(3),L | E,F |
| P44 | *P. carneus* | G | |

| | | | |
|---|---|---|---|
| P4 | *Sporotrichum (?)* | J | G |

Appendix 4/...

| Isolate No. | Fungus | dp | sp |
|---|---|---|---|
| P7 | *Verticillium* isolates | I | |
| P11 | | J | |
| P12 | | H | |
| P8 | *Pestalotia sensu lato* | D | |
| P14 | *Botrytis* | L | |
| P19 | *Chaetomium* | A,B,H,J | G |

Sterile cultures

| | | | |
|---|---|---|---|
| P10 | * | | |
| P15 | | | L |
| P17 | * | | |
| P18 | * | | |
| P27 | | K,L | J(2) |
| P28 | * | | |
| P73 | | C | D |

| | | | |
|---|---|---|---|
| P16 | Unidentified hyphomycete | E | |

*Isolated from roots of unidentified grass sp. + subgeneric classifications of *Penicillium* isolates as for Appendix 2.

APPENDIX 5: Analyses of variance for data of Table 28a pertaining to individual fungal genera and species groups from wheat-field soil.

Appendix 5a: Wheat-field soil *Penicillium* isolates

| Source of variation | df | Sum of squares | Mean square | F |
|---|---|---|---|---|
| *Penicillium* isolates | 9 | 536.7 | 59.64 | 83.42 *** |
| Nematode isolates | 4 | 364.4 | 91.09 | 127.42 *** |
| Interaction | 16 | 87.4 | 5.46 | 7.64 *** |
| Residual | 108 | 77.2 | 0.71 | |
| Total | 137 | 1065.7 | | |

Appendix 5b: Wheat-field soil *Fusarium* isolates

| Source of variation | df | Sum of squares | Mean square | F |
|---|---|---|---|---|
| *Fusarium* isolates | 12 | 172.5 | 14.38 | 31.47 *** |
| Nematode isolates | 5 | 543.5 | 108.70 | 237.91 *** |
| Interaction | 37 | 240.3 | 6.50 | 14.22 *** |
| Residual | 216 | 98.7 | 0.46 | |
| Total | 270 | 1055.0 | | |

Significance levels for variance ratios: $P = 0.001$ (***); $P = 0.01$ (**); $P = 0.05$ (*); N.S. – non-significant.

Appendix 5c:  Wheat-field soil *Mortierella* isolates

| Source of variation | df | Sum of squares | Mean square | F |
|---|---|---|---|---|
| *Mortierella* isolates | 4 | 454.78 | 113.69 | 175.42 *** |
| Nematode isolates | 3 | 29.04 | 9.68 | 14.93 *** |
| Interaction | 5 | 4.08 | 0.82 | 1.26 N.S. |
| Residual | 54 | 34.99 | 0.65 | |
| Total | 66 | 522.89 | | |

Appendix 5d:  Wheat-field soil mucorales[z] isolates

| Source of variation | df | Sum of squares | Mean square | F |
|---|---|---|---|---|
| Mucorales isolates[z] | 2 | 6.75 | 3.38 | 8.54 *** |
| Nematode isolates | 5 | 276.33 | 55.27 | 139.79 *** |
| Interaction | 6 | 66.64 | 11.11 | 28.09 *** |
| Residual | 69 | 27.28 | 0.39 | |
| Total | 82 | 377.00 | | |

[z]Other than *Mortierella*.

Appendix 5e:　Wheat-field soil *Trichoderma* isolates

| Source of variation | df | Sum of squares | Mean square | F |
|---|---|---|---|---|
| *Trichoderma* isolates | 1 | 2.45 | 2.45 | 9.00 ** |
| Nematode isolates | 4 | 6.61 | 1.65 | 6.09 ** |
| Residual | 22 | 5.97 | 0.27 | |
| Total | 27 | 15.03 | | |

Appendix 5f:　Wheat-field soil *Aspergillus* isolates

| Source of variation | df | Sum of squares | Mean square | F |
|---|---|---|---|---|
| Nematode isolates | 5 | 142.56 | 28.51 | 64.8 *** |
| Residual | 22 | 9.68 | 0.44 | |
| Total | 27 | 152.24 | | |

Appendix 5g:　Wheat-field soil *Metarrhizium* isolates

| Source of variation | df | Sum of squares | Mean square | F |
|---|---|---|---|---|
| Nematode isolates | 1 | 2.77 | 2.77 | 6.39 * |
| Residual | 6 | 2.60 | 0.43 | |
| Total | 7 | 5.37 | | |

Appendix 5h: Wheat-field soil *Cladosporium* isolates

| Source of variation | df | Sum of squares | Mean square | F |
|---|---|---|---|---|
| Nematode isolates | 1 | 7.50 | 7.50 | 11.23 * |
| Residual | 6 | 4.01 | 0.67 | |
| Total | 7 | 11.51 | | |

Appendix 5i: Wheat-field soil *Paecilomyces* isolates

| Source of variation | df | Sum of squares | Mean square | F |
|---|---|---|---|---|
| Nematode isolates | 1 | 4.55 | 4.55 | 11.49 * |
| Residual | 5 | 1.98 | 0.40 | |
| Total | 6 | 6.53 | | |

Appendix 5j: Wheat-field soil *Acremonium* isolates

| Source of variation | df | Sum of squares | Mean square | F |
|---|---|---|---|---|
| *Acremonium* isolates | 1 | 208.23 | 208.23 | 460.23 *** |
| Nematode isolates | 4 | 107.21 | 26.80 | 59.24 *** |
| Interaction | 1 | 6.57 | 6.57 | 14.52 ** |
| Residual | 20 | 9.05 | 0.45 | |
| Total | 2 | 331.06 | | |

Appendix 5.k:  Wheat-field soil *Gliocladium* isolates

| Source of variation | df | Sum of squares | Mean square | F |
|---|---|---|---|---|
| Nematode isolates | 4 | 99.89 | 24.97 | 116.13 *** |
| Residual | 15 | 3.23 | 0.22 | |
| Total | 19 | 103.11 | | |

Appendix 51:  Wheat-field soil *Graphium* isolates

| Source of variation | df | Sum of squares | Mean square | F |
|---|---|---|---|---|
| Nematode isolates | 3 | 60.08 | 20.03 | 26.59 *** |
| Residual | 10 | 7.53 | 0.75 | |
| Total | 13 | 67.61 | | |

Appendix 5m:  Wheat-field soil *Broomella* isolates

| Source of variation | df | Sum of squares | Mean square | F |
|---|---|---|---|---|
| Nematode isolates | 5 | 159.79 | 31.96 | 46.02 *** |
| Residual | 27 | 18.75 | 0.69 | |
| Total | 32 | 170.54 | | |

Appendix 5n:   Wheat-field soil *Phoma* isolates

| Source of variation | df | Sum of squares | Mean square | F |
|---|---|---|---|---|
| *Phoma* isolates | 2 | 4.26 | 2.13 | 4.73 * |
| Nematode isolates | 5 | 106.19 | 21.24 | 47.14 *** |
| Interaction | 5 | 18.47 | 3.69 | 8.20 *** |
| Residual | 41 | 18.47 | 0.45 | |
| Total | 53 | 147.39 | | |

Appendix 5o:   Wheat-field soil *Cochliobolus* isolates

| Source of variation | df | Sum of squares | Mean square | F |
|---|---|---|---|---|
| Nematode isolates | 1 | 1.53 | 1.53 | 9.58 * |
| Residual | 4 | 0.64 | 0.16 | |
| Total | 5 | 2.17 | | |

Appendix 5p:   Wheat-field soil *Myrothecium* isolates

| Source of variation | df | Sum of squares | Mean square | F |
|---|---|---|---|---|
| *Myrothecium* isolates | 3 | 212.86 | 70.95 | 156.41 *** |
| Nematodes isolates | 5 | 365.10 | 73.02 | 160.96 *** |
| Interaction | 9 | 77.23 | 8.58 | 18.92 *** |
| Residual | 52 | 23.59 | 0.45 | |
| Total | 69 | 678.78 | | |

Appendix 5q:    Wheat-field soil *Torulomyces* isolates

| Source of variation | df | Sum of squares | Mean square | F |
|---|---|---|---|---|
| *Torulomyces* isolates | 1 | 5.99 | 5.99 | 20.35 *** |
| Nematode isolates | 1 | 5.45 | 5.45 | 18.50 ** |
| Interaction | 1 | 0.05 | 0.05 | 0.16 N.S. |
| Residual | 12 | 3.53 | 0.29 | |
| Total | 15 | 15.02 | | |

Appendix 5r:    Wheat-field soil *Doratomyces* isolates

| Source of variation | df | Sum of squares | Mean square | F |
|---|---|---|---|---|
| Nematode isolates | 3 | 74.99 | 24.99 | 44.78 *** |
| Residual | 16 | 8.93 | 0.56 | |
| Total | 19 | 83.92 | | |

Appendix 5 s:    Wheat-field soil *Coniothyrium* (?) isolates

| Source of variation | df | Sum of squares | Mean square | F |
|---|---|---|---|---|
| Nematode isolates | 2 | 35.22 | 17.61 | 41.33 *** |
| Residual | 13 | 5.54 | 0.43 | |
| Total | 15 | 40.76 | | |

Appendix 5t:   Wheat-field soil *Periconia* isolates

| Source of variation | df | Sum of squares | Mean square | F |
|---|---|---|---|---|
| Nematode isolates | 1 | 0.18 | 0.18 | 0.26 N.S. |
| Residual | 8 | 5.53 | 0.69 | |
| Total | 9 | 5.71 | | |

Appendix 5u:   Wheat-field soil *Ulocladium* isolates

| Source of variation | df | Sum of squares | Mean square | F |
|---|---|---|---|---|
| Nematode isolates | 3 | 178.68 | 59.56 | 269.99 *** |
| Residual | 15 | 3.31 | 0.22 | |
| Total | 18 | 181.99 | | |

Appendix 5v:   Wheat-field soil sterile fungi isolates

| Source of variation | df | Sum of squares | Mean square | F |
|---|---|---|---|---|
| Sterile fungi | 14 | 571.7 | 40.83 | 64.26 *** |
| Nematode isolates | 5 | 944.8 | 189.00 | 297.36 *** |
| Interaction | 44 | 534.1 | 12.14 | 19.10 *** |
| Residual | 197 | 125.2 | 0.64 | |
| Total | 260 | 2175.8 | | |

APPENDIX 6 : Analysis of variance for data of Table 29a pertaining to individual fungal genera and species groups from pine-forest soil.

Appendix 6a: Pine-forest soil *Penicillium* isolates

| Source of variation | df | Sum of squares | Mean square | F |
|---|---|---|---|---|
| *Penicillium* isolates | 32 | 1219 | 38.09 | 80.87 *** |
| Nematode isolates | 4 | 1307 | 326.80 | 693.78 *** |
| Interaction | 56 | 375 | 6.70 | 14.23 *** |
| Residual | 266 | 125 | 0.47 | |
| Total | 358 | 3027 | | |

Appendix 6b: Pine-forest soil *Trichoderma* isolates

| Source of variation | df | Sum of squares | Mean square | F |
|---|---|---|---|---|
| *Trichoderma* isolates | 1 | 3.69 | 3.69 | 17.29 *** |
| Nematode isolates | 4 | 81.47 | 20.37 | 95.39 *** |
| Interaction | 2 | 1.31 | 0.66 | 3.07 N.S. |
| Residual | 32 | 6.83 | 0.21 | |
| Total | 39 | 93.30 | | |

Appendix 6c:   Pine-forest soil *Mortierella* isolates

| Source of variation | df | Sum of squares | Mean square | F |
|---|---|---|---|---|
| *Mortierella* isolates | 1 | 0.64 | 0.64 | 2.86 N.S. |
| Nematode isolates | 4 | 163.01 | 40.75 | 183.09 *** |
| Interaction | 4 | 106.69 | 26.67 | 119.83 *** |
| Residual | 32 | 7.12 | 0.22 | |
| Total | 41 | 277.46 | | |

Appendix 6d:   Pine-forest soil *Mucor* isolates

| Source of variation | df | Sum of Squares | Mean square | F |
|---|---|---|---|---|
| Nematode isolates | 1 | 0.46 | 0.46 | 4.48 N.S. |
| Residual | 8 | 0.83 | 0.10 | |
| Total | 9 | 1.29 | | |

Appendix 6e:    Pine-forest soil *Fusarium* isolates

| Source of variation | df | Sum of squares | Mean square | F |
|---|---|---|---|---|
| *Fusarium* isolates | 3 | 45.44 | 15.15 | 39.83 *** |
| Nematode isolates | 5 | 380.04 | 76.01 | 199.90 *** |
| Interaction | 9 | 101.23 | 11.24 | 29.58 *** |
| Residual | 88 | 33.46 | 0.38 | |
| Total | 105 | 560.17 | | |

Appendix 6f:    Pine-forest soil *Paecilomyces* isolates

| Source of variation | df | Sum of squares | Mean square | F |
|---|---|---|---|---|
| *Paecilomyces* isolates | 1 | 10.92 | 10.92 | 34.04 *** |
| Nematode isolates | 4 | 49.48 | 12.37 | 38.55 *** |
| Interaction | 1 | 0.38 | 0.38 | 1.17 N.S. |
| Residual | 28 | 8.98 | 0.32 | |
| Total | 34 | 69.76 | | |

Appendix 6g:  Pine-forest soil *Verticillium* isolates

| Source of variation | df | Sum of squares | Mean square | F |
|---|---|---|---|---|
| *Verticillium* isolates | 1 | 134.97 | 134.97 | 274.88 *** |
| Nematode isolates | 4 | 214.85 | 53.71 | 109.39 *** |
| Interaction | 2 | 33.70 | 16.85 | 34.32 *** |
| Residual | 29 | 14.24 | 0.49 | |
| Total | 36 | .397.76 | | |

Appendix 6h:  Pine-forest soil *Pestalotia* isolates

| Source of variation | df | Sum of squares | Mean square | F |
|---|---|---|---|---|
| Nematode isolates | 4 | 149.33 | 37.33 | 119.57 *** |
| Residual | 24 | 7.49 | 0.31 | |
| Total | 28 | 156.82 | | |

Appendix 6i:    Pine-forest soil *Botrytis* isolates

| Source of variation | df | Sum of squares | Mean square | F |
|---|---|---|---|---|
| Nematode isolate | 2 | 186.14 | 93.07 | 226.49 *** |
| Residual | 16 | 6.57 | 0.41 | |
| Total | 18 | 192.71 | | |

Appendix 6j:    Pine-forest soil *Chaetomium* isolates

| Source of variation | df | Sum of squares | Mean square | F |
|---|---|---|---|---|
| Nematode isolates | 1 | 0.13 | 0.13 | 0.73 N.S. |
| Residual | 5 | 0.89 | 0.18 | |
| Total | 6 | 1.02 | | |

Appendix 6k:   Pine-forest soil sterile fungi isolates

| Source of variation | df | Sum of squares | Mean square | F |
|---|---|---|---|---|
| Sterile fungi isolates | 3 | 53.10 | 17.70 | 50.75 *** |
| Nematode isolates | 5 | 304.24 | 60.85 | 174.47 *** |
| Interaction | 9 | 133.11 | 14.79 | 42.41 *** |
| Residual | 60 | 20.92 | 0.35 | |
| Total | 77 | 511.37 | | |

Appendix 6l:   Pine-forest soil unknown Hyphomycete (P16)

| Source of variation | df | Sum of squares | Mean square | F |
|---|---|---|---|---|
| Nematode isolates | 3 | 83.67 | 27.89 | 22.94 *** |
| Residual | 15 | 18.23 | 1.22 | |
| Total | 18 | 101.90 | | |

APPENDIX 7:    Analyses of variance for % adults at harvest of nematode
isolates on fungal groups from pine-forest soil.    Data
subjected to an angular transformation.

