The Influence of Cropping Practice and Application of Farmyard Manure on the Soil Microflora at Samaru, Northern Nigeria

By

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INTRODUCTION

Much previous work on tropical soil mycology has consisted of preparing floristic lists of fungi obtained from virgin soils. This has given information about types of fungi indigenous to such soils but no data on any changes that may be brought about by agronomic practices that alter soil fertility. Soil fungi by decomposing plant and animal residues play an important part in building up and maintaining soil fertility (Garrett, 1963). Any changes in the composition of the soil microflora brought about by agronomic treatments can involve pathogenic as well as saprophytic organisms.

Cotton, groundnuts and sorghum in Northern Nigeria are all subject to diseases caused by soil fungi. Cotton is attacked by *Rhizoctonia solani* and *Sclerotium rolfsii;* sorghum leaf spots are caused by species of *Alternaria, Curvularia* and *Helminthosporium;* groundnuts are probably the most affected because the fruits develop below ground and many common soil fungi (e.g. *Aspergillus* spp., *Macrophomina phaseoli, Fusarium* spp.) have been found to be associated with diseased conditions of fruits and seeds.

The present study was undertaken in 1960 to determine the extent to which differences in soil fertility and cropping practice influence the soil microflora. There is a permanent agronomy trial at Samaru in which the three crops are grown with various amounts of farmyard manure both in monoculture and in rotation. The first replicate of the trial was laid down in 1949 and a similar block added in 1954. The trial is sited on a poorly drained, fine sandy loam with a low clay content. By the end of 1959 some marked trends in yield had been observed. All crops showed steady increases in yield with annual applications of farmyard manure at 3 and 5 tons per acre (t.p.a.). Crops without manure or with only 1 t.p.a. tended to give decreased yields in successive years. With cotton there were no consistent differences in yield between monocropping and rotation, but both groundnuts and sorghum grown in rotation showed consistently higher yields than when grown in continuous monoculture. In 1959 the average yields of cotton, sorghum and groundnuts from the plots receiving 5 t.p.a. of manure were respectively seven, six and four times greater than those of the same crops grown without manure.

MATERIALS AND METHODS

The rotation used was cotton/sorghum/groundnuts, all three crops being grown both under monocropping and under rotation each year. Sorghum (*Sorghum vulgare,* variety Short Kaura) and groundnuts (*Arachis hypogaea,* variety Samaru 38) were sown on 27-29th May 1960 and cotton (*Gossypium hirsutum,* variety Samaru 26J) was sown on 28-29th June. The crops were grown on ridges 3 feet apart in plots 44 yards long and 9 yards wide; spacing between stands was 18 in. for cotton, 9 in. for groundnuts and 24 in. for sorghum. The groundnuts were harvested on 17th October, but the cotton and sorghum were not harvested during the period of soil sampling. Farmyard manure was applied on 18-19th April to all cropping treatments at levels of nil, 1, 3 and 5 t.p.a. Soil microflora studies were restricted to plots with no manure and to those receiving 5 t.p.a. of manure.

Sampling began at the beginning of April and continued until the end of November (See Table 1).

Table 1. Dates of taking soil samples

Sample number	*Week 1*	*Week 2*	*Week 3*
	Cotton	*Sorghum*	*Groundnuts*
1	5 April	12 April	20 April
2	3 May	10 May	17 May
3	1 June	7 June	14 June
4	28 June	5 July	12 July
5	26 July	2 August	9 August
6	23 August	30 August	7 September
7	20 September	27 September	5 October
8	18 October	25 October	1 November
9	15 November	22 November	29 November

Samples were taken every four weeks from each crop treatment, the rotation plots being sampled according to the previous year's crop in each case. Soil from the cotton plots was sampled in Week 1, from sorghum in Week 2 and from groundnuts in Week 3: samples were always collected between 7 and 8 a.m.