Appendix 7a:    Pine-forest soil *Penicillium* isolates

| Source of variation | df | Sum of squares | Mean square | F |
|---|---|---|---|---|
| *Penicillium* isolates | 32 | 19290 | 602.8 | 6.24 *** |
| Nematode isolates | 4 | 51660 | 12920.0 | 133.61 *** |
| Interaction | 56 | 21610 | 385.8 | 3.99 *** |
| Residual | 248 | 23970 | 96.7 | |
| Total | 340 | 116500 | | |

Appendix 7b:    Pine-forest soil *Trichoderma* isolates

| Source of variation | df | Sum of squares | Mean square | F |
|---|---|---|---|---|
| *Trichoderma* isolates | 1 | 111.25 | 111.25 | 1.79 N.S. |
| Nematode isolates | 4 | 880.62 | 220.16 | 3.54 * |
| Interaction | 2 | 157.63 | 78.81 | 1.27 N.S. |
| Residual | 32 | 1990.79 | 62.21 | |
| Total | 39 | 3140.29 | | |

Appendix 7c:  Pine-forest soil *Mortierella* isolates

| Source of variation | df | Sum of squares | Mean square | F |
|---|---|---|---|---|
| *Mortierella* isolates | 1 | 904.53 | 904.53 | 13.70 *** |
| Nematode isolates | 4 | 9618.59 | 2404.65 | 36.41 *** |
| Interaction | 4 | 12922.81 | 3230.70 | 48.91 *** |
| Residual | 31 | 2047.47 | 66.05 | |
| Total | 40 | 25493.40 | | |

Appendix 7d:  Pine-forest soil *Fusarium* isolates

| Source of variation | df | Sum of squares | Mean square | F |
|---|---|---|---|---|
| *Fusarium* isolates | 3 | 2240.53 | 746.84 | 9.02 *** |
| Nematode isolates | 5 | 3980.41 | 796.08 | 9.61 *** |
| Interaction | 9 | 4837.57 | 537.51 | 6.49 *** |
| Residual | 85 | 7039.70 | | |
| Total | 102 | 18098.21 | | |

Appendix 7e:   Pine-forest soil *Paecilomyces* isolates

| Source of variation | df | Sum of squares | Mean square | F |
|---|---|---|---|---|
| *Paecilomyces* isolates | 1 | 30.91 | 30.91 | 0.35 N.S. |
| Nematode isolates | 4 | 1411.97 | 352.99 | 3.92 * |
| Interaction | 1 | 39.63 | 39.63 | 0.44 N.S. |
| Residual | 28 | 2521.13 | 90.04 | |
| Total | 34 | 4003.64 | | |

Appendix 7f:   Pine-forest soil *Verticillium* isolates

| Source of variation | df | Sum of squares | Mean square | F |
|---|---|---|---|---|
| *Verticillium* isolates | 1 | 1821.26 | 1821.26 | 26.29 *** |
| Nematode isolates | 4 | 28013.57 | 7003.39 | 101.11 *** |
| Interaction | 2 | 345.48 | 172.74 | 2.49 N.S. |
| Residual | 27 | 1870.24 | | |
| Total | 34 | 32050.55 | | |

Appendix 7g:    Pine-forest soil *Pestalotia* isolates

| Source of variation | df | Sum of squares | Mean square | F |
|---|---|---|---|---|
| Nematode isolates | 4 | 11572.52 | 2893.13 | 30.93 *** |
| Residual | 24 | 2245.02 | 93.54 | |
| Total | 28 | 13817.54 | | |

Appendix 7h:    Pine-forest soil *Botrytis* isolates

| Source of variation | df | Sum of squares | Mean square | F |
|---|---|---|---|---|
| Nematode isolates | 2 | 5875.6 | 2937.8 | 9.49 ** |
| Residual | 16 | 4953.6 | 309.6 | |
| Total | 18 | 10829.2 | | |

Appendix 7i:    Pine-forest soil *Chaetomium* isolates

| Source of variation | df | Sum of squares | Mean square | F |
|---|---|---|---|---|
| Nematode isolates | 1 | 2.88 | 2.88 | 0.08 N.S. |
| Residual | 5 | 188.41 | 37.68 | |
| Total | 6 | 191.28 | | |

Appendix 7j:    Pine-forest *Mucor* isolates

| Source of variation | df | Sum of squares | Mean square | F |
|---|---|---|---|---|
| Nematode isolates | 1 | 81.10 | 81.10 | 7.50 * |
| Residual | 8 | 86.49 | 10.81 | |
| Total | 9 | 167.59 | | |

Appendix 7k:    Pine-forest sterile fungi

| Source of variation | df | Sum of squares | Mean square | F |
|---|---|---|---|---|
| Fungal isolates | 3 | 5826.65 | 1942.22 | 20.11 *** |
| Nematode isolates | 5 | 19432.77 | 3886.55 | 40.24 *** |
| Interaction | 9 | 16852.50 | 1872.50 | 19.39 *** |
| Residual | 59 | 5698.33 | 96.58 | |
| Total | 76 | 47810.25 | | |

Appendix 7l:    Pine-forest soil unknown Hyphomycete (P16)

| Source of variation | df | Sum of squares | Mean square | F |
|---|---|---|---|---|
| Nematode isolates | 3 | 13007.38 | 4335.79 | 104.16 *** |
| Residual | 15 | 624.42 | 41.63 | |
| Total | 18 | 13631.80 | | |

APPENDIX 8: Results of feeding trials of mycophagous nematodes on fungi from wheat-field and pine-forest soils. Five adult female nematodes, treated with either antibiotics or chlorhexidine gluconate, were inoculated onto fungal cultures growing on NDY agar. After two weeks at 25°C, nematodes were extracted, a sub-sample counted and the number of adults (a) and larvae calculated (number of adults + larvae = b).

A. avenae isolates:   P - from pine-forest soil
W - from wheat-field soil
S - from *Suillus luteus* sporocorp collected from pine-forest

*Aphelenchoides* isolates:   L - from L-litter layer
C - from pine-forest soil
B) - from wheat-field soil
H)

(A) Populations of nematodes (pre-treated with antibiotics) on fungi from wheat-field soil

| Fungi | Aphelenchus avenae | | | | Aphelenchoides spp. | | | | | | | |
| | P | | W | | Pine-forest | | | | Wheat-field | | | |
| | | | | | L | | C | | B | | H | |
| | a | b | a | b | a | b | a | b | a | b | a | b |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Penicillium* isolates | | | | | | | | | | | | |
| 1. W41H | | | 500 | 9400 | | | | | 270 | 1785 | | |
| | | | 900 | 10600 | | | | | 396 | 2332 | | |
| | | | 500 | 11400 | | | | | 255 | 1155 | | |
| | | | 800 | 15100 | | | | | 165 | 1275 | | |
| | | | | | | | | | 960 | 5040 | | |
| | | | | | | | | | 240 | 900 | | |
| | | | | | | | | | 120 | 780 | | |
| | | | | | | | | | 300 | 2460 | | |
| 2. W42 | | | 192 | 882 | | | 15 | 24 | 5 | 7 | | |
| | | | 252 | 870 | | | 3 | 3 | 4 | 13 | | |
| | | | 2160 | 11040 | | | 4 | 4 | 12 | 68 | | |
| | | | 2160 | 13080 | | | 4 | 12 | 10 | 30 | | |
| | | | | | | | 0 | 2 | | | | |
| | | | | | | | 1 | 1 | | | | |
| | | | | | | | 0 | 0 | | | | |
| | | | | | | | 0 | 0 | | | | |

continued (i)

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 3. W43 | | | 70 | 180 | | 2 | 2 | 1 | 4 | | |
| | | | 110 | 260 | | 2 | 2 | 3 | 4 | | |
| | | | 300 | 630 | | 1 | 1 | 1 | 1 | | |
| | | | 320 | 540 | | 0 | 1 | 0 | 0 | | |
| 4. W48J | | | 195 | 705 | | | | 4 | 15 | | |
| | | | 345 | 1245 | | | | 2 | 14 | | |
| | | | 510 | 1410 | | | | 6 | 16 | | |
| | | | 345 | 1305 | | | | 5 | 6 | | |
| 5. W56 | | | 105 | 345 | | | | 1 | 3 | | |
| | | | 360 | 1335 | | | | 4 | 9 | | |
| | | | 285 | 1380 | | | | 2 | 5 | | |
| | | | 195 | 660 | | | | 1 | 2 | | |
| 6. W70H | 5 | 18 | 91 | 196 | | 1 | 1 | 11 | 52 | 17 | 65 |
| | 13 | 77 | 165 | 399 | | 1 | 6 | 39 | 127 | 7 | 40 |
| | 11 | 24 | 168 | 501 | | 1 | 1 | 28 | 81 | 36 | 71 |
| | 12 | 46 | 99 | 372 | | 0 | 0 | 40 | 142 | 13 | 58 |
| | | | 100 | 410 | | | | | | | |
| | | | 50 | 210 | | | | | | | |
| | | | 50 | 180 | | | | | | | |
| | | | 20 | 150 | | | | | | | |
| 7. W73B | 400 | 4300 | 800 | 9600 | | | | 300 | 6120 | 450 | 630 |
| | 100 | 4700 | 4000 | 27250 | | | | 600 | 3720 | 420 | 1070 |
| | 900 | 7800 | 1500 | 16750 | | | | 630 | 2730 | 330 | 1090 |
| | 300 | 4100 | 3000 | 23750 | | | | 25 | 120 | 270 | 680 |
| | | | 3500 | 13000 | | | | | | | |
| | | | 1000 | 7000 | | | | | | | |
| | | | 2500 | 18000 | | | | | | | |
| | | | 2000 | 17500 | | | | | | | |
| 8. W75 | | | 60 | 480 | | | | 330 | 1140 | | |
| | | | 320 | 2760 | | | | 390 | 2145 | | |
| | | | 50 | 370 | | | | 225 | 2325 | | |
| | | | 250 | 1310 | | | | 255 | 3135 | | |

continued (ii)

| Isolate | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **9. W79** | 260 | 870 | 300 | 9200 | | | 126 | 1494 | 240 | 360 |
| | 200 | 810 | 900 | 10300 | | | 5 | 17 | 190 | 330 |
| | 160 | 420 | 800 | 8100 | | | 20 | 91 | 300 | 400 |
| | 90 | 150 | 600 | 10700 | | | 17 | 74 | 440 | 680 |
| | | | | | | | 360 | 1560 | | |
| | | | | | | | 630 | 7230 | | |
| **10. W108** | | | 450 | 4800 | | | 84 | 222 | 46 | 51 |
| | | | 750 | 5100 | | | 132 | 246 | 92 | 128 |
| | | | 900 | 9450 | | | 168 | 276 | 77 | 107 |
| | | | 600 | 6150 | | | 90 | 156 | 65 | 73 |

*Fusarium* isolates

| Isolate | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **1. W55L** | 250 | 3750 | 2000 | 16000 | | | 750 | 2400 | 90 | 260 |
| | 1000 | 10500 | 400 | 3800 | | | 600 | 1740 | 240 | 440 |
| | 500 | 6750 | 350 | 2750 | | | 480 | 1140 | 170 | 240 |
| | 250 | 4500 | 1500 | 8000 | | | 780 | 3060 | 240 | 650 |
| | 1250 | 9000 | 2000 | 9500 | | | | | | |
| | 2000 | 19750 | 1750 | 8500 | | | | | | |
| | | | 2750 | 12250 | | | | | | |
| | | | 1250 | 4750 | | | | | | |
| **2. W64** | 400 | 9000 | 1400 | 14600 | 768 | 4224 | 1240 | 4000 | 21 | 25 |
| | 1000 | 6400 | 600 | 18400 | 1440 | 5220 | 1680 | 7569 | 19 | 25 |
| | 400 | 13600 | 2400 | 28600 | 1020 | 2160 | 1080 | 3180 | 9 | 13 |
| | 600 | 15400 | 2400 | 27600 | 600 | 2160 | 2280 | 8040 | 3 | 6 |
| | 4000 | 18000 | 13000 | 33000 | | | | | | |
| | 4500 | 27500 | 13000 | 34000 | | | | | | |
| | 1000 | 12000 | 14000 | 41000 | | | | | | |
| | 2000 | 12500 | 7000 | 33000 | | | | | | |
| | | | 7500 | 41500 | | | | | | |
| | | | 9500 | 44000 | | | | | | |
| | | | 11500 | 37500 | | | | | | |
| | | | 7500 | 37000 | | | | | | |

continued (iii)

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3. W84K | 150 | 2070 | 1500 | 12150 | 60 | 405 | 180 | 990 | 360 | 1890 | 30 | 50 |
| | 150 | 480 | 600 | 6750 | 80 | 1216 | 120 | 1650 | 150 | 630 | 100 | 140 |
| | 30 | 960 | 2850 | 20250 | 150 | 645 | 180 | 2790 | 300 | 1440 | 20 | 20 |
| | 90 | 720 | 750 | 10950 | 75 | 675 | 150 | 1350 | 300 | 1260 | 10 | 20 |
| | 800 | 6000 | | | 150 | 2730 | | | 180 | 1150 | | |
| | 150 | 1620 | | | 120 | 1080 | | | 110 | 940 | | |
| | 500 | 3200 | | | 390 | 1920 | | | 80 | 660 | | |
| | 600 | 4700 | | | 300 | 2430 | | | 210 | 1220 | | |
| 4. W85I | 375 | 7750 | 5500 | 20500 | 800 | 6300 | | | | | 7 | 9 |
| | 1950 | 17400 | 2500 | 22500 | 200 | 4400 | | | | | 28 | 29 |
| | 450 | 4950 | 7500 | 26500 | 800 | 6300 | | | | | 7 | 9 |
| | 1200 | 10650 | 6000 | 21500 | 200 | 4400 | | | | | 28 | 29 |
| | 1400 | 14400 | 2000 | 22500 | 400 | 5400 | | | | | 11 | 16 |
| | 2600 | 11000 | 1500 | 16250 | 700 | 3500 | | | | | 29 | 29 |
| | 1600 | 9200 | 3750 | 35250 | | | | | | | | |
| | 4400 | 17400 | 3500 | 25750 | | | | | | | | |
| | | | 2000 | 11500 | | | | | | | | |
| | | | 2500 | 15500 | | | | | | | | |
| | | | 3000 | 18000 | | | | | | | | |
| | | | 1000 | 17500 | | | | | | | | |
| 5. W90G | 7000 | 46500 | 750 | 7500 | | | 30 | 270 | 11 | 55 | | |
| | 3000 | 34000 | 750 | 5250 | | | 50 | 230 | 8 | 32 | | |
| | 4000 | 41000 | 1000 | 4750 | | | 40 | 100 | 2 | 24 | | |
| | 1000 | 26000 | 750 | 6500 | | | | | | | | |
| | | | 1650 | 5100 | | | | | | | | |
| | | | 750 | 4950 | | | | | | | | |
| 6. W93A | 800 | 7000 | 3750 | 16500 | | | | | | | | |
| | 900 | 18600 | 1250 | 5250 | | | | | | | | |
| | 1500 | 12000 | 2750 | 12750 | | | | | | | | |
| | 800 | 12400 | 1750 | 11250 | | | | | | | | |

| | | | | | | | | | | | | |
|---|---:|---:|---:|---:|---:|---:|---:|---:|---:|---:|---:|---:|
| 7. W96 | 150 | 6000 | 1750 | 14500 | 240 | 2370 | 540 | 4800 | 210 | 1650 | 120 | 720 |
| | 330 | 2420 | 2100 | 19500 | 150 | 1830 | 60 | 600 | 840 | 6060 | 270 | 1200 |
| | 600 | 3450 | 1500 | 22500 | 180 | 1521 | 180 | 780 | 540 | 3360 | 300 | 1230 |
| | | | 1800 | 15600 | 330 | 2250 | 240 | 3840 | 360 | 3840 | 150 | 1050 |
| | | | | | | | | | 300 | 2400 | | |
| | | | | | | | | | 180 | 420 | | |
| | | | | | | | | | 240 | 2460 | | |
| | | | | | | | | | 1140 | 5400 | | |
| 8. W112G | 400 | 3800 | 200 | 4000 | | | 10 | 20 | 180 | 450 | 150 | 480 |
| | 200 | 2000 | 1100 | 5400 | | | 10 | 10 | 420 | 1080 | 120 | 270 |
| | 800 | 4600 | 400 | 2600 | | | 20 | 40 | 10 | 60 | 140 | 230 |
| | | | 900 | 2500 | | | | | 60 | 180 | 90 | 120 |
| 9. W121D | 500 | 4500 | 2500 | 19000 | | | | | | | 90 | 435 |
| | 2000 | 13500 | 5000 | 18000 | | | | | | | 135 | 540 |
| | 1250 | 9500 | 5000 | 15500 | | | | | | | 165 | 510 |
| | 1500 | 17500 | 7500 | 26500 | | | | | | | 45 | 450 |
| | | | 1000 | 13250 | | | | | | | | |
| | | | 1000 | 9250 | | | | | | | | |
| | | | 750 | 14500 | | | | | | | | |
| | | | 3750 | 23250 | | | | | | | | |
| 10. W125 | 240 | 1500 | 540 | 5100 | | | | | | | | |
| | 360 | 2040 | 1200 | 10320 | | | | | | | | |
| | 300 | 2520 | 1140 | 9360 | | | | | | | | |
| | 240 | 3240 | 1260 | 8760 | | | | | | | | |
| 11. W126 | 100 | 2100 | 2400 | 12450 | | | 580 | 3240 | 80 | 235 | 240 | 1740 |
| | 400 | 3500 | 1650 | 3150 | | | 96 | 888 | 5 | 10 | 120 | 1050 |
| | 300 | 2600 | 2550 | 13050 | | | 10 | 12 | 390 | 1350 | 270 | 2704 |
| | 400 | 3700 | 2250 | 11850 | | | 26 | 76 | 300 | 810 | 300 | 1590 |
| | | | | | | | 15 | 52 | | | | |
| 12. W127 | 750 | 7750 | 4500 | 19000 | | | 400 | 3000 | 690 | 3420 | 300 | 710 |
| | 1750 | 11000 | 1750 | 12500 | | | 400 | 4600 | 960 | 3930 | 220 | 500 |
| | 1750 | 13250 | 3250 | 14750 | | | 800 | 7000 | 2800 | 10400 | 160 | 520 |
| | 1750 | 11750 | 2250 | 25750 | | | | | 1600 | 9300 | 340 | 1010 |

continued (v)

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **13. W129** | 1500 | 13500 | 2500 | 23500 | 90 | 390 | 900 | 5400 | | |
| | 1000 | 9000 | 7000 | 27000 | 90 | 360 | 1200 | 7800 | | |
| | 1000 | 11500 | 3500 | 15500 | 150 | 150 | 1500 | 6900 | | |
| | 1000 | 9000 | 4000 | 18000 | 10 | 10 | 1500 | 6150 | | |
| | | | | | | | 270 | 1830 | | |
| | | | | | | | 510 | 1890 | | |
| | | | | | | | 330 | 1650 | | |
| | | | | | | | 1080 | 2880 | | |

*Mortierella* isolates

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **1. W62G** | 300 | 4400 | 60 | 1740 | | | | | 60 | 1800 |
| | 500 | 2900 | 240 | 4440 | | | | | 150 | 1590 |
| | 400 | 6300 | 300 | 3360 | | | | | 120 | 1290 |
| | 200 | 2100 | 4000 | 23000 | | | | | 150 | 1440 |
| | 4500 | 24750 | 4500 | 21500 | | | | | | |
| | 2750 | 29500 | 9500 | 30000 | | | | | | |
| | 1750 | 21750 | 10000 | 31500 | | | | | | |
| | 2000 | 29000 | 9000 | 22000 | | | | | | |
| **2. W66** | 600 | 4600 | 1200 | 20100 | | | | | | |
| | 600 | 11400 | 300 | 8700 | | | | | | |
| | 1400 | 19100 | 1500 | 17400 | | | | | | |
| | 200 | 6900 | 1050 | 6450 | | | | | | |
| **3. W67F** | | | 2 | 4 | | | 1 | 1 | | |
| | | | 2 | 2 | | | 2 | 2 | | |
| | | | 4 | 5 | | | 0 | 0 | | |
| | | | 2 | 3 | | | 0 | 0 | | |
| **4. W67L** | 1000 | 26800 | 200 | 22300 | | | | | | |
| | 400 | 17800 | 1000 | 32400 | | | | | | |
| | 800 | 17400 | 200 | 26800 | | | | | | |
| | 1200 | 20600 | 1000 | 20400 | | | | | | |
| | 500 | 3700 | 1625 | 8125 | | | | | | |
| | 700 | 3800 | 600 | 6300 | | | | | | |
| | 1700 | 8100 | 750 | 3300 | | | | | | |
| | 400 | 4500 | 750 | 4050 | | | | | | |

continued (vi)

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 5. W182 | 240 | 4800 | 1750 | 22000 | | | | | 7250 | 30000 | 350 | 1260 |
| | 720 | 7040 | 500 | 13250 | | | | | 5000 | 17500 | 380 | 1160 |
| | 320 | 4960 | 250 | 4000 | | | | | 3750 | 16500 | 470 | 1550 |
| | 640 | 9040 | 1250 | 6500 | | | | | | | 120 | 350 |
| *Mucor* isolates | | | | | | | | | | | | |
| 1. W86 | 300 | 4900 | 1000 | 10500 | 330 | 1560 | 180 | 1620 | 540 | 1800 | 22 | 29 |
| | 200 | 4500 | 1500 | 20000 | 150 | 1320 | 150 | 1650 | 420 | 1560 | 34 | 41 |
| | 600 | 5300 | 3000 | 21000 | 360 | 2250 | 180 | 780 | 240 | 1500 | 40 | 48 |
| | 400 | 4200 | 5000 | 38500 | 300 | 1110 | 30 | 90 | 180 | 1500 | 32 | 42 |
| | | | 2000 | 10000 | 55 | 260 | | | 480 | 1980 | 330 | 420 |
| | | | 1000 | 17500 | 90 | 465 | | | 660 | 2700 | 150 | 260 |
| | | | 3000 | 18000 | 195 | 855 | | | 360 | 1080 | 220 | 330 |
| | | | 2500 | 13500 | 70 | 325 | | | 360 | 2640 | 260 | 340 |
| *Gongronella* isolates | | | | | | | | | | | | |
| 1. W88I | 800 | 14400 | 2750 | 32500 | 150 | 1920 | | | | | 7 | 11 |
| | 1250 | 8000 | 2750 | 19250 | 150 | 2430 | | | | | 7 | 10 |
| | 250 | 8750 | 5000 | 41000 | 150 | 1170 | | | | | 5 | 7 |
| | 750 | 11000 | 5000 | 26500 | 60 | 1170 | | | | | 2 | 2 |
| | 1350 | 12900 | 3000 | 31000 | | | | | | | | |
| | 450 | 6000 | 2500 | 14500 | | | | | | | | |
| | 450 | 6450 | 2500 | 17000 | | | | | | | | |
| | 1050 | 11700 | | | | | | | | | | |
| *Cunninghamella* isolates | | | | | | | | | | | | |
| 1. W21G | 240 | 5220 | 1020 | 7620 | | | | | 60 | 180 | 120 | 520 |
| | 240 | 6060 | 450 | 3450 | | | | | 50 | 140 | 210 | 490 |
| | 120 | 1260 | 600 | 6000 | | | | | 20 | 80 | 200 | 640 |
| | 100 | 1740 | 450 | 8550 | | | | | 10 | 100 | 270 | 930 |
| | | | 600 | 5200 | | | | | | | | |
| | | | 400 | 5600 | | | | | | | | |
| | | | 700 | 7700 | | | | | | | | |
| | | | 500 | 6400 | | | | | | | | |

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continued (vii)

**_Trichoderma_ isolates**

1. W51D

| | |
|---|---|
| 56 | 792 |
| 135 | 1320 |
| 150 | 1320 |
| 180 | 1995 |

2. W83

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 240 | 840 | 300 | 4600 | 1650 | 10950 | 240 | 1200 | 270 | 3270 |
| 120 | 1740 | 100 | 4800 | 300 | 1650 | 180 | 2910 | 900 | 6270 |
| 60 | 1560 | 100 | 2100 | 300 | 4500 | 240 | 2430 | 960 | 9420 |
| 300 | 1080 | 200 | 3500 | 1050 | 6000 | 420 | 3870 | 750 | 9750 |
| | | 100 | 1100 | | | | | | |
| | | 200 | 2000 | | | | | | |
| | | 700 | 3800 | | | | | | |
| | | 600 | 2100 | | | | | | |

**_Aspergillus_ isolates**

1. W71

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 4 | 76 | 140 | 290 | 0 | 0 | 0 | 0 | 90 | 174 | 230 | 430 |
| 4 | 33 | 110 | 320 | 0 | 0 | 0 | 0 | 16 | 22 | 130 | 380 |
| 5 | 179 | 60 | 240 | 0 | 0 | 0 | 0 | 2 | 5 | 220 | 290 |
| 4 | 54 | 130 | 430 | 0 | 0 | 0 | 0 | 2 | 5 | 130 | 230 |
| 6 | 76 | | | | | | | | | | |
| 12 | 69 | | | | | | | | | | |
| 0 | 53 | | | | | | | | | | |
| 3 | 49 | | | | | | | | | | |

**_Metarrhizium_ isolates**

1. W13E

| | | | |
|---|---|---|---|
| 300 | 2300 | 1000 | 10250 |
| 1050 | 6300 | 1000 | 6750 |
| 90 | 750 | 750 | 8750 |
| 450 | 3900 | 500 | 7750 |

**_Cladosporium_ isolates**

1. W10H

| | | | |
|---|---|---|---|
| 180 | 720 | 1100 | 8600 |
| 480 | 4080 | 1000 | 6300 |
| 180 | 840 | 100 | 3700 |
| 60 | 300 | 1100 | 8600 |

continued (viii)

**Paecilomyces isolates**

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. W16I | 600 | 4950 | 1500 | 12750 | | | | | | | | |
| | 1050 | 5700 | 3900 | 20400 | | | | | | | | |
| | 240 | 1230 | 2100 | 27300 | | | | | | | | |
| | | | 1800 | 10800 | | | | | | | | |

**Acremonium isolates**

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. W22A | 255 | 915 | 9500 | 60500 | | | | | | | | |
| | 105 | 525 | 6500 | 49500 | | | | | | | | |
| | 360 | 2160 | 13000 | 77000 | | | | | | | | |
| | 195 | 690 | 20500 | 68000 | | | | | | | | |
| 2. W155 | 20 | 30 | 90 | 170 | | | 1 | 1 | 1 | 1 | 25 | 33 |
| | 40 | 60 | 50 | 260 | | | 1 | 1 | 0 | 0 | 29 | 41 |
| | 20 | 30 | 80 | 170 | | | 0 | 0 | 3 | 4 | 47 | 71 |
| | | | 60 | 150 | | | 0 | 0 | 1 | 1 | 198 | 660 |

**Gliocladium isolates**

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. W173 | 80 | 160 | 130 | 650 | | | 7 | 14 | 0 | 0 | 210 | 270 |
| | 150 | 430 | 200 | 770 | | | 13 | 22 | 0 | 1 | 230 | 420 |
| | 90 | 300 | 170 | 700 | | | 11 | 18 | 0 | 0 | 100 | 160 |
| | 30 | 170 | 50 | 530 | | | 5 | 8 | 1 | 1 | 75 | 80 |

**Graphium isolates**

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. W107 | 400 | 5200 | 3000 | 21500 | | | 144 | 480 | 70 | 500 | | |
| | 1100 | 10300 | 1500 | 8000 | | | 400 | 1872 | 30 | 250 | | |
| | 400 | 8400 | 2000 | 20500 | | | | | 10 | 30 | | |
| | 400 | 11800 | 3000 | 19500 | | | | | 10 | 40 | | |

**Broomella isolates**

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. W68C | 1250 | 6750 | 1950 | 9600 | 126 | 408 | 204 | 888 | 162 | 882 | 13 | 19 |
| | 4250 | 19750 | 750 | 8700 | 180 | 492 | 21 | 64 | 410 | 1810 | 6 | 9 |
| | 1000 | 10750 | 2100 | 17400 | 228 | 594 | 7 | 53 | 140 | 940 | 6 | 12 |
| | 200 | 2250 | 1350 | 12300 | 246 | 864 | | | 310 | 1330 | 8 | 10 |
| | | | 20000 | 72000 | 110 | 1250 | | | 70 | 440 | | |
| | | | 24000 | 75000 | 580 | 3940 | | | 130 | 440 | | |
| | | | | | 320 | 1990 | | | 120 | 520 | | |
| | | | | | 180 | 600 | | | 40 | 560 | | |

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**Phoma isolates**

| | C1 | C2 | C3 | C4 | C5 | C6 | C7 | C8 | C9 | C10 | C11 | C12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. W57 | 2100 | 14100 | 500 | 6500 | 630 | 3690 | 315 | 975 | 300 | 3360 | 130 | 240 |
| | 1050 | 7050 | 2000 | 8500 | 570 | 3810 | 100 | 1140 | 60 | 2100 | 470 | 1850 |
| | 2100 | 16950 | 3000 | 14000 | 360 | 1860 | 165 | 1425 | | | 270 | 1570 |
| | 1350 | 5400 | | | 120 | 660 | 255 | 1920 | | | 160 | 680 |
| 2. W58 | 400 | 3700 | 900 | 7000 | 203 | 742 | | | | | | |
| | 1100 | 8300 | 1700 | 11200 | 182 | 560 | | | | | | |
| | 600 | 8200 | 800 | 5500 | 77 | 392 | | | | | | |
| | 1000 | 8000 | 800 | 4300 | 91 | 343 | | | | | | |
| | 750 | 13500 | | | | | | | | | | |
| 3. W104 | 700 | 7300 | 1800 | 10500 | | | 21 | 31 | 120 | 390 | | |
| | 1100 | 14400 | 400 | 5200 | | | 39 | 143 | 110 | 520 | | |
| | 2400 | 26800 | 18000 | 67000 | | | | | 220 | 710 | | |
| | 1200 | 21600 | 13500 | 67000 | | | | | 110 | 360 | | |
| | 1500 | 6750 | 12500 | 56500 | | | | | | | | |
| | 2250 | 16500 | 10500 | 60000 | | | | | | | | |
| | 1000 | 4750 | | | | | | | | | | |
| | 5000 | 19500 | | | | | | | | | | |

**Cochliobolus isolates**

| | C1 | C2 | C3 | C4 |
|---|---|---|---|---|
| 1. W179 | 3200 | 15000 | 2500 | 22000 |
| | 600 | 5000 | 14000 | 28000 |
| | | | 5000 | 27000 |
| | | | 1500 | 24500 |

**Myrothecium isolates**

| | C1 | C2 | C3 | C4 | C5 | C6 | C7 | C8 | C9 | C10 | C11 | C12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. W14 | 780 | 4140 | 2700 | 13200 | 0 | 0 | 0 | 0 | 1 | 1 | 68 | 95 |
| | 360 | 660 | 2250 | 12750 | 0 | 0 | 0 | 0 | 9 | 32 | 112 | 171 |
| | 240 | 840 | 750 | 4950 | 0 | 0 | 0 | 0 | 1 | 2 | 196 | 332 |
| | 30 | 200 | 900 | 8550 | 0 | 0 | 0 | 0 | 2 | 3 | 248 | 372 |
| | 10 | 100 | | | | | | | | | | |
| 2. W92 | 20 | 30 | 170 | 1870 | | | 3 | 4 | 2 | 2 | 110 | 210 |
| | 30 | 100 | 270 | 1470 | | | 0 | 0 | 3 | 3 | 60 | 90 |
| | 30 | 100 | 90 | 780 | | | 0 | 0 | 1 | 1 | 20 | 50 |
| | 80 | 180 | 240 | 810 | | | 3 | 3 | 0 | 0 | 30 | 70 |

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| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 3. W95 | 100 | 3000 | 240 | 2460 | | 21 | 42 | 300 | 2520 | 35 | 145 |
| | 400 | 4600 | 540 | 4140 | | | | 180 | 2220 | 50 | 170 |
| | 600 | 3100 | 300 | 6060 | | | | 180 | 2400 | 130 | 350 |
| | 200 | 4100 | 560 | 4830 | | | | 60 | 1140 | 75 | 225 |
| 4. W133 | 250 | 1350 | 550 | 2500 | | | | | | | |
| | 125 | 727 | 700 | 3150 | | | | | | | |
| | 300 | 1900 | 850 | 4500 | | | | | | | |
| | 325 | 1900 | 400 | 3050 | | | | | | | |
| *Torulomyces* isolates | | | | | | | | | | | |
| 1. W18B | 2000 | 11250 | 3500 | 64000 | | | | | | | |
| | 2500 | 23500 | 3000 | 44000 | | | | | | | |
| | 2250 | 12750 | 7000 | 30500 | | | | | | | |
| | 250 | 8000 | 4000 | 52000 | | | | | | | |
| 2. W19B | 500 | 5000 | 250 | 19000 | | | | | | | |
| | 200 | 1400 | 250 | 17500 | | | | | | | |
| | 120 | 6480 | 750 | 11750 | | | | | | | |
| | 300 | 6900 | 500 | 5500 | | | | | | | |
| *Doratomyces* isolates | | | | | | | | | | | |
| 1. W165 | 40 | 260 | 1500 | 25250 | | | | 40 | 80 | 780 | 2400 |
| | 220 | 1190 | 100 | 1750 | | | | 60 | 70 | 300 | 1560 |
| | 10 | 120 | 200 | 5500 | | | | 40 | 80 | 480 | 2280 |
| | 20 | 370 | 250 | 9750 | | | | 30 | 70 | 660 | 2160 |
| | | | 500 | 15500 | | | | | | | |
| | | | 5500 | 25000 | | | | | | | |
| | | | 3000 | 23000 | | | | | | | |
| | | | 500 | 7000 | | | | | | | |
| *Coniothyrium* isolates (?) | | | | | | | | | | | |
| 1. W164 | 480 | 1640 | 210 | 2445 | | | | 30 | 57 | | |
| | 420 | 2550 | 390 | 4035 | | | | 17 | 40 | | |
| | 300 | 1170 | 600 | 6360 | | | | 53 | 117 | | |
| | 440 | 2400 | 360 | 4140 | | | | 27 | 65 | | |
| | | | 420 | 2220 | | | | | | | |
| | | | 360 | 840 | | | | | | | |
| | | | 240 | 1080 | | | | | | | |
| | | | 180 | 720 | | | | | | | |

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*Periconia* isolates

*Ulocladium* isolates

Sterile cultures

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. W193 | 3500 | 21000 | 4500 | 21500 | | | | | | | | |
| | 1250 | 15750 | 6000 | 28750 | | | | | | | | |
| | 750 | 3500 | 5500 | 27750 | | | | | | | | |
| | 500 | 7500 | 750 | 4250 | | | | | | | | |
| | 5500 | 31000 | | | | | | | | | | |
| | 1500 | 14000 | | | | | | | | | | |
| 1. W60G | 1400 | 11900 | 3000 | 11000 | 12 | 29 | | | | | 23 | 28 |
| | 100 | 9200 | 5000 | 25000 | 14 | 25 | | | | | 6 | 8 |
| | 600 | 6700 | 2500 | 10000 | 25 | 54 | | | | | 16 | 17 |
| | | | 4000 | 15000 | 5 | 10 | | | | | 22 | 23 |
| | | | 300 | 7500 | | | | | | | | |
| 1. W50H | 1600 | 11800 | 450 | 10800 | | | 0 | 0 | 150 | 810 | 111 | 123 |
| | 600 | 4000 | 2100 | 12450 | | | 0 | 0 | 50 | 150 | 108 | 129 |
| | 3400 | 15600 | 300 | 8700 | | | 5 | 67 | 100 | 350 | 177 | 288 |
| | 1000 | 3800 | 2250 | 15000 | | | 2 | 73 | | | 159 | 210 |
| 2. W53C | 1500 | 9750 | 10500 | 25000 | 420 | 2040 | | | | | 29 | 35 |
| | 3250 | 13750 | 7500 | 22500 | 1500 | 5100 | | | | | 22 | 29 |
| | 2400 | 12600 | 12000 | 39000 | 1500 | 5520 | | | | | | |
| | 1250 | 11750 | 20000 | 49000 | 2940 | 7200 | | | | | | |
| 3. W54 | 1250 | 13500 | 750 | 9500 | | | | | | | | |
| | 250 | 10750 | 250 | 11750 | | | | | | | | |
| | 750 | 11750 | 375 | 8750 | | | | | | | | |
| | 1500 | 10000 | | | | | | | | | | |
| 4. W59A | 800 | 6800 | 100 | 6800 | | | 10 | 180 | 310 | 1250 | 390 | 1140 |
| | 300 | 5500 | 900 | 15600 | | | 70 | 520 | 320 | 1020 | 270 | 2370 |
| | 1000 | 6800 | 200 | 2700 | | | 120 | 1540 | 160 | 450 | 360 | 2250 |
| | 300 | 4700 | 2200 | 20400 | | | 170 | 2030 | 400 | 1280 | 390 | 1920 |
| | 1200 | 11400 | | | | | | | | | | |
| | 900 | 8250 | | | | | | | | | | |
| | 600 | 6150 | | | | | | | | | | |