A 2-yard wide strip was left as a discard around each plot. Ten sample cores of soil were collected at random from the remainder of the plot. (After the crops were sown, the cores were taken from between stands to avoid inclusion of roots.) A clean surface of soil was exposed half-way up the side of the ridge and the cores of soil were removed with a size 12 cork borer, transferred to a clean tin and thoroughly mixed. Soil was taken from the composite sample for moisture content determination by the standard oven-drying method. Soil fungi were estimated quantitatively and qualitatively by the dilution plate method, which also permitted quantitative assessment of bacteria and actinomycetes. Warcup soil plates were used to complement the dilution plate technique.

The dilution plates were prepared as follows: 7-8 g.[5] of soil were added to 250 ml. sterile water in a 500 ml. conical flask and shaken for 5 minutes at 120 oscillations per minute on a reciprocating platform shaker. Serial dilutions were prepared from the suspension by successive 1 ml. transfers to 9 ml. sterile water blanks until a dilution of 1:100,000 was reached. The weight[5a] of soil originally added to the flask was found by oven-drying the suspension at 105°C to constant weight; no allowance was made for the small amount of soil removed for preparing the dilution series as this was of the same order each time. Four 1 ml. aliquots of the 1:10,000 dilution were placed in sterile petri dishes. Czapek-Dox/rose-bengal/streptomycin agar medium cooled to 45°C was added to each dish, the plates being agitated to spread the soil suspension through the medium before it set. The plates were incubated at room temperature (18-26°C) and the number of fungal colonies on each plate was recorded after three days. After a further four days incubation the fungi were identified: those not immediately identifiable were sub-cultured on potato dextrose agar slants for later examination. Quantitative estimation of bacteria and actinomycetes was made by plating out 1 ml. aliquots of the 1:100,000 dilution with melted and cooled corn meal agar. After two days incubation at room temperature the number of colonies on each plate was counted using a stereo-binocular microscope fitted with x 10 eye-pieces and x 1.25 objectives. Total numbers of fungi, bacteria and actinomycetes were calculated per gram of dry soil.

Warcup soil plates were prepared by placing small quantities of soil in sterile petri dishes and adding cooled corn meal agar. The plates were agitated during pouring to disperse the soil particles throughout the medium. Three plates were prepared from each soil sample and the fungi that developed were identified after seven and fourteen days incubation at room temperature. Unknown fungi were sub-cultured on potato dextrose slants as before.

Difco dehydrated culture media were used throughout; the Czapek-Dox agar was modified by adding rose-bengal (1:30,000 dilution) before sterilisation and streptomycin sulphate solution (30 ug[1] per ml. of medium) after the agar had cooled to 45°C.

On 12th December five further samples of soil were collected from each plot, bulked and mixed thoroughly. About 20 g of each sample was shaken for 30 minutes with 100 ml. sterile distilled water and the pH of the suspension was measured with a pH meter.

METEOROLOGICAL OBSERVATIONS

The soil temperature and the rainfall data shown in Fig. 1 were taken at the Samaru meteorological station less than a mile from the site of the trial; soil moisture data were obtained from each original soil sample. The rainfall for 1960 was 42.97 in. (just below the 40-year mean) and was well distributed with no long dry periods and few heavy storms. (See Fig 1.) Air temperatures were also around the Samaru means.

Although not shown in Fig. 1, it should be recorded that the soil receiving 5 t.p.a. of manure retained more moisture than the unmanured soil. This small increase, averaging 11 per cent over the season, might have played some small part in affecting the soil microflora, but any effect of moisture would undoubtedly have been masked by the large differences in available nutrients between the two treatments.