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continued (xii)

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 5. W80 | 750 | 8850 | 2000 | 13250 | 0 | 0 | 105 | 465 | 15 | 22 | 70 | 160 |
| | 900 | 9450 | 1000 | 5500 | 4 | 12 | 150 | 720 | 7 | 22 | 140 | 190 |
| | 1800 | 11850 | 2250 | 11500 | 0 | 1 | 135 | 1125 | 16 | 41 | 130 | 190 |
| | | | 500 | 13750 | 6 | 13 | 60 | 375 | 7 | 13 | 150 | 200 |
| | | | 1050 | 6300 | | | | | 60 | 570 | | |
| | | | 750 | 5700 | | | | | 345 | 1335 | | |
| | | | 450 | 2550 | | | | | 75 | 510 | | |
| | | | 1050 | 8400 | | | | | 270 | 825 | | |
| 6. W81 | 390 | 1410 | 180 | 1560 | | | 1 | 1 | 7 | 13 | 34 | 35 |
| | 145 | 315 | 780 | 4500 | | | 8 | 8 | 7 | 10 | 55 | 59 |
| | 52 | 106 | 660 | 3480 | | | | | 21 | 66 | 71 | 102 |
| | | | 400 | 1240 | | | | | 5 | 7 | 84 | 98 |
| 7. W97 | 700 | 3300 | 1800 | 12300 | 480 | 4020 | 0 | 0 | 720 | 3480 | 190 | 310 |
| | 200 | 4900 | 2200 | 15200 | 720 | 5100 | 0 | 0 | 300 | 1560 | 350 | 490 |
| | 3900 | 15300 | 1800 | 10050 | 720 | 4140 | 0 | 0 | 480 | 1560 | 270 | 350 |
| | 1500 | 9600 | 900 | 7650 | 540 | 3600 | 0 | 0 | 480 | 2280 | | |
| 8. W103D | 600 | 6300 | 7500 | 31000 | 720 | 2220 | | | | | 5 | 6 |
| | 100 | 2400 | 10000 | 31000 | 240 | 1020 | | | | | 2 | 3 |
| | 700 | 6400 | 11500 | 41000 | 240 | 1260 | | | | | 7 | 10 |
| | 400 | 3500 | 10000 | 34000 | | | | | | | 7 | 8 |
| | | | 1600 | 9900 | | | | | | | | |
| | | | 700 | 5800 | | | | | | | | |
| | | | 3000 | 19100 | | | | | | | | |
| | | | 2250 | 11500 | | | | | | | | |
| | | | 1500 | 7750 | | | | | | | | |
| | | | 750 | 8750 | | | | | | | | |
| | | | 1500 | 12250 | | | | | | | | |
| 9. W136 | | | 2250 | 19250 | 7500 | 32000 | 12 | 12 | 9500 | 29500 | 435 | 1020 |
| | | | 1250 | 23500 | 11250 | 62500 | 0 | 12 | 7500 | 39500 | 345 | 870 |
| | | | 1000 | 23250 | 7500 | 40000 | 24 | 384 | 10500 | 30000 | 405 | 660 |
| | | | 2500 | 24000 | 7750 | 36750 | | | 13000 | 32500 | 105 | 195 |

continued (xiii)

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 10. W176I | | | 6000 | 39000 | | | | | 3150 | 13200 | 450 | 960 |
| | | | 3500 | 16000 | | | | | 5250 | 19500 | 150 | 660 |
| | | | 1000 | 17500 | | | | | 5250 | 15300 | 180 | 930 |
| | | | 3500 | 41000 | | | | | 5400 | 18900 | 150 | 570 |
| 11. W177K | | | 13 | 35 | | | 0 | 0 | | | 210 | 360 |
| | | | 3 | 11 | | | 2 | 9 | | | 130 | 190 |
| | | | 14 | 38 | | | 0 | 1 | | | 150 | 250 |
| | | | 26 | 58 | | | 0 | 0 | | | 300 | 490 |
| 12. W178I | 100 | 460 | 2000 | 5500 | 105 | 480 | 1 | 1 | 280 | 910 | 170 | 260 |
| | 30 | 150 | 3150 | 12300 | 60 | 525 | 1 | 1 | 360 | 2040 | 170 | 170 |
| | 60 | 240 | 2400 | 13500 | 70 | 410 | 5 | 10 | 120 | 540 | 90 | 200 |
| | 160 | 2000 | 3000 | 10800 | 15 | 30 | 18 | 23 | 80 | 200 | 260 | 360 |
| 13. W194 | | | 2200 | 10600 | 270 | 520 | 0 | 0 | 540 | 2520 | 90 | 330 |
| | | | 2000 | 12100 | 190 | 580 | 0 | 0 | 120 | 2280 | 210 | 590 |
| | | | 1100 | 6600 | 70 | 320 | 0 | 1 | 120 | 960 | 110 | 220 |
| | | | 3600 | 14700 | 190 | 390 | 0 | 0 | 360 | 1800 | 40 | 80 |
| 14. W195C | 300 | 3000 | 2000 | 33750 | | | | | | | 190 | 370 |
| | 510 | 3510 | 5000 | 52000 | | | | | | | 330 | 840 |
| | | | 10000 | 73000 | | | | | | | 540 | 990 |
| | | | 6000 | 25000 | | | | | | | 250 | 480 |
| 15. W196 | | | 3300 | 13600 | | | | | | | 390 | 2580 |
| | | | 1800 | 29700 | | | | | | | 270 | 1620 |
| | | | 3800 | 20900 | | | | | | | 330 | 1590 |
| | | | 2700 | 12100 | | | | | | | 210 | 210 |

(B) Populations of nematodes (pre-treated with antibiotics) on fungi from pine-forest soil

| Fungi | *Aphelenchus avenae* | | | | | | *Aphelenchoides* spp. | | | | | | | |
| | | | | | | | Pine-forest | | | | Wheat-field | | | |
| | P | | W | | S | | L | | C | | B | | H | |
| | a | b | a | b | a | b | a | b | a | b | a | b | a | b |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Penicillium* isolates 1. P40 | 720 | 3180 | 345 | 1815 | 6000 | 21500 | 22 | 36 | | | | | | |
| | 360 | 2700 | 2240 | 10560 | 13250 | 40000 | 15 | 17 | | | | | | |
| | 450 | 2850 | 1620 | 8250 | 6250 | 26750 | 7 | 15 | | | | | | |
| | 120 | 1590 | 1600 | 4440 | 10750 | 43750 | 5 | 12 | | | | | | |
| 2. P41C | 55 | 99 | 11 | 30 | | | | | | | | | | |
| | 20 | 50 | 11 | 45 | | | | | | | | | | |
| | 20 | 40 | 21 | 72 | | | | | | | | | | |
| | 20 | 30 | 21 | 63 | | | | | | | | | | |
| 3. P42 | 50 | 70 | 2750 | 13750 | | | | | | | | | | |
| | 140 | 230 | 2250 | 15500 | | | | | | | | | | |
| | 190 | 740 | 3750 | 21000 | | | | | | | | | | |
| | 260 | 590 | 7500 | 19750 | | | | | | | | | | |
| 4. P43 | 180 | 900 | | | | | | | | | | | | |
| | 180 | 990 | | | | | | | | | | | | |
| | 120 | 450 | | | | | | | | | | | | |
| | 120 | 390 | | | | | | | | | | | | |
| 5. P46 | 300 | 2800 | 1000 | 6900 | | | | | | | | | | |
| | 200 | 1400 | 500 | 3000 | | | | | | | | | | |
| | 300 | 1300 | 900 | 4700 | | | | | | | | | | |
| | 100 | 1000 | 1200 | 4900 | | | | | | | | | | |
| 6. P48B | 180 | 810 | 480 | 6240 | | | | | 65 | 151 | | | | |
| | 90 | 720 | 800 | 5400 | | | | | 26 | 125 | | | | |
| | 180 | 1170 | 900 | 5100 | | | | | 20 | 81 | | | | |
| | 150 | 600 | 700 | 6800 | | | | | | | | | | |
| 7. P49 | 90 | 645 | | | | | | | | | | | | |
| | 165 | 600 | | | | | | | | | | | | |
| | 75 | 360 | | | | | | | | | | | | |
| | 105 | 510 | | | | | | | | | | | | |

| | C1 | C2 | C3 | C4 | C5 | C6 | C7 | C8 | C9 | C10 |
|---|---|---|---|---|---|---|---|---|---|---|
| 8.P50 | 225 | 615 | | | | | | | | |
| | 330 | 1560 | | | | | | | | |
| | 105 | 525 | | | | | | | | |
| | 180 | 580 | | | | | | | | |
| 9.P52 | 60 | 190 | 4000 | 12250 | | | | | | |
| | 130 | 950 | 1250 | 10250 | | | | | | |
| | 360 | 2160 | 750 | 8000 | | | | | | |
| 10.P53 | 30 | 90 | | | 2000 | 13000 | 10 | 120 | | |
| | 210 | 1410 | | | 2500 | 13250 | 150 | 660 | | |
| | 300 | 3420 | | | 4250 | 17250 | 100 | 520 | | |
| | 330 | 5580 | | | 1250 | 15000 | 140 | 830 | | |
| 11.P54 | 360 | 2340 | 6000 | 25050 | 1000 | 14500 | 4 | 10 | 1 | 1 |
| | 800 | 4800 | 6600 | 33000 | 4500 | 13500 | 48 | 88 | 8 | 19 |
| | 320 | 2360 | 1800 | 14400 | 9500 | 26000 | 2 | 7 | 1 | 3 |
| | 150 | 4650 | | | | | | | 1 | 6 |
| | 660 | 3180 | | | | | | | | |
| | 480 | 3480 | | | | | | | | |
| | 720 | 3660 | | | | | | | | |
| | 540 | 8340 | | | | | | | | |
| 12.P55 | 150 | 525 | | | | | | | | |
| | 105 | 465 | | | | | | | | |
| | 105 | 765 | | | | | | | | |
| | 105 | 345 | | | | | | | | |
| 13.P56 | 130 | 460 | | | 1800 | 10200 | 13 | 35 | | |
| | 50 | 240 | | | 600 | 10950 | 16 | 47 | | |
| | | | | | 900 | 10500 | 17 | 112 | | |
| | | | | | 1350 | 12450 | 160 | 436 | | |
| 14.P57 | 1500 | 27500 | 3500 | 25500 | | | | | | |
| | 2500 | 14000 | 4500 | 32000 | | | | | | |
| | 2500 | 12000 | 2500 | 16000 | | | | | | |
| | 3000 | 26000 | 1000 | 19500 | | | | | | |
| 15.P58 | 240 | 330 | | | 4500 | 17500 | 150 | 720 | 2 | 2 |
| | 450 | 1640 | | | 2500 | 16000 | 210 | 330 | 0 | 0 |
| | 200 | 330 | | | 7000 | 11500 | 210 | 480 | 0 | 0 |
| | 270 | 570 | | | 3000 | 11000 | 330 | 870 | 0 | 0 |

|  | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
|  | 360 | 1500 | | | | | | | | |
|  | 240 | 1560 | | | | | | | | |
|  | 540 | 1680 | | | | | | | | |
| 16.P59 | 120 | 3560 | | | | | | | | |
|  | 440 | 1240 | | | | | | | | |
|  | 480 | 3040 | | | | | | | | |
|  | 360 | 1400 | | | | | | | | |
| 17.P60 | 1000 | 3500 | 5500 | 29000 | 16500 | 39500 | 176 | 640 | 2 | 2 |
|  | 1200 | 4600 | 9000 | 29000 | 4000 | 21500 | 150 | 225 | 13 | 30 |
|  | 200 | 500 | 7000 | 29000 | 500 | 2700 | 195 | 1050 | 2 | 2 |
|  | 400 | 2800 | 7500 | 39500 | | | 420 | 1140 | 2 | 2 |
| 18.P61 | 120 | 250 | 2000 | 14000 | 1350 | 7350 | 540 | 2490 | | |
|  | 250 | 1420 | 3000 | 16500 | 900 | 6150 | 240 | 1440 | | |
|  | 150 | 550 | 4500 | 23500 | 300 | 1350 | 120 | 1320 | | |
|  | 330 | 1400 | 1500 | 5000 | | | 2040 | 8100 | | |
| 19.P62 | 80 | 170 | 130 | 520 | | | | | | |
|  | 80 | 210 | 290 | 970 | | | | | | |
|  | 50 | 200 | 230 | 940 | | | | | | |
|  | 50 | 110 | 600 | 4380 | | | | | | |
| 20.P63 | 4 | 14 | 40 | 110 | 7 | 37 | 3 | 3 | 0 | 0 |
|  | 2 | 12 | 10 | 120 | 9 | 72 | 0 | 0 | 2 | 2 |
|  | 1 | 14 | 30 | 150 | 12 | 36 | 0 | 0 | 1 | 2 |
|  | 3 | 14 | 10 | 90 | | | 0 | 0 | 1 | 1 |
| 21.P64I | 180 | 360 | 1200 | 8400 | | | 132 | 560 | 3 | 3 |
|  | 240 | 480 | 800 | 5900 | | | 204 | 384 | 0 | 0 |
|  | 450 | 1470 | 500 | 1700 | | | 324 | 1500 | 2 | 2 |
|  | | | 1300 | 4900 | | | 288 | 1128 | | |
| 22.P65 | 160 | 560 | 600 | 5220 | | | | | | |
|  | 240 | 930 | 480 | 5520 | | | | | | |
|  | 120 | 480 | 800 | 8600 | | | | | | |
|  | 390 | 1920 | 1200 | 10800 | | | | | | |
| 23.P75B | 190 | 410 | 1200 | 6000 | | | 270 | 1230 | 1 | 1 |
|  | 340 | 1150 | 750 | 6450 | | | 450 | 2310 | 0 | 0 |
|  | 130 | 680 | 2850 | 13200 | | | 150 | 600 | 0 | 0 |
|  | 330 | 740 | | | | | 270 | 1770 | 1 | 1 |

184

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 24.P85C | 130 | 450 | | | | 552 | 1452 | 0 | 0 |
| | 160 | 290 | | | | 948 | 2244 | 0 | 0 |
| | 190 | 390 | | | | 456 | 1356 | 2 | 9 |
| | 300 | 670 | | | | 60 | 156 | 0 | 0 |
| 25.P86B | 90 | 170 | | | | 3 | 7 | 0 | 0 |
| | 30 | 200 | | | | 0 | 0 | 0 | 0 |
| | 100 | 220 | | | | 1 | 1 | 1 | 1 |
| | 10 | 70 | | | | 0 | 0 | 2 | 2 |
| 26.P89I | 600 | 4500 | | | | 10750 | 61750 | | |
| | 800 | 4000 | | | | 7500 | 35000 | | |
| | 800 | 4000 | | | | 2500 | 17000 | | |
| | 1300 | 11400 | | | | 1000 | 5000 | | |
| 27.P92C | 250 | 9250 | | | | 42 | 784 | 1 | 1 |
| | 750 | 3750 | | | | 120 | 1260 | 0 | 0 |
| | 350 | 1000 | | | | | | | |
| | 400 | 1000 | | | | | | | |
| 28.P93I | 400 | 7000 | 1000 | 8000 | | 540 | 2100 | 2 | 2 |
| | 400 | 3800 | 3500 | 17500 | | 3430 | 13860 | 2 | 2 |
| | 320 | 2720 | 2750 | 14250 | | 360 | 2400 | 2 | 2 |
| | 320 | 1760 | 5500 | 17500 | | 1380 | 5100 | | |
| | | | 1350 | 12450 | | | | | |
| | | | 750 | 7950 | | | | | |
| | | | 3600 | 25650 | | | | | |
| | | | 1800 | 18900 | | | | | |
| 29.P94B | 500 | 2300 | | | | 110 | 620 | 10 | 14 |
| | 240 | 1440 | | | | 130 | 600 | 16 | 47 |
| | 120 | 450 | | | | 330 | 1590 | 27 | 70 |
| | | | | | | 380 | 1590 | | |
| 30.P95C | 240 | 960 | | | | 780 | 4680 | | 1 1 |
| | 210 | 420 | | | | 420 | 1140 | | |
| | 150 | 690 | | | | 300 | 1620 | | |
| | 90 | 210 | | | | 60 | 180 | | |
| 31.P98C | 10 | 200 | 72 | 296 | | 66 | 336 | 4 | 4 |
| | 130 | 540 | 76 | 280 | | 84 | 372 | 3 | 3 |
| | 72 | 232 | 88 | 300 | | 42 | 180 | 5 | 5 |
| | 30 | 110 | 80 | 192 | | 84 | 396 | 3 | 26 |

| | 1a | 1b | 2a | 2b | 3a | 3b | 4a | 4b | 5a | 5b | 6a | 6b |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 32.P103I | 17 | 116 | | | | | 15 | 20 | 1 | 1 | | |
| | 12 | 106 | | | | | 10 | 20 | 3 | 8 | | |
| | 7 | 83 | | | | | 5 | 35 | | | | |
| | 9 | 65 | | | | | 35 | 145 | | | | |
| 34.P105B | 10 | 50 | | | | | 6 | 11 | 3 | 3 | | |
| | 10 | 60 | | | | | 11 | 21 | 3 | 3 | | |
| | 10 | 70 | | | | | 14 | 32 | 4 | 4 | | |
| | 10 | 120 | | | | | 14 | 36 | | | | |
| *Trichoderma* isolates | | | | | | | | | | | | |
| 1.P21 | 1950 | 19200 | 2000 | 16500 | | | 300 | 1950 | 60 | 615 | 320 | 1270 |
| | 1650 | 16200 | 1000 | 10500 | | | 200 | 750 | 90 | 405 | 195 | 1575 |
| | 2100 | 21300 | 6000 | 21500 | | | 96 | 624 | 45 | 165 | 105 | 1065 |
| | 1650 | 15300 | 4500 | 15000 | | | 144 | 336 | 375 | 2940 | 195 | 1335 |
| | | | 2500 | 12750 | | | | | | | | |
| | | | 2500 | 12500 | | | | | | | | |
| | | | 1000 | 17500 | | | | | | | | |
| | | | 1250 | 15750 | | | | | | | | |
| 2.P115 | 400 | 8700 | 4000 | 15000 | | | | | 60 | 600 | | |
| | 300 | 700 | 4000 | 18500 | | | | | 60 | 840 | | |
| | 600 | 8400 | 5500 | 16000 | | | | | 90 | 630 | | |
| | 400 | 10600 | 4500 | 20000 | | | | | 90 | 720 | | |
| | | | 3000 | 27000 | | | | | | | | |
| | | | 2250 | 17250 | | | | | | | | |
| | | | 2500 | 16250 | | | | | | | | |
| | | | 2000 | 21750 | | | | | | | | |
| *Mortierella* isolates | | | | | | | | | | | | |
| 1.P122B | 250 | 10000 | 150 | 5700 | 450 | 8850 | | | 240 | 1470 | 420 | 1560 |
| | 500 | 8000 | 450 | 900 | 600 | 7200 | | | 210 | 2670 | 660 | 2460 |
| | 250 | 5250 | 500 | 3125 | 150 | 8550 | | | 150 | 1830 | 240 | 1020 |
| | 500 | 10500 | 625 | 6125 | | | | | 270 | 3390 | 540 | 1320 |
| 2.P123 | 800 | 21800 | 1500 | 25000 | 7000 | 24500 | | | 1 | 1 | 320 | 2752 |
| | 1600 | 16200 | 2500 | 22500 | 2000 | 18500 | | | 2 | 2 | 300 | 1200 |
| | 400 | 10600 | 2000 | 30500 | 2000 | 26500 | | | 0 | 0 | 1080 | 6420 |
| | 1000 | 13200 | 1500 | 19500 | 4000 | 15500 | | | 2 | 2 | 1140 | 6660 |
| | 1250 | 16750 | | | | | | | | | | |
| | 750 | 9000 | | | | | | | | | | |
| | 750 | 13750 | | | | | | | | | | |

*Mucor*

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.P26 | 200 | 4600 | 800 | 5200 | | | | | | | |
| | 300 | 6500 | 800 | 6500 | | | | | | | |
| | 700 | 8800 | 400 | 2700 | | | | | | | |
| | 300 | 5800 | | | | | | | | | |
| | 700 | 8700 | | | | | | | | | |
| | 900 | 9100 | | | | | | | | | |
| | 1200 | 8300 | | | | | | | | | |

*Fusarium* isolates

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | 780 4560 |
| 1.P22 | 300 | 800 | 3500 | 23000 | | | | | 4 | 4 | 480 2340 |
| | 700 | 4100 | 2500 | 17000 | | | | | 8 | 20 | 600 2280 |
| | 300 | 1500 | 5000 | 24000 | | | | | 16 | 32 | 1200 3420 |
| | 500 | 2200 | 900 | 5250 | | | | | 72 | 168 | |
| | 150 | 870 | 750 | 4350 | | | | | | | |
| | 330 | 960 | 750 | 5550 | | | | | | | |
| | 180 | 1170 | 1250 | 8000 | | | | | | | |
| | 30 | 360 | 5000 | 15250 | | | | | | | |
| | | | 3000 | 22000 | | | | | | | |
| | | | 4750 | 18500 | | | | | | | |
| 2.P23 | 250 | 2750 | 3875 | 16500 | | | 16 | 31 | 0 | 0 | |
| | 250 | 11500 | 2750 | 13750 | | | 8 | 41 | 0 | 0 | |
| | 260 | 3500 | 2500 | 14500 | | | 4 | 42 | 1 | 2 | |
| | 1250 | 9000 | 4000 | 19000 | | | 12 | 59 | 0 | 0 | |
| | | | 250 | 17250 | | | | | | | |
| | | | 2000 | 12750 | | | | | | | |
| | | | 500 | 12750 | | | | | | | |
| | | | 250 | 8500 | | | | | | | |
| | | | 750 | 10500 | | | | | | | |
| | | | 1500 | 12000 | | | | | | | |
| | | | 1250 | 7500 | | | | | | | |
| | | | 100 | 11000 | | | | | | | |
| 3.P24 | 500 | 3000 | 8000 | 42000 | 4000 | 11000 | 930 | 5730 | 45 | 435 | |
| | 500 | 3900 | 2500 | 31500 | 4500 | 8000 | 180 | 1440 | 15 | 420 | |
| | 600 | 2300 | 5000 | 34000 | 3000 | 12000 | 480 | 2700 | 45 | 450 | |
| | 1500 | 11100 | 8000 | 41500 | 2500 | 7000 | 540 | 1920 | 90 | 585 | |
| | 750 | 5000 | 2000 | 13750 | | | | | | | |
| | 200 | 1200 | 1000 | 10000 | | | | | | | |
| | 500 | 7500 | 2500 | 12500 | | | | | | | |
| | 1250 | 9500 | 2250 | 9250 | | | | | | | |

| | A | | B | | C | | D | | E | | F | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 4.P25 | 1200 | 4200 | 1200 | 7500 | | | 270 | 1460 | 110 | 1100 | 150 | 1065 |
| | 800 | 5700 | 520 | 4940 | | | 360 | 3870 | 140 | 1570 | 210 | 1725 |
| | 1000 | 7300 | 1625 | 11250 | | | 330 | 1500 | 90 | 540 | 285 | 3060 |
| | 800 | 3900 | 1250 | 5750 | | | 100 | 780 | 90 | 540 | 180 | 1980 |
| | 800 | 9400 | 3500 | 15750 | | | | | | | | |
| | 1400 | 8800 | 3750 | 21000 | | | | | | | | |
| | 600 | 4400 | 2500 | 32250 | | | | | | | | |
| | 600 | 4800 | 3250 | 29750 | | | | | | | | |
| **Sterile cultures** | | | | | | | | | | | | |
| 1.P10 | 1200 | 9000 | 750 | 4350 | | | | | 0 | 0 | 8500 | 49000 |
| | 1200 | 11600 | 300 | 1050 | | | | | 4 | 4 | 700 | 43500 |
| | 600 | 4400 | 1350 | 2250 | | | | | 4 | 4 | 5500 | 51000 |
| | 600 | 8600 | | | | | | | 4 | 4 | 5500 | 37000 |
| 2.P17 | 300 | 1110 | 600 | 7800 | 1050 | 6600 | 2 | 4 | 2 | 2 | | |
| | 180 | 990 | 200 | 900 | 450 | 1950 | 2 | 3 | 1 | 1 | | |
| | 150 | 1620 | 300 | 2400 | 1950 | 8700 | | | 2 | 2 | | |
| | 240 | 720 | 200 | 600 | | | | | | | | |
| | | | 960 | 3840 | | | | | | | | |
| | | | 900 | 8100 | | | | | | | | |
| | | | .600 | 4620 | | | | | | | | |
| | | | 280 | 3850 | | | | | | | | |
| 3.P18 | 800 | 3900 | 700 | 4900 | 3250 | 9000 | 416 | 1920 | 150 | 948 | | |
| | 300 | 4200 | 1600 | 6300 | 2750 | 11500 | 420 | 2340 | 96 | 368 | | |
| | 400 | 3600 | 400 | 7600 | 2500 | 8500 | 360 | 1650 | | | | |
| | 500 | 4600 | 1000 | 8700 | | | 30 | 270 | | | | |
| | 420 | 720 | 900 | 8200 | | | | | | | | |
| | 660 | 3660 | 1400 | 9000 | | | | | | | | |
| | 300 | 5100 | 1000 | 5200 | | | | | | | | |
| | 1000 | 7750 | 900 | 7800 | | | | | | | | |
| | 50 | 5750 | | | | | | | | | | |
| | 700 | 3300 | | | | | | | | | | |
| 4.P27 | 700 | 9500 | 4250 | 20250 | | | | | 72 | 368 | 20 | 740 |
| | 600 | 8000 | 8250 | 41000 | | | | | 104 | 560 | 60 | 680 |
| | 700 | 7200 | 6750 | 17500 | | | | | 80 | 240 | 80 | 720 |
| | 1800 | 8300 | 1750 | 9750 | | | | | 104 | 592 | 60 | 380 |

**Paecilomyces isolates**

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 1.P1 | 150 | 2850 | 3250 | 14250 | 1260 | 3540 | 300 | 2070 | 20 | 210 |
| | 600 | 2400 | 250 | 8000 | 270 | 660 | 300 | 1770 | 120 | 750 |
| | 450 | 4050 | 1500 | 10500 | 120 | 600 | 240 | 1830 | 40 | 80 |
| | 900 | 6300 | 2000 | 17750 | | | 660 | 7320 | 40 | 100 |
| 2.P44 | 375 | 5500 | 1400 | 7900 | | | | | | |
| | 375 | 3000 | 4100 | 20000 | | | | | | |
| | 400 | 1900 | 2100 | 14900 | | | | | | |
| | 1000 | 2833 | 1400 | 14100 | | | | | | |
| | 510 | 2370 | 1250 | 14250 | | | | | | |
| | 600 | 2610 | 3000 | 13000 | | | | | | |
| | 420 | 2100 | 1250 | 14500 | | | | | | |
| | 390 | 1410 | 2500 | 19000 | | | | | | |

**Verticillium isolates**

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 1.P11 | 3 | 15 | 220 | 860 | | | 3 | 3 | | |
| | 5 | 15 | 130 | 290 | | | 0 | 0 | | |
| | 2 | 15 | 60 | 220 | | | 4 | 4 | | |
| | 10 | 50 | 40 | 80 | | | 2 | 2 | | |
| | 70 | 140 | | | | | | | | |
| | 30 | 80 | | | | | | | | |
| 2.P12 | 1000 | 11750 | 1500 | 9250 | 420 | 2070 | 2 | 2 | 4000 | 7750 |
| | 1500 | 12250 | 2500 | 14250 | 810 | 3510 | 2 | 2 | 550 | 1700 |
| | 500 | 6500 | 500 | 4750 | 300 | 1950 | 4 | 4 | 1500 | 3700 |
| | 750 | 4000 | 2000 | 9000 | 330 | 1950 | 0 | 0 | 1600 | 4000 |
| | | | 4750 | 17250 | | | | | | |
| | | | 3750 | 18500 | | | | | | |
| | | | 4500 | 20250 | | | | | | |

**Pestalotia**

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 1.P8 | 600 | 4650 | 625 | 10500 | 3750 | 18750 | 420 | 1050 | 34 | 41 |
| | 750 | 6900 | 2750 | 8500 | 4950 | 22950 | 60 | 450 | 7 | 13 |
| | 300 | 2400 | 1875 | 12875 | 2250 | 10800 | 510 | 1230 | 17 | 20 |
| | 900 | 12900 | 4000 | 23750 | 3000 | 9900 | 450 | 780 | 23 | 36 |
| | 960 | 11820 | 5000 | 33750 | | | | | | |
| | 900 | 10800 | 5000 | 30500 | | | | | | |
| | 600 | 6300 | 5000 | 46500 | | | | | | |
| | 1000 | 7800 | 10500 | 46500 | | | | | | |
| | | | 7500 | 39500 | | | | | | |

Botrytis
1.P14

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Botrytis** 1.P14 | 1000 | 9750 | 13500 | 63000 | | | | | | | 1 | 11 |
| | 750 | 6250 | 12000 | 63000 | | | | | | | 9 | 13 |
| | 125 | 9250 | 9000 | 37500 | | | | | | | 6 | 6 |
| | 4500 | 44000 | 7000 | 45000 | | | | | | | 10 | 22 |
| | 5500 | 33500 | 500 | 13750 | | | | | | | | |
| | | | 2250 | 21500 | | | | | | | | |
| | | | 3250 | 23250 | | | | | | | | |
| | | | 2000 | 18750 | | | | | | | | |
| | | | 13000 | 63500 | | | | | | | | |
| | | | 3000 | 47000 | | | | | | | | |
| **Chaetomium** 1.P19B | 400 | 5000 | 900 | 5000 | | | | | | | | |
| | 200 | 3600 | 200 | 11100 | | | | | | | | |
| | 1000 | 8900 | 200 | 900 | | | | | | | | |
| | 800 | 8200 | | | | | | | | | | |
| **Unidentified hyphomycete** 1.P16 | 300 | 3100 | 720 | 6000 | 1200 | 12450 | | | 8 | 8 | | |
| | 200 | 600 | 1000 | 20200 | 2550 | 24300 | | | 4 | 4 | | |
| | 300 | 5800 | 500 | 11750 | 1200 | 13050 | | | 408 | 408 | | |
| | 300 | 1200 | 750 | 8500 | 1350 | 12900 | | | | | | |
| | 400 | 4800 | | | | | | | | | | |
| | 180 | 3840 | | | | | | | | | | |
| | 150 | 5925 | | | | | | | | | | |
| | 1350 | 8700 | | | | | | | | | | |

(C)  Populations of nematodes (pre-treated with chlorhexidine gluconate) on fungi from pine-forest soil