RESULTS

1. Numbers of micro-organisms

Figs. 2, 3 and 4 show the mean numbers of fungi, actinomycetes and bacteria which were isolated by the dilution plate method.[6] There was surprisingly little variation in the numbers of micro-organisms throughout the season despite wide fluctuations in soil moisture content and smaller variations in soil temperature. The only factor that noticeably affected the numbers of all three classes of organisms was the farmyard manure. This was applied after the first soil sample had been taken from the cotton and sorghum plots, but just before the first sampling of the groundnut plots. There were sufficient residual nutrients in the soil for the new applications of manure not to have had an immediate effect on microbial numbers. The apparent increases visible in Sample 2 also occurred in the unmanured plots showing that they were due to factors other than manure. At the end of the season the soil receiving 5 t.p.a. manure had an organic carbon content of 0.60 per cent, while the unmanured plots registered only 0.22 per cent organic carbon.

Fewer fungi occurred in unmanured soil cropped continuously with cotton than with other crops, but manuring removed this difference. (See Table 2.). A possible explanation is discussed later.

Table 2. Effect of monocropping on numbers of fungi per gram of dry soil

Crop	*Without manure*	*5 t.p.a. manure*
Cotton	29,000	81,900
Groundnuts	45,300	80,000
Sorghum	46,900	82,200

The numbers of organisms were not obviously affected by soil temperature, soil moisture or rainfall. The pH of all plots lay between 5.9 and 6.7 and it is unlikely that this narrow difference could have influenced microbial numbers.[7] There was a slight, but consistent,

[1] u Greek "mu"