| | P | | W | | S | | L | | C | | R | | B | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | a | b | a | b | a | b | a | b | a | b | a | b | a | b |
| **Penicillium isolates** | | | | | | | | | | | | | | |
| 1. P6 | 1000 | 14000 | 220 | 760 | | | 0 | 0 | | | | | | |
| | 1000 | 6000 | 60 | 380 | | | 0 | 0 | | | | | | |
| | 3200 | 15200 | 270 | 1600 | | | 0 | 0 | | | | | | |
| | 2600 | 15600 | 420 | 4320 | | | 0 | 0 | | | | | | |
| 2. P9 | 261 | 1674 | 420 | 2870 | | | 177 | 369 | | | | | | |
| | 189 | 2376 | 980 | 4900 | | | 3100 | 10000 | | | | | | |
| | 558 | 3231 | 175 | 1435 | | | 4100 | 9500 | | | | | | |
| | 873 | 6975 | 350 | 6400 | | | 2700 | 8900 | | | | | | |
| 3. P29 | 78 | 288 | 55 | 210 | | | | | | | | | | |
| | 30 | 159 | 49 | 120 | | | | | | | | | | |
| | 108 | 498 | 51 | 155 | | | | | | | | | | |
| | | | 26 | 69 | | | | | | | | | | |
| | | | 50 | 95 | | | | | | | | | | |
| 4. P30 | 1100 | 15200 | | | | | 1 | 5 | | | | | | |
| | 700 | 15300 | | | | | 1 | 12 | | | | | | |
| | 1300 | 17300 | | | | | 22 | 49 | | | | | | |
| | 1500 | 12800 | | | | | 8 | 89 | | | | | | |
| 5. P31 | | | 34 | 79 | | | | | | | | | | |
| | | | 175 | 545 | | | | | | | | | | |
| | | | 73 | 116 | | | | | | | | | | |
| | | | 46 | 140 | | | | | | | | | | |
| | | | 342 | 903 | | | | | | | | | | |
| | | | 630 | 2355 | | | | | | | | | | |
| | | | 150 | 590 | | | | | | | | | | |
| 6. P33 | 1500 | 9200 | 420 | 1980 | | | | | | | | | | |
| | 2500 | 8800 | 180 | 1500 | | | | | | | | | | |
| | 2600 | 19500 | 120 | 3120 | | | | | | | | | | |
| | 2500 | 27800 | 150 | 750 | | | | | | | | | | |
| | | | 196 | 672 | | | | | | | | | | |
| | | | 214 | 1572 | | | | | | | | | | |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 7. P34 | 700 | 14300 | 850 | 4250 | | | 12 | 70 | | | | |
| | 300 | 6100 | 800 | 4800 | | | 6 | 43 | | | | |
| | 400 | 9000 | 100 | 630 | | | 5 | 20 | | | | |
| | 1000 | 15000 | 140 | 790 | | | 6 | 39 | | | | |
| 8. P35 | 1800 | 14600 | 70 | 770 | | | | | | | | |
| | 400 | 5200 | 100 | 400 | | | | | | | | |
| | 1000 | 9800 | 660 | 5340 | | | | | | | | |
| | 600 | 3400 | 315 | 2660 | | | | | | | | |
| 9. P36 | 1300 | 14400 | 250 | 1780 | | | | | | | | |
| | 600 | 6000 | 120 | 900 | | | | | | | | |
| | 800 | 6800 | 290 | 1460 | | | | | | | | |
| | 2600 | 22800 | 250 | 2460 | | | | | | | | |
| 10. P37 | 300 | 1836 | 37 | 100 | | | | | | | | |
| | 168 | 804 | 68 | 151 | | | | | | | | |
| | 120 | 1440 | 84 | 285 | | | | | | | | |
| | 312 | 1272 | 7 | 47 | | | | | | | | |
| 11. P38 | 3400 | 15400 | 120 | 720 | | | 13 | 51 | | | | |
| | 1400 | 14400 | 420 | 3660 | | | 30 | 127 | | | | |
| | 4200 | 27800 | 120 | 3240 | | | 57 | 249 | | | | |
| | 3000 | 14600 | 240 | 3120 | | | 78 | 387 | | | | |
| 12. P39 | 800 | 4900 | 2400 | 13800 | | | 2760 | 14160 | | | | |
| | 4400 | 21000 | 1200 | 6000 | | | 2640 | 8160 | | | | |
| | 5600 | 27600 | 100 | 4800 | | | 800 | 9200 | | | | |
| | 3200 | 24600 | 1900 | 7300 | | | 3840 | 19680 | | | | |
| 13. P40 | 480 | 2520 | 1600 | 3650 | | | | | 20 | 88 | 60 | 270 |
| | 135 | 765 | 4800 | 18600 | | | | | 360 | 1950 | 420 | 2580 |
| | 270 | 1320 | 5400 | 24000 | | | | | 105 | 1095 | | |
| | | | 2100 | 7200 | | | | | 180 | 1410 | | |
| 14. P41C | | | 5 | 18 | | | | | | | | |
| | | | 8 | 26 | | | | | | | | |
| | | | 22 | 59 | | | | | | | | |
| | | | 30 | 56 | | | | | | | | |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 15. P42 | | | 7000 | 28000 | | | | | | | | | | |
| | | | 3250 | 11750 | | | | | | | | | | |
| | | | 3250 | 20000 | | | | | | | | | | |
| | | | 3000 | 15500 | | | | | | | | | | |
| 16. P43 | 60 | 60 | 210 | 630 | | | | | 192 | 1344 | 270 | 1450 | 156 | 804 |
| | 360 | 2160 | 600 | 6950 | | | | | 84 | 1116 | 40 | 790 | 288 | 684 |
| | 240 | 1200 | 500 | 2250 | | | | | 168 | 1428 | 90 | 1030 | | |
| | 480 | 2880 | 330 | 3780 | | | | | | | 120 | 1060 | | |
| 17. P45 | 210 | 2640 | 690 | 4740 | | | | | | | | | | |
| | 270 | 4215 | 600 | 5820 | | | | | | | | | | |
| | | | 600 | 3870 | | | | | | | | | | |
| | | | 780 | 5670 | | | | | | | | | | |
| 18. P48B | 350 | 3200 | | | | | 17 | 98 | | | | | | |
| | 250 | 3150 | | | | | 19 | 104 | | | | | | |
| | 440 | 4120 | | | | | 6 | 30 | | | | | | |
| | 440 | 6560 | | | | | 130 | 960 | | | | | | |
| | 8 | 28 | | | | | | | | | | | | |
| | 70 | 430 | | | | | | | | | | | | |
| | 385 | 3273 | | | | | | | | | | | | |
| | 210 | 2888 | | | | | | | | | | | | |
| 19. P49 | 285 | 1200 | 135 | 1155 | | | | | 200 | 2220 | 120 | 440 | | |
| | 105 | 930 | 330 | 2115 | | | | | 204 | 1596 | 400 | 3960 | | |
| | 285 | 1095 | 90 | 660 | | | | | 336 | 1752 | 160 | 1360 | | |
| | 345 | 2925 | 300 | 3540 | | | | | 300 | 1812 | 200 | 1880 | | |
| 20. P50 | 390 | 2760 | 450 | 6500 | 225 | 3525 | | | 116 | 1000 | 30 | 390 | | |
| | 570 | 5730 | 420 | 3240 | 600 | 5520 | | | 150 | 1128 | 60 | 450 | | |
| | 420 | 5340 | 300 | 2430 | 560 | 6960 | | | 78 | 1056 | 750 | 4890 | | |
| | 420 | 2040 | 870 | 6090 | 1200 | 6300 | | | 156 | 1410 | 240 | 2850 | | |
| 21. P51 | | | 870 | 3900 | | | | | | | | | 0 | 13 |
| | | | 625 | 10000 | | | | | | | | | 260 | 624 |
| | | | 1000 | 8500 | | | | | | | | | 26 | 91 |
| | | | 1250 | 9500 | | | | | | | | | 65 | 221 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 22. P52 | 3000 | 18750 | 2600 | 28600 | | | | | | | | |
| | 750 | 5250 | 3800 | 27400 | | | | | | | | |
| | 500 | 2500 | 3200 | 32800 | | | | | | | | |
| | 2000 | 11500 | 2200 | 35200 | | | | | | | | |
| 23. P53 | 750 | 5850 | 4000 | 45000 | 125 | 500 | 287 | 1694 | 100 | 240 | | |
| | 900 | 8700 | 5500 | 27000 | 2000 | 9250 | 270 | 615 | 306 | 1278 | | |
| | | | 13500 | 52000 | 1000 | 7250 | 90 | 920 | 612 | 2184 | | |
| | | | 4500 | 34500 | 1750 | 13625 | 75 | 915 | 480 | 3420 | | |
| 24. P54 | 4000 | 17250 | 7000 | 29500 | | | | | | | | |
| | 4000 | 12250 | 3000 | 22750 | | | | | | | | |
| | 6250 | 19750 | 11000 | 65000 | | | | | | | | |
| | 5250 | 18500 | 5750 | 25750 | | | | | | | | |
| 25. P55 | 270 | 2700 | 120 | 1380 | 352 | 1952 | 117 | 465 | 70 | 212 | | |
| | 330 | 1560 | 360 | 5040 | 288 | 1952 | 80 | 1020 | 114 | 435 | | |
| | 360 | 1260 | 240 | 1980 | 102 | 714 | 34 | 205 | 57 | 198 | | |
| | 450 | 1230 | 240 | 1800 | 576 | 3744 | 30 | 171 | 54 | 141 | | |
| 26. P56 | 1400 | 14800 | 2700 | 15600 | 900 | 5800 | 10 | 26 | 2 | 7 | | |
| | 400 | 7800 | 5500 | 36250 | 600 | 5900 | 63 | 137 | 3 | 9 | | |
| | | | 750 | 13750 | | | 72 | 252 | 4 | 13 | | |
| | | | 2500 | 19125 | | | 26 | 71 | 2 | 2 | | |
| 27. P58 | 3750 | 15750 | 10250 | 41250 | | | | | | | | |
| | 2800 | 10300 | 9500 | 40750 | | | | | | | | |
| | 6000 | 17000 | 10750 | 50000 | | | | | | | | |
| | 2333 | 9000 | 9000 | 38000 | | | | | | | | |
| 28. P59 | | | 1000 | 2000 | | | | | | | 3360 | 16720 |
| | | | 8250 | 29250 | | | | | | | | |
| | | | 6000 | 18500 | | | | | | | | |
| | | | 9250 | 27250 | | | | | | | | |
| 29. P61 | 130 | 590 | 200 | 2300 | | | 255 | 3060 | 82 | 150 | | |
| | 140 | 615 | 500 | 6300 | | | 400 | 2000 | 26 | 44 | | |
| | 330 | 1800 | 350 | 2000 | | | 60 | 270 | 36 | 84 | | |
| | | | 100 | 650 | | | 120 | 720 | 84 | 182 | | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 30. P64I | 108 | 909 | | | | | | |
| | 90 | 225 | | | | | | |
| | 45 | 135 | | | | | | |
| | 9 | 153 | | | | | | |
| 31. P65 | | | 2000 | 17800 | | | | |
| | | | 600 | 8400 | | | | |
| | | | 1400 | 8200 | | | | |
| | | | 800 | 9600 | | | | |
| 32. P75B | 7 | 14 | | | | | | |
| | 90 | 210 | | | | | | |
| | 52 | 114 | | | | | | |
| | 1400 | 12900 | | | | | | |
| | 1500 | 13250 | | | | | | |
| 33. P85C | 33 | 88 | | | | | | |
| | 253 | 1309 | | | | | | |
| | 44 | 286 | | | | | | |
| | 5000 | 17000 | | | | | | |
| | 3000 | 26000 | | | | | | |
| 34. P86B | 32 | 64 | | | | 0 | 0 | |
| | 7 | 14 | | | | 0 | 0 | |
| | 23 | 94 | | | | 0 | 0 | |
| | 18 | 45 | | | | 0 | 0 | |
| | | | | | | 0 | 0 | |
| 35. P89I | 240 | 1120 | | | | | | |
| | 196 | 1120 | | | | | | |
| | 8000 | 26000 | | | | | | |
| | 750 | 6000 | | | | | | |
| | 36 | 64 | | | | | | |
| 36. P92C | 187 | 1738 | | | | | | |
| | 2200 | 21600 | | | | | | |
| | 1000 | 17000 | | | | | | |
| | 21 | 32 | | | | | | |
| | 6 | 9 | | | | | | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 37. P93I | 99 | 242 | | | | | | |
| | 209 | 1375 | | | | | | |
| | 660 | 2736 | | | | | | |
| | 77 | 1111 | | | | | | |
| | 800 | 7800 | | | | | | |
| | 1600 | 6400 | | | | | | |
| 38. P94B | 900 | 6900 | | | 7 | 14 | | |
| | 3200 | 18240 | | | 0 | 0 | | |
| | 2800 | 16800 | | | 2 | 5 | | |
| | 1920 | 11040 | | | 8 | 37 | | |
| | 20 | 120 | | | 20 | 42 | | |
| | 150 | 650 | | | 0 | 0 | | |
| | 500 | 7100 | | | | | | |
| | 500 | 5250 | | | | | | |
| 39. P95C | 0 | 2 | | | | | | |
| | 0 | 5 | | | | | | |
| | 70 | 1106 | | | | | | |
| | 1050 | 3885 | | | | | | |
| | 2905 | 11795 | | | | | | |
| 40. P98C | 90 | 420 | | | | | | |
| | 240 | 2080 | | | | | | |
| | 154 | 836 | | | | | | |
| | 5500 | 27500 | | | | | | |
| | 2250 | 9750 | | | | | | |
| 41. P103I | 0 | 0 | 0 | 1 | | | | |
| | 1 | 1 | 1 | 1 | | | | |
| | 1 | 2 | 0 | 0 | | | | |
| | 0 | 0 | 1 | 2 | | | | |
| 42. P105B | 68 | 380 | | | 0 | 0 | | |
| | 80 | 292 | | | 0 | 0 | | |
| | 41 | 236 | | | 0 | 0 | | |
| | 34 | 100 | | | 0 | 0 | | |
| | 42 | 68 | | | 0 | 0 | | |
| | 9 | 15 | | | 0 | 0 | | |
| | 216 | 684 | | | | | | |
| | 243 | 666 | | | | | | |

| | | | | |
|---|---|---|---|---|
| 43. P121B | 1 | 4 | | |
| | 1 | 3 | | |
| | 24 | 59 | | |
| | 22 | 59 | | |
| | 279 | 2925 | | |
| | 81 | 1341 | | |
| *Basidiomycetes* | | | | |
| 1. H | 43 | 172 | | |
| | 33 | 100 | | |
| | 51 | 361 | | |
| | 72 | 399 | | |
| 2. L | 19 | 40 | 0 | 0 |
| | 94 | 655 | 1 | 1 |
| | 32 | 139 | 0 | 0 |
| | 264 | 1464 | 0 | 0 |
| 3. C | 144 | 924 | 0 | 0 |
| | 108 | 828 | 0 | 0 |
| | 114 | 744 | 0 | 0 |
| | 54 | 612 | 0 | 0 |
| 4. A | 103 | 441 | 0 | 0 |
| | 50 | 302 | 0 | 0 |
| | 52 | 316 | 0 | 0 |
| | 52 | 316 | 0 | 0 |
| | | | 0 | 0 |
| | | | 0 | 3 |
| 5. *Suillus luteus* | 22 | 8932 | 1600 | 11500 |
| | 330 | 9130 | 1700 | 16800 |
| | 88 | 8404 | 1500 | 12000 |
| | 440 | 15730 | 1300 | 12000 |

*Pythium* isolates
1. *P.irregulare*

| | | | | | |
|---|---|---|---|---|---|
| | | | | 1 | 1 |
| | | | | 0 | 0 |
| | | | | 0 | 0 |
| | | | | 0 | 0 |
| | | | | 0 | 0 |
| | | | | 0 | 0 |
| | | | | 0 | 0 |
| | | | | 0 | 0 |

*Trichoderma* isolates

| | | | | | | |
|---|---|---|---|---|---|---|
| 1. P5C | 400 | 12500 | | | 1 | 1 |
| | 1200 | 10600 | | | 0 | 0 |
| | 6400 | 23000 | | | 1 | 1 |
| | 4400 | 22200 | | | 0 | 0 |
| 2. P21 | 1480 | 7120 | | | 420 | 1078 |
| | 880 | 9160 | | | 840 | 4170 |
| | 880 | 7760 | | | 91 | 1197 |
| | 1080 | 6040 | | | 252 | 2282 |

*Aspergillus* isolates

| | | | | | | |
|---|---|---|---|---|---|---|
| 1. P3 | 1 | 2 | 0 | 0 | 0 | 0 |
| | 0 | 0 | 0 | 0 | 0 | 0 |
| | 0 | 0 | 0 | 1 | 0 | 1 |
| | 1 | 1 | 0 | 0 | 1 | 1 |
| 2. P32 | 280 | 8610 | 5 | 50 | | |
| | 630 | 7280 | 160 | 2570 | | |
| | 140 | 5950 | 110 | 1500 | | |
| | | | 110 | 4170 | | |
| | | | 72 | 1188 | | |

*Fusarium* isolates

| | | |
|---|---|---|
| 1. P22 | 420 | 1050 |
| | 2400 | 6600 |
| | 1190 | 5110 |
| | 665 | 1855 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 2. P23 | 800 | 2650 | | | | | |
| | 1650 | 8700 | | | | | |
| | 200 | 3500 | | | | | |
| | 600 | 3200 | | | | | |
| 3. P24 | | | 4800 | 16800 | | | |
| | | | 1000 | 4200 | | | |
| | | | 4400 | 12200 | | | |
| | | | 3800 | 9900 | | | |
| 4. P25 | 4200 | 15800 | 500 | 2675 | | | |
| | 3800 | 19000 | 1300 | 9300 | | | |
| | 5800 | 28400 | 375 | 1350 | | | |
| | 8000 | 24600 | 75 | 825 | | | |
| **Sterile cultures** | | | | | | | |
| 1. P10 | 3 | 15 | 64 | 216 | | 1215 | 3945 |
| | 72 | 456 | 64 | 72 | | 330 | 1230 |
| | 231 | 1488 | 12 | 52 | | 2010 | 7530 |
| | | | 136 | 896 | | 1290 | 4260 |
| 2. P17 | 300 | 2375 | | | | 0 | 2 |
| | 75 | 1750 | | | | 1 | 1 |
| | 75 | 475 | | | | 3 | 3 |
| | 25 | 475 | | | | 7 | 21 |
| 3. P27 | 540 | 5790 | 800 | 8400 | | | |
| | 1740 | 11190 | 1200 | 14200 | | | |
| | 1680 | 13600 | 1000 | 7800 | | | |
| | 1440 | 8480 | 1600 | 8500 | | | |
| *Verticillium* | | | | | | | |
| 1. P7 | 40 | 120 | 3 | 19 | | 0 | 0 |
| | 24 | 184 | 4 | 11 | | 0 | 0 |
| | 8 | 24 | 3 | 7 | | 1 | 1 |
| | 56 | 64 | 2 | 3 | | 0 | 0 |
| | 270 | 714 | | | | | |
| | 168 | 392 | | | | | |
| 2. P11 | 210 | 805 | 3 | 3 | | 12 | 36 |
| | 875 | 2590 | 0 | 1 | | 24 | 72 |
| | 2400 | 6400 | 5 | 5 | | 4 | 20 |
| | | | 1 | 1 | | 4 | 16 |

| | | | | | | | |
|---|--:|--:|--:|--:|--:|--:|--:|
| 3. P12 | 2250 | 16250 | 108 | 620 | | 0 | 0 |
| | 13500 | 48500 | 1700 | 9500 | | 0 | 0 |
| | 6000 | 28000 | 600 | 4900 | | 4 | 4 |
| | 6500 | 32500 | | | | 0 | 0 |
| | 850 | 7600 | | | | 54 | 102 |
| | 2000 | 25200 | | | | 40 | 104 |
| | 2600 | 13000 | | | | 82 | 223 |
| | 1600 | 12400 | | | | 35 | 75 |