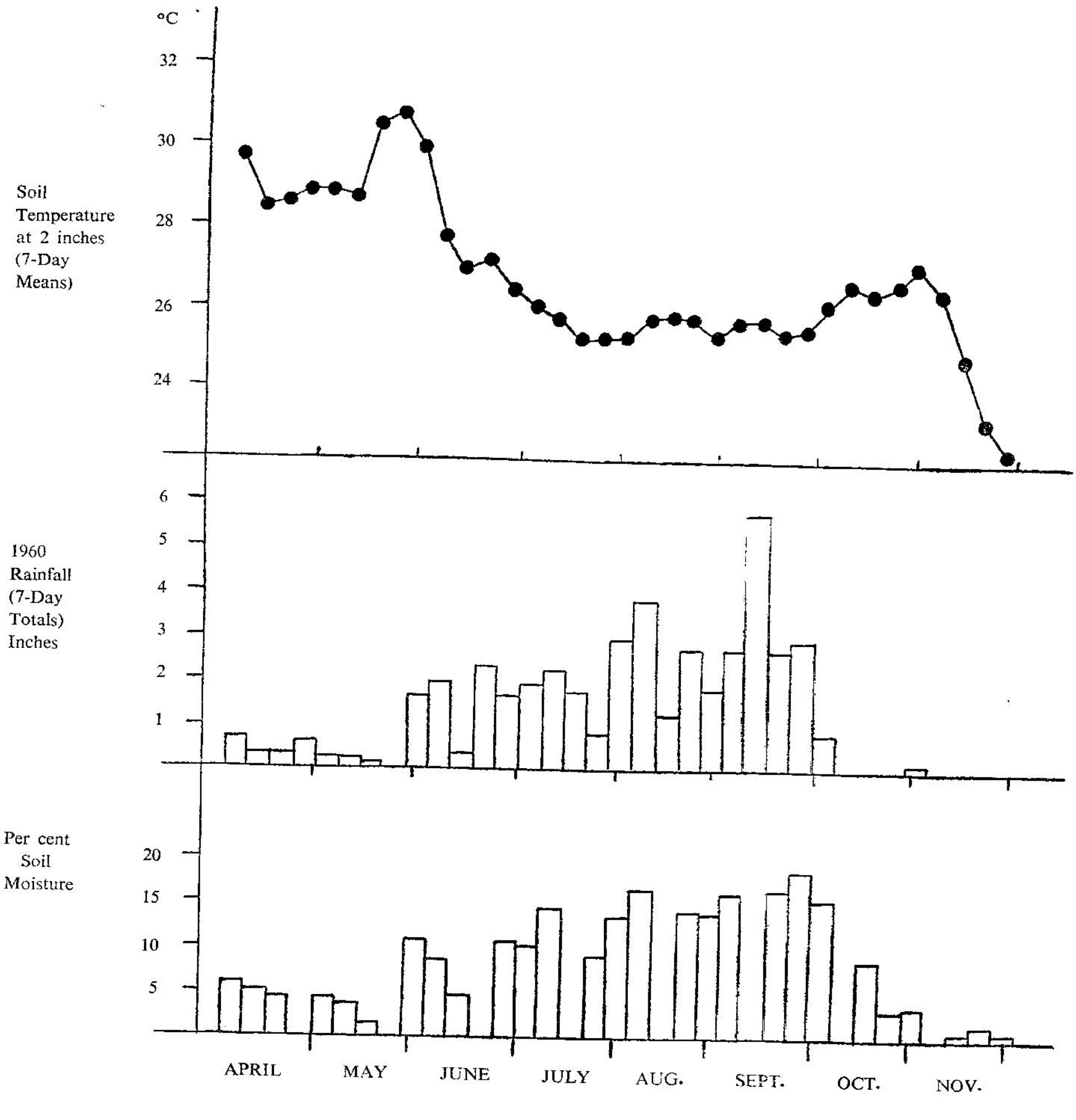

Fig. 1 Meteorological data

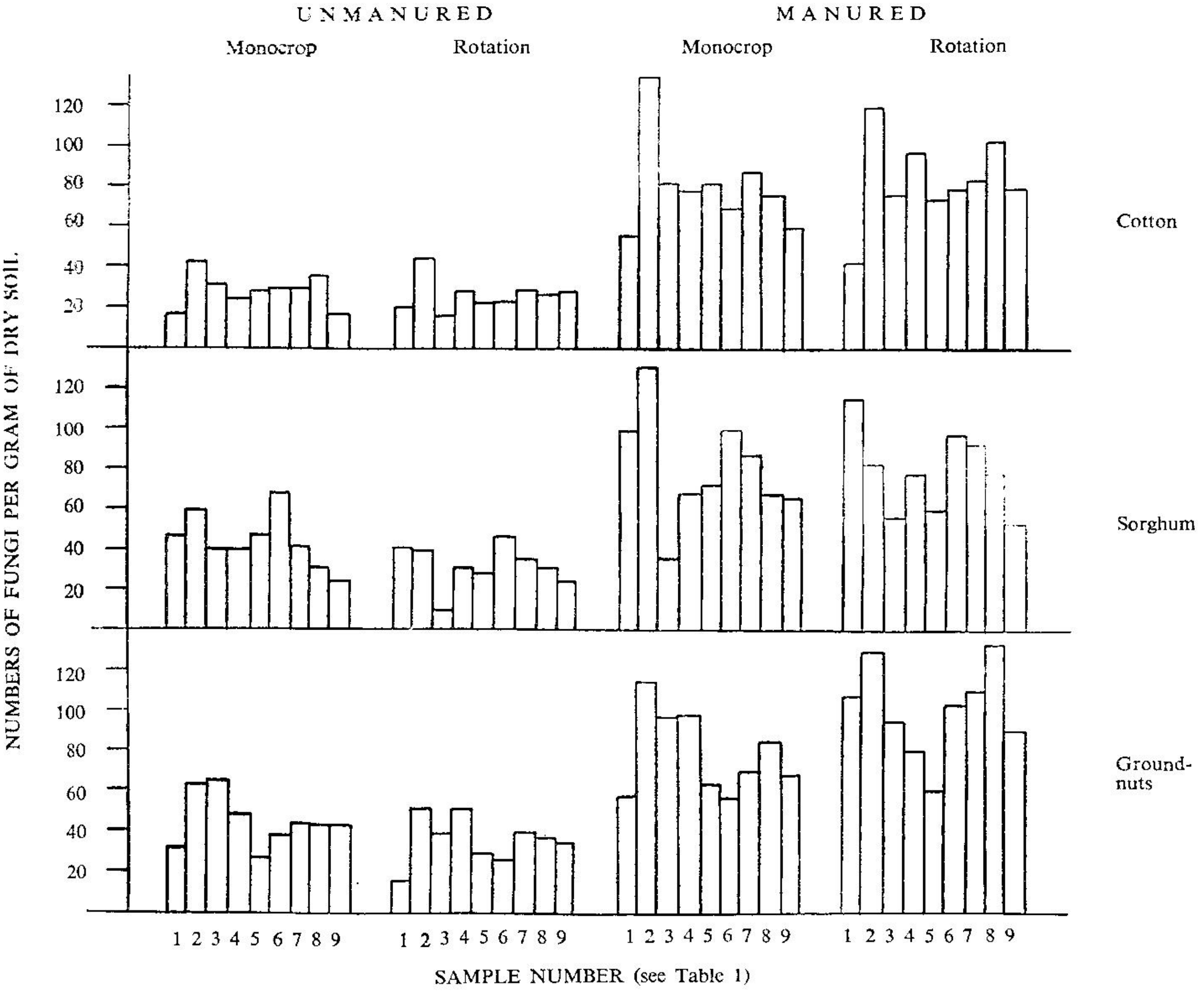

Fig. 2 Number of Fungi

difference in pH between the two levels of manuring: soils treated with 5 t.p.a. manure were about half a pH unit higher due to the buffering action of the farmyard manure.

2. Qualitative composition of the mycoflora

Identifications were made to species level if possible, although on Warcup plates this was only carried out for the more important fungi. Species identification of *Penicillium* was not attempted, but *Aspergillus* isolates were identified to groups according to Thom and Raper (1945).

As expected, the dilution plate technique selected a different sector of the fungal spectrum to that of the Warcup method: dilution plates, on which 104 species were identified, favoured the sporulating types, particularly the Fungi Imperfecti; while on Warcup plates, where 78 species were found, Phycomycetes were more common. Even with two techniques, only a partial picture of the soil mycoflora could be obtained, although Table 3 shows that the commoner species consistently appeared with both methods.