*Paecilomyces* isolates

| | | | | | | | |
|---|--:|--:|--:|--:|--:|--:|--:|
| 1. P1 | 91 | 1036 | 240 | 1275 | | 3 | 3 |
| | 99 | 948 | 204 | 1751 | | 2 | 2 |
| | 119 | 837 | 195 | 840 | | 0 | 0 |
| | | | 150 | 675 | | 1 | 1 |

*Sporotrichum(?)* isolates

| | | | | | | | |
|---|--:|--:|--:|--:|--:|--:|--:|
| 1. P4 | 5 | 30 | 33 | 53 | | 1080 | 2190 |
| | 35 | 120 | 120 | 320 | | 540 | 2220 |
| | 210 | 660 | 90 | 370 | | 1680 | 3540 |
| | 35 | 155 | | | | 450 | 960 |

*Pestalotia* isolates

| | | | | | | | |
|---|--:|--:|--:|--:|--:|--:|--:|
| 1. P8 | 5 | 10 | 300 | 700 | | 320 | 1824 |
| | 4 | 8 | 20 | 200 | | 528 | 1680 |
| | 36 | 121 | 1100 | 7000 | | 102 | 646 |
| | 64 | 76 | 50 | 5150 | | | |
| | 160 | 2080 | | | | | |
| | 480 | 4640 | | | | | |
| | 3750 | 36000 | | | | | |
| | 3000 | 17500 | | | | | |

*Botrytis* isolates

| | | | | | | | |
|---|--:|--:|--:|--:|--:|--:|--:|
| 1. P14 | 600 | 5800 | | | | 0 | 1 |
| | 600 | 11200 | | | | 84 | 168 |
| | 1800 | 18900 | | | | 54 | 113 |
| | 500 | 6200 | | | | 29 | 161 |

*Chaetomium* isolates

| | | | | | | | |
|---|--:|--:|--:|--:|--:|--:|--:|
| 1. P19B | 150 | 300 | | | | 750 | 13350 |
| | 300 | 2650 | | | | 600 | 12900 |
| | 400 | 5550 | | | | 900 | 11700 |
| | 450 | 3150 | | | | 1050 | 13200 |

*Mucor* isolates

| 1. P26 | 143 | 2365 | 49 | 308 | | |
|--------|-----|------|-----|------|---|---|
| | 187 | 2783 | 238 | 896 | | |
| | 165 | 1441 | 270 | 1365 | | |
| | 77 | 1761 | 315 | 2025 | | |

Unknown hyphomycete

| 1. P16 | 100 | 630 | | | 2 | 6 |
|--------|-----|------|---|---|---|----|
| | 690 | 3610 | | | 9 | 22 |
| | 630 | 1490 | | | 4 | 5 |
| | 990 | 4590 | | | 4 | 12 |

(D)  Populations of nematodes (pre-treated with chlorhexidine gluconate) on fungi from wheat-field soil

| Fungi | P | | W | | S | | L | | C | | R | | B | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | a | b | a | b | a | b | a | b | a | b | a | b | a | b |
| *Rhizoctonia solani* sensu lato | | | 20 | 85 | | | 91 | 144 | | | | | | |
| | | | 3 | 15 | | | 152 | 604 | | | | | | |
| | | | 2 | 2 | | | | | | | | | | |
| | | | 5 | 32 | | | | | | | | | | |
| *Alternaria alternata* | | | 15 | 28 | | | 265 | 655 | | | | | | |
| | | | 7 | 22 | | | 480 | 1224 | | | | | | |
| | | | 11 | 35 | | | 510 | 2010 | | | | | | |
| | | | 2 | 8 | | | | | | | | | | |
| *Pythium* isolates | | | | | | | | | | | | | | |
| 1. *P.acanthicum* | | | 5 | 19 | | | 2 | 2 | | | | | | |
| | | | 3 | 5 | | | 3 | 3 | | | | | | |
| | | | 2 | 4 | | | 4 | 4 | | | | | | |
| | | | 4 | 10 | | | 4 | 4 | | | | | | |
| 2. *P.afertile* sp. gr. | | | 7 | 28 | | | | | | | | | | |
| | | | 2 | 3 | | | | | | | | | | |
| | | | 2 | 2 | | | | | | | | | | |
| | | | 5 | 8 | | | | | | | | | | |
| 3. *P.irregulare* | | | 2 | 2 | | | | | | | | | | |
| | | | 1 | 6 | | | | | | | | | | |
| | | | 3 | 7 | | | | | | | | | | |
| | | | 3 | 5 | | | | | | | | | | |
| 4. *P.afertile* sp. gr. | | | 26 | 198 | | | | | | | | | | |
| | | | 23 | 52 | | | | | | | | | | |
| | | | 39 | 153 | | | | | | | | | | |
| 5. *P.monospermum* | | | 1 | 1 | | | | | | | | | | |
| | | | 0 | 24 | | | | | | | | | | |
| | | | 1 | 11 | | | | | | | | | | |
| | | | 0 | 1 | | | | | | | | | | |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6. *P.paroecandrum* | | | 7 | 37 | | | | | | | | |
| | | 4 | 26 | | | | | | | | | |
| | | 0 | 3 | | | | | | | | | |
| | | 3 | 5 | | | | | | | | | |
| *Aspergillus* isolates | | | | | | | | | | | | |
| 1. W3C | 140 | 976 | 65 | 175 | | | | | | | | |
| | 24 | 92 | 20 | 107 | | | | | | | | |
| | 120 | 688 | 63 | 307 | | | | | | | | |
| | 128 | 768 | 36 | 187 | | | | | | | | |
| 2. W6 | 0 | 0 | 0 | 0 | | | | | | | | |
| *A.niger* sp. gr. | 0 | 0 | 0 | 0 | | | | | | | | |
| | 0 | 0 | 1 | 1 | | | | | | | | |
| | 0 | 0 | 0 | 0 | | | | | | | | |
| 3. W8 | 220 | 1740 | 195 | 1620 | | | | | | | | |
| | 440 | 3140 | 165 | 2160 | | | | | | | | |
| | 80 | 1320 | 30 | 1080 | | | | | | | | |
| | 140 | 640 | 170 | 1020 | | | | | | | | |
| 4. W15 | 245 | 1155 | 174 | 576 | | | | | | | | |
| *A. terreus* | 280 | 4340 | 60 | 990 | | | | | | | | |
| | 280 | 5110 | 90 | 498 | | | | | | | | |
| | 210 | 2170 | 78 | 198 | | | | | | | | |
| 5. W36 | | | 165 | 435 | 13 | 58 | 210 | 450 | 20 | 72 | 33 | 63 |
| | | | 90 | 529 | 35 | 80 | 64 | 204 | 28 | 73 | 57 | 183 |
| | | | 180 | 608 | | | 60 | 192 | 13 | 71 | 108 | 312 |
| | | | 120 | 293 | | | 72 | 546 | 15 | 33 | 39 | 87 |
| | | | | | | | | | 124 | 440 | | |
| | | | | | | | | | 44 | 284 | | |
| | | | | | | | | | 116 | 424 | | |
| 6. W37 | | | 300 | 2280 | 110 | 495 | 60 | 568 | 585 | 3495 | 120 | 332 |
| | | | 180 | 510 | 160 | 415 | 56 | 260 | 156 | 668 | 120 | 732 |
| | | | 450 | 1170 | 160 | 505 | 96 | 532 | 90 | 600 | 44 | 260 |
| | | | 210 | 930 | | | 68 | 380 | 195 | 285 | 36 | 212 |
| | | | 1375 | 11875 | | | | | | | | |
| | | | 1000 | 15625 | | | | | | | | |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 7. W38F | | | 264 | 636 | | | 260 | 1340 | 24 | 73 | 136 | 944 | 14 | 52 |
| | | | 192 | 2136 | | | 65 | 315 | 45 | 93 | 180 | 830 | 208 | 684 |
| | | | 440 | 2160 | | | 270 | 635 | 35 | 82 | 60 | 250 | 46 | 121 |
| | | | 264 | 3420 | | | 50 | 540 | 49 | 182 | 60 | 660 | | |
| | | | 1125 | 7875 | | | | | | | | | | |
| 8. W39 | | | 240 | 1344 | | | 15 | 196 | | | 5 | 33 | 108 | 276 |
| | | | 216 | 2016 | | | | | | | 12 | 76 | 128 | 520 |
| | | | 336 | 3984 | | | | | | | 3 | 12 | 88 | 328 |
| | | | 240 | 1632 | | | | | | | 4 | 17 | 8 | 16 |
| 9. W40 | | | 72 | 96 | | | 12 | 30 | 58 | 212 | 7 | 28 | 104 | 180 |
| | | | 48 | 90 | | | 126 | 306 | 84 | 510 | 63 | 140 | 148 | 236 |
| | | | 312 | 1368 | | | 204 | 612 | 42 | 176 | 189 | 763 | 64 | 192 |
| | | | 300 | 3350 | | | | | 18 | 134 | 49 | 623 | 144 | 432 |
| | | | 750 | 8950 | | | | | | | | | | |
| | | | 700 | 7100 | | | | | | | | | | |
| 10. W71 | | | 48 | 84 | | | | | | | | | 0 | 0 |
| | | | 135 | 460 | | | | | | | | | 0 | 0 |
| | | | 102 | 414 | | | | | | | | | 0 | 0 |
| | | | 324 | 828 | | | | | | | | | 1 | 1 |

Sterile cultures

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. W53C | 1000 | 10250 | 3000 | 26500 | 10500 | 28500 | 2200 | 10000 | 660 | 4740 | | | 1530 | 3420 |
| | 500 | 5000 | 5500 | 22500 | 9500 | 42000 | 700 | 3000 | 175 | 4340 | | | 840 | 1560 |
| | 1250 | 4500 | 7500 | 31000 | 9000 | 24500 | 2100 | 8300 | 280 | 1960 | | | 600 | 1560 |
| | 1500 | 7500 | 6500 | 20000 | 5500 | 12000 | 100 | 2200 | 270 | 3180 | | | 576 | 3540 |
| 2. W54 | 20 | 1000 | 420 | 7320 | | | 735 | 2790 | 704 | 5536 | | | 7000 | 39500 |
| | 625 | 6500 | 704 | 4416 | | | 882 | 3096 | 416 | 2464 | | | 8500 | 47500 |
| | 250 | 3250 | 704 | 7360 | | | 510 | 3960 | 512 | 4192 | | | 7000 | 41500 |
| | 250 | 2000 | 360 | 9540 | | | | | 210 | 840 | | | | |
| 3. W59A | 60 | 120 | 3700 | 20100 | 3375 | 14500 | 350 | 520 | 450 | 3210 | | | 210 | 430 |
| | 420 | 2100 | 3000 | 14250 | 875 | 8875 | 340 | 1120 | 420 | 3600 | | | 470 | 900 |
| | 960 | 5880 | 1500 | 6500 | 3750 | 15875 | 240 | 370 | 120 | 1320 | | | 450 | 640 |
| | 180 | 660 | 4500 | 15500 | 2125 | 9250 | 1080 | 3900 | 480 | 3600 | | | 240 | 290 |
| 4. W80 | | | 1875 | 5875 | | | | | | | | | 2 | 8 |
| | | | 1450 | 5200 | | | | | | | | | 6 | 25 |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 4. W80 | | | 550 | 1850 | | | | | | | | | 26 | 125 |
| | | | 550 | 1950 | | | | | | | | | 1 | 3 |
| 5. W103D | 3400 | 30400 | 2300 | 16000 | 500 | 1000 | 93 | 300 | 84 | 448 | | | 114 | 192 |
| | 1200 | 12600 | 800 | 4700 | 16500 | 41000 | 84 | 462 | 32 | 420 | | | 162 | 258 |
| | 4400 | 31800 | 4000 | 27100 | 3000 | 11500 | 111 | 459 | 76 | 520 | | | 114 | 192 |
| | 2600 | 14800 | 1600 | 9200 | 3500 | 8000 | | | 80 | 664 | | | 96 | 162 |

### Fusarium isolates

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. W1I | 1040 | 12720 | 560 | 4720 | | | | | | | | | | |
| F. roseum sp. gr. | 960 | 8400 | 780 | 5700 | | | | | | | | | | |
| | 2560 | 18560 | 480 | 2640 | | | | | | | | | | |
| | 160 | 9120 | | | | | | | | | | | | |
| 2. W2K | 1320 | 12000 | 210 | 2135 | | | | | | | | | | |
| F. roseum sp. gr. | 2760 | 17880 | 735 | 6020 | | | | | | | | | | |
| | 1364 | 8680 | 735 | 3290 | | | | | | | | | | |
| | 2040 | 20160 | 490 | 3150 | | | | | | | | | | |
| 3. W33L | | | 18 | 48 | | | 1650 | 5250 | 1040 | 8100 | 4250 | 23250 | 630 | 4680 |
| | | | 45 | 175 | | | 3750 | 11850 | 1800 | 9240 | 3500 | 17250 | 390 | 3060 |
| | | | 51 | 312 | | | 1200 | 4650 | 1080 | 6720 | 5000 | 26000 | 480 | 3600 |
| | | | 12 | 22 | | | 1800 | 4050 | 832 | 6656 | 1750 | 8250 | 600 | 3180 |
| | | | 5000 | 25000 | | | | | | | | | | |
| | | | 6500 | 24000 | | | | | | | | | | |
| 4. W55L | 500 | 2950 | 320 | 1440 | | | 2 | 3 | 40 | 192 | | | 68 | 308 |
| | 3100 | 11600 | 1520 | 6400 | | | 0 | 1 | 36 | 158 | | | 76 | 236 |
| | 200 | 1300 | 180 | 960 | | | 2 | 4 | 16 | 50 | | | 68 | 244 |
| | | | 720 | 1880 | | | | | | | | | 36 | 80 |
| 5. W64 | 1000 | 3000 | 9000 | 31500 | 6250 | 17250 | 450 | 2190 | 135 | 1485 | 1300 | 10500 | 1200 | 5300 |
| | 900 | 4100 | 6000 | 26500 | 9750 | 22250 | 960 | 4440 | 368 | 2064 | 625 | 4875 | 900 | 4400 |
| | 600 | 3800 | 6500 | 28500 | 15000 | 33000 | 450 | 3060 | 270 | 2970 | 2500 | 12250 | 1100 | 7100 |
| | 100 | 1300 | 9500 | 30000 | 7500 | 18750 | 148 | 1360 | 135 | 2820 | 1250 | 7000 | 500 | 3600 |
| 6. W84K | | | 2400 | 12600 | | | | | | | | | 960 | 7360 |
| | | | 4400 | 17600 | | | | | | | | | 640 | 1920 |
| | | | 200 | 4000 | | | | | | | | | 320 | 2400 |
| | | | 1600 | 9800 | | | | | | | | | 320 | 1760 |
| | | | 2800 | 9800 | | | | | | | | | | |
| 7. W85I | 120 | 300 | 6400 | 21600 | | | 330 | 2760 | 189 | 567 | | | 60 | 138 |
| | 70 | 220 | 4200 | 14400 | | | 105 | 1845 | 161 | 294 | | | 294 | 768 |
| | 150 | 830 | 7200 | 39000 | | | 255 | 2145 | 203 | 721 | | | 228 | 492 |
| | | | 5400 | 16400 | | | 120 | 2925 | 140 | 377 | | | 318 | 996 |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **8. W96** | | | 2100 | 12100 | | | | | | | | | 210 | 1650 |
| | | | 2600 | 16800 | | | | | | | | | 1320 | 5640 |
| | | | 3100 | 12700 | | | | | | | | | 1860 | 5160 |
| | | | 700 | 2600 | | | | | | | | | 840 | 4200 |
| **9. W121D** | 90 | 510 | 16000 | 51000 | 3400 | 10200 | 180 | 720 | 42 | 273 | | | 104 | 224 |
| | 1140 | 2760 | 11000 | 35000 | 10800 | 29000 | | | 35 | 168 | | | 104 | 196 |
| | 1440 | 4380 | 9000 | 36000 | 14000 | 43500 | | | 6 | 102 | | | 160 | 328 |
| | 2040 | 6960 | 8000 | 27000 | 36000 | 98000 | | | 12 | 96 | | | 128 | 476 |
| _Gliocladium_ isolates | | | | | | | | | | | | | | |
| 1. W34L | | | 48 | 1740 | | | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 3 |
| _G.catenulatum_ | | | 192 | 3240 | | | 0 | 0 | 5 | 17 | 0 | 0 | 7 | 11 |
| | | | 168 | 3768 | | | 0 | 0 | 3 | 6 | 0 | 0 | 81 | 179 |
| | | | 132 | 864 | | | 0 | 0 | 35 | 61 | 0 | 0 | 1 | 3 |
| | | | 720 | 3840 | | | | | | | | | | |
| _Cladosporium_ isolates | | | | | | | | | | | | | | |
| 1. W10H | 136 | 544 | 5 | 29 | | | | | | | | | | |
| _C.cladosporioides_ | 230 | 1140 | 23 | 67 | | | | | | | | | | |
| | 100 | 920 | 26 | 38 | | | | | | | | | | |
| | 110 | 650 | 35 | 73 | | | | | | | | | | |
| _Mucorales_ isolates | | | | | | | | | | | | | | |
| 1. W11 | 240 | 12880 | 200 | 3440 | | | | | | | | | | |
| _Rhizopus_ sp. | 240 | 11840 | 240 | 7920 | | | | | | | | | | |
| | 160 | 10080 | 120 | 2920 | | | | | | | | | | |
| | 160 | 14240 | 120 | 2160 | | | | | | | | | | |
| 2. W86 | | | | | | | | | | | | | 1000 | 7000 |
| _Mucor_ sp. | | | | | | | | | | | | | 10500 | 54000 |
| | | | | | | | | | | | | | 11500 | 45000 |
| | | | | | | | | | | | | | 5500 | 44000 |
| 3. W63 | 15 | 34 | 15 | 145 | 18 | 36 | 56 | 462 | 9 | 96 | | | 40 | 220 |
| _Actinomucor_ sp. | 2 | 4 | 36 | 168 | 14 | 24 | 42 | 336 | 12 | 138 | | | 10 | 160 |
| | 12 | 23 | 28 | 300 | 8 | 31 | 84 | 413 | 6 | 111 | | | 10 | 160 |
| | 13 | 28 | 75 | 370 | 9 | 14 | 42 | 238 | 18 | 369 | | | 60 | 200 |
| 4. W88I | 304 | 1776 | 4500 | 34500 | | | 700 | 7300 | 225 | 1995 | | | 90 | 180 |
| _Gongronella_ sp. | 135 | 2325 | 1500 | 47500 | | | 900 | 11900 | 300 | 1290 | | | 420 | 1085 |
| | 60 | 510 | 3500 | 33500 | | | 300 | 2000 | 90 | 1320 | | | 210 | 1295 |
| | 240 | 2250 | 5000 | 36000 | | | 800 | 6000 | 90 | 2280 | | | 120 | 570 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 5. W21G | | | 204 | 592 | | | 1 | 1 |
| *Cunninghamella* sp. | | | 204 | 472 | | | 0 | 0 |
| | | | 192 | 676 | | | 1 | 1 |
| | | | 54 | 186 | | | 0 | 0 |
| | | | 50 | 290 | | | | |
| | | | 84 | 644 | | | | |
| | | | 40 | 160 | | | | |
| | | | 20 | 124 | | | | |
| 6. W130 | | | 120 | 4320 | | | 540 | 4320 |
| *Cunninghamella* sp. | | | 90 | 2010 | | | 120 | 2220 |
| | | | 210 | 2445 | | | 540 | 5490 |
| | | | 150 | 2790 | | | 90 | 1440 |
| **Metarrhizium isolates** | | | | | | | | |
| 1. W13E | 350 | 2765 | 57 | 156 | | | | |
| | 560 | 4095 | 55 | 171 | | | | |
| | 105 | 1295 | | | | | | |
| | 35 | 2240 | | | | | | |
| **Myrothecium isolates** | | | | | | | | |
| 1. W14 | | | 14 | 24 | 0 | 0 | 0 | 0 |
| *M.verrucaria* | | | 126 | 495 | 0 | 0 | 0 | 0 |
| | | | 58 | 117 | 0 | 0 | 1 | 1 |
| | | | 42 | 261 | 0 | 2 | | |
| | | | 153 | 882 | | | | |
| | | | 162 | 1134 | | | | |
| | | | 378 | 1854 | | | | |
| **Paecilomyces isolates** | | | | | | | | |
| 1. W16I | 735 | 5670 | 140 | 510 | | | | |
| *P. lilacinus* | 210 | 3815 | 56 | 252 | | | | |
| | 385 | 2940 | 49 | 196 | | | | |
| | 385 | 3465 | 119 | 483 | | | | |
| **Torulomyces isolates** | | | | | | | | |
| 1. W17A | 900 | 2950 | 110 | 480 | | | | |
| | 500 | 3600 | 240 | 3880 | | | | |
| | 400 | 5300 | 400 | 3320 | | | | |
| | 650 | 10100 | 200 | 2300 | | | | |
| 2. W18B | 50 | 1300 | 69 | 213 | | | | |
| | 700 | 12900 | 345 | 3570 | | | | |
| | 300 | 7200 | 330 | 1200 | | | | |
| | | | 240 | 1305 | | | | |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3. W19B | 120 | 1890 | 4 | 8 | | | | | | | | | | |
| | 400 | 4725 | 33 | 73 | | | | | | | | | | |
| | 160 | 1760 | 80 | 240 | | | | | | | | | | |
| | 340 | 2860 | | | | | | | | | | | | |
| *Phialocephala* isolates | | | | | | | | | | | | | | |
| 1. W20C | | | 30 | 72 | | | | | | | | | | |
| | | | 7 | 12 | | | | | | | | | | |
| | | | 18 | 81 | | | | | | | | | | |
| | | | 6 | 14 | | | | | | | | | | |
| *Acremonium* isolates | | | | | | | | | | | | | | |
| 1. W22A | | | 108 | 372 | | | | | | | | | | |
| | | | 207 | 279 | | | | | | | | | | |
| | | | 345 | 1725 | | | | | | | | | | |
| | | | 285 | 1260 | | | | | | | | | | |
| *Phoma* isolates | | | | | | | | | | | | | | |
| 1. W57 | 2750 | 25250 | 6000 | 24750 | 12000 | 41500 | 1860 | 6780 | 270 | 1190 | 300 | 1360 | 80 | 140 |
| | 2000 | 18500 | 5500 | 20250 | 9500 | 30000 | 1200 | 4560 | 330 | 1790 | 70 | 320 | 420 | 1701 |
| | 4250 | 28500 | 6000 | 23750 | 6000 | 18000 | 480 | 1740 | 200 | 1420 | 150 | 340 | 231 | 455 |
| | 4000 | 32500 | 2250 | 10500 | 8500 | 21500 | 660 | 4140 | 170 | 600 | 100 | 440 | 340 | 867 |
| 2. W58 | 1400 | 16600 | 1040 | 5200 | 690 | 2310 | 420 | 1022 | 8 | 45 | 6 | 11 | 60 | 435 |
| | 3000 | 12400 | 1150 | 4150 | 480 | 1680 | 728 | 1988 | 21 | 55 | 36 | 280 | 546 | 2268 |
| | 2400 | 16600 | 550 | 1700 | 1980 | 6480 | 98 | 882 | 16 | 61 | 4 | 500 | 42 | 196 |
| | | | 650 | 2550 | | | 98 | 625 | 25 | 73 | 210 | 1290 | 756 | 2492 |
| | | | | | | | 615 | 1665 | | | | | | |
| *Broomella* isolates | | | | | | | | | | | | | | |
| 1. W68C | | | 180 | 830 | | | | | | | | | 4800 | 22100 |
| | | | 190 | 1210 | | | | | | | | | 1900 | 12000 |
| | | | 180 | 1020 | | | | | | | | | 3500 | 22800 |
| | | | 300 | 1600 | | | | | | | | | 4300 | 25700 |
| *Ulocladium* isolates | | | | | | | | | | | | | | |
| 1. W60G | 20 | 200 | 2750 | 8500 | 3800 | 8800 | 1575 | 7125 | 390 | 5340 | | | 256 | 2768 |
| | 2000 | 12600 | 2400 | 24400 | 3000 | 17200 | 450 | 4350 | 120 | 7980 | | | 320 | 2528 |
| | 600 | 6100 | 3700 | 18300 | 4200 | 13400 | 375 | 5925 | 300 | 5340 | | | 1344 | 9984 |
| | 700 | 6800 | 2600 | 8200 | 3200 | 12400 | | | 420 | 5700 | | | 256 | 992 |

*Penicillium* isolates

| | | | | |
|---|---|---|---|---|
| 1. W5F | 840 | 5180 | 195 | 603 |
| | 70 | 2800 | 115 | 800 |
| | 770 | 4830 | 105 | 600 |
| | 1680 | 8330 | 115 | 670 |
| 2. W7E | 35 | 75 | 3 | 3 |
| | 312 | 1134 | 5 | 12 |
| | 168 | 486 | 2 | 2 |
| | 258 | 864 | 1 | 7 |
| 3. W23B | 50 | 1400 | 1250 | 5100 |
| | 3200 | 14000 | 80 | 410 |
| | 1600 | 8200 | 20 | 990 |
| | 3000 | 20600 | 50 | 350 |
| 4. W24L | | | 34 | 82 |
| | | | 204 | 2724 |
| | | | 140 | 1036 |
| 5. W25J | 6000 | 14500 | 30 | 240 |
| | 3400 | 7000 | 280 | 3255 |
| | 2600 | 7400 | 120 | 2790 |
| | 5800 | 14000 | 210 | 1140 |
| 6. W26 | 300 | 1680 | 111 | 483 |
| | 150 | 930 | 168 | 1288 |
| | 90 | 660 | 156 | 864 |
| | 150 | 630 | 144 | 471 |
| 7. W27 | 1000 | 5100 | 140 | 790 |
| | 900 | 7300 | 160 | 4560 |
| | 600 | 3300 | 240 | 1335 |
| | | | 120 | 2970 |
| 8. W28 | 3600 | 19600 | 864 | 2976 |
| | 4000 | 21200 | 192 | 1984 |
| | 2000 | 20400 | 270 | 2970 |
| | 1000 | 9400 | 240 | 2790 |
| | 1300 | 11600 | | |
| | 3100 | 22700 | | |
| | 2300 | 7500 | | |
| | 5400 | 15400 | | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 648 | | | | | | | | |
| 450 | | | | | | | | |
| 138 | | | | | | | | |
| 573 | | | | | | | | |
| 5 | | | | | | | | |
| 221 | | | | | | | | |
| 13 | | | | | | | | |
| 40 | | | | | | | | |
| 3570 | | | | | | | | |
| 2310 | | | | | | | | |
| 1470 | | | | | | | | |
| 1110 | | | | | | | | |
| 140 | | | | | | | | |
| 1104 | | | | | | | | |
| 2736 | | | | | | | | |
| 903 | | | | | | | | |
| 22 | 8 | 40 | | | | | 13 | 20 |
| 20 | 0 | 1 | | | | | 1 | 5 |
| 13 | 0 | 0 | | | | | 24 | 76 |
| 67 | | | | | | | 48 | 104 |
| | | | | | | | 246 | 840 |
| 5340 | | | | | | | | |
| 8000 | | | | | | | | |
| 7980 | | | | | | | | |
| 11580 | | | | | | | | |
| 294 | 0 | 1 | 1 | 5 | | | 2 | 2 |
| 210 | 0 | 0 | 2 | 3 | | | 2 | 3 |
| 635 | | | 1 | 2 | | | 0 | 0 |
| 1905 | | | 4 | 9 | | | | |
| 49 | 0 | 0 | 1 | 5 | | | 0 | 1 |
| 76 | | | 11 | 29 | | | 0 | 0 |
| 64 | | | 2 | 19 | | | 0 | 1 |
| 38 | | | 5 | 16 | | | 0 | 1 |
| 408 | | | 2 | 2 | | | 0 | 1 |
| 504 | | | 3 | 6 | | | 2 | 3 |
| 576 | | | 2 | 6 | | | 0 | 0 |
| 336 | | | 1 | 7 | | | 0 | 0 |

| | A1 | A2 | B1 | B2 | C1 | C2 | D1 | D2 | E1 | E2 | | | G1 | G2 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 18. W45 | 32 | 46 | 144 | 492 | | | | | 1 | 7 | | | 1 | 2 |
| | 27 | 39 | 132 | 732 | | | | | 4 | 5 | | | 1 | 1 |
| | 55 | 74 | 144 | 636 | | | | | 2 | 4 | | | 4 | 6 |
| | 35 | 52 | 180 | 636 | | | | | 2 | 11 | | | 1 | 1 |
| 19. W48J | 100 | 232 | 85 | 174 | | | | | 1 | 4 | | | 1 | 2 |
| | | | 109 | 237 | | | | | 2 | 2 | | | 1 | 4 |
| | | | 116 | 230 | | | | | 1 | 1 | | | 0 | 2 |
| | | | 56 | 138 | | | | | 5 | 33 | | | 1 | 3 |
| 20. W56 | 6 | 11 | 129 | 264 | | | 0 | 0 | 1 | 1 | | | 0 | 0 |
| | 6 | 17 | 245 | 546 | | | 0 | 0 | 1 | 1 | | | 0 | 0 |
| | 7 | 11 | 150 | 240 | | | 0 | 0 | | | | | 0 | 0 |
| | 3 | 11 | 162 | 300 | | | | | | | | | 0 | 0 |
| 21. W70H | | | 80 | 240 | | | | | | | | | 4 | 12 |
| | | | 148 | 892 | | | | | | | | | 4 | 5 |
| | | | 48 | 212 | | | | | | | | | 3 | 7 |
| | | | 88 | 400 | | | | | | | | | 22 | 46 |
| 22. W73B | | | 2200 | 10400 | | | | | | | | | 420 | 6840 |
| | | | 3000 | 8600 | | | | | | | | | 120 | 1020 |
| | | | 4200 | 13400 | | | | | | | | | 960 | 9180 |
| | | | 600 | 4200 | | | | | | | | | 300 | 4740 |
| 23. W73D | | | 2800 | 10050 | | | | | | | | | 660 | 3570 |
| | | | 5000 | 26000 | | | | | | | | | 420 | 1920 |
| | | | 3000 | 7200 | | | | | | | | | 96 | 448 |
| | | | 3800 | 17000 | | | | | | | | | 270 | 1800 |
| 24. W75 | | | 800 | 9700 | | | | | | | | | 144 | 600 |
| | | | 300 | 5600 | | | | | | | | | 152 | 536 |
| | | | 200 | 2600 | | | | | | | | | 368 | 1456 |
| | | | 1300 | 7900 | | | | | | | | | 224 | 1248 |
| 25. W79 | | | 1500 | 30000 | | | | | | | | | 300 | 4080 |
| | | | 4000 | 24000 | | | | | | | | | 120 | 2400 |
| | | | 1000 | 17000 | | | | | | | | | 60 | 1140 |
| | | | 600 | 9400 | | | | | | | | | | |
| 26. W102 | 12 | 54 | 1 | 26 | 22 | 46 | 2 | 3 | 54 | 354 | | | 5 | 17 |
| | 17 | 35 | 1 | 10 | 15 | 33 | 5 | 23 | 54 | 372 | | | 1 | 6 |
| | 20 | 82 | 7 | 23 | 33 | 63 | 3 | 10 | 48 | 270 | | | 2 | 6 |
| | | | 0 | 8 | 23 | 31 | 5 | 19 | 36 | 216 | | | 9 | 18 |
| | | | | | | | 3 | 12 | | | | | | |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **27. W108** | | | 700 | 3250 | | | | | | | 250 | 715 |
| | | | 250 | 750 | | | | | | | | |
| | | | 600 | 1650 | | | | | | | | |
| | | | 750 | 3550 | | | | | | | | |
| *Mortierella* isolates | | | | | | | | | | | | |
| 1. W62G | 480 | 4800 | 1250 | 10500 | | | 25 | 58 | 6 | 60 | 480 | 1920 |
| | 1080 | 4500 | 1000 | 2250 | | | 0 | 0 | 24 | 128 | 60 | 270 |
| | 300 | 2100 | 1750 | 9750 | | | 1 | 2 | 24 | 216 | 510 | 2070 |
| | | | 500 | 12250 | | | | | 144 | 1120 | 224 | 704 |
| 2. W66 | 400 | 10600 | 1000 | 10100 | | | 6 | 11 | 600 | 6300 | 105 | 765 |
| | 400 | 6300 | 200 | 16900 | | | 14 | 34 | 320 | 3040 | 75 | 450 |
| | 500 | 11300 | 200 | 8200 | | | | | | | 165 | 540 |
| | 300 | 8300 | 800 | 16800 | | | | | | | 368 | 1472 |
| 3. W67F | | | 2 | 4 | | | | | | | 1 | 1 |
| | | | 2 | 2 | | | | | | | 2 | 2 |
| | | | 4 | 5 | | | | | | | 0 | 0 |
| | | | 2 | 3 | | | | | | | 0 | 0 |
| 4. W67L | 900 | 10100 | 120 | 8700 | 100 | 13500 | 4 | 5 | 150 | 4650 | 4 | 6 |
| | 1100 | 17100 | 240 | 10500 | 250 | 12750 | 5 | 21 | 100 | 3600 | 8 | 25 |
| | 200 | 6200 | 60 | 13260 | 50 | 9625 | 8 | 45 | 50 | 2900 | 4 | 10 |
| | 200 | 8700 | 180 | 16320 | 50 | 10125 | 9 | 19 | 100 | 3850 | 2 | 12 |
| | | | | | | | 27 | 35 | | | | |
| *Trichoderma* isolates | | | | | | | | | | | | |
| 1. W51D | 24 | 132 | | | | | 1 | 1 | 23 | 66 | 2 | 28 |
| | 12 | 68 | | | | | | | 35 | 97 | 4 | 10 |
| | 28 | 116 | | | | | | | 38 | 96 | 4 | 17 |
| | 16 | 156 | | | | | | | 18 | 46 | 4 | 18 |

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APPENDIX 9:   Publications


Papers accepted for publication (approximate date

of publication March, 1984).

WALKER, G.E. (1984).   Ecology of the mycophagous nematode *Aphelenchus*
        *avenae* in wheat-field and pine-forest soils.
        *Plant and Soil* (14 text pages, 8 tables, 1 figure).

WALKER, G.E. (1984).   Feeding trials of *Aphelenchus avenae* on soil
        bacteria and actinomycetes.   *Plant and Soil* (5 text
        pages, 1 table).

## VIII.  BIBLIOGRAPHY

ANGUS, R.A. (1980).   Geographic dispersal and clonal diversity in unisexual fish populations.   *The American Naturalist* 15: 531-550.

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