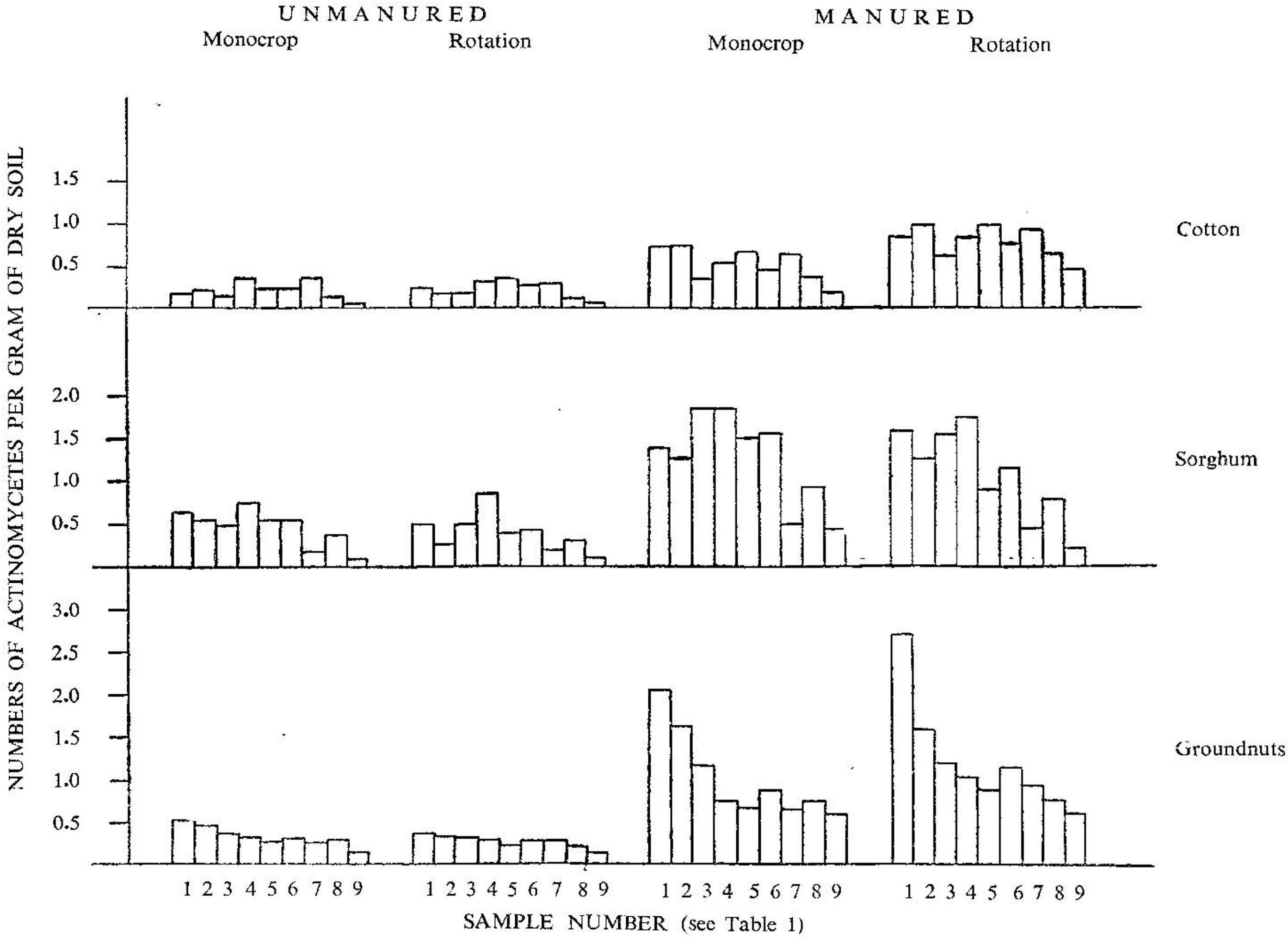

Fig. 3 Numbers of actinomycetes

A complete list of species isolated during the eight months of sampling is given in Table 3, arranged according to the manurial and cropping treatments. Even though there were three times as many fungal propagules in soil receiving manure than in unmanured soil (according to the dilution plate results), there appeared to have been no great difference in the qualitative composition of the fungal population. A few species were commoner in the less fertile soil (e.g. *Aspergillus niger* and *A. fumigatus*), but others were more often found in manured soil (e.g. *A. nidulans* and *Rhizoctonia solani*). Monocropping appeared to have very little effect on the fungal flora: there were very similar numbers of species in the soils of all three crops, but a few differences were observed in the composition of the mycoflora; these will be considered in Section 3. There was virtually no difference between monocropping and rotation in the numbers of species isolated, 113 species being recorded under the former system and 117 under the latter.

Tables 4 and 5 show the total species list for each of the two isolation techniques separately; the data are arranged according to the time of sampling to bring out any changes that occurred during the season. The total number of species isolated each month was fairly constant, although certain species appeared to be influenced by changes in soil moisture or temperature or both.

Table 6 and 7 include only those fungi most frequently isolated, but with the data arranged to show the interaction of the individual crop with monocropping *versus* rotation and nil *versus* 5 t.p.a. farmyard manure. The crops shown in the table were those being grown in 1959, the year before the sampling period. This is because soil sampling was started in April before any of the 1960 crops were sown and because it has been repeatedly shown (e.g. Williams and Schmitthenner, 1960) that the decomposing plant residues left in the soil from the previous crop influence the soil microflora far more than do the root exudates from the current crop. This is especially true when soil samples are taken, as in this experiment, to avoid the roots of the growing crop as far as possible.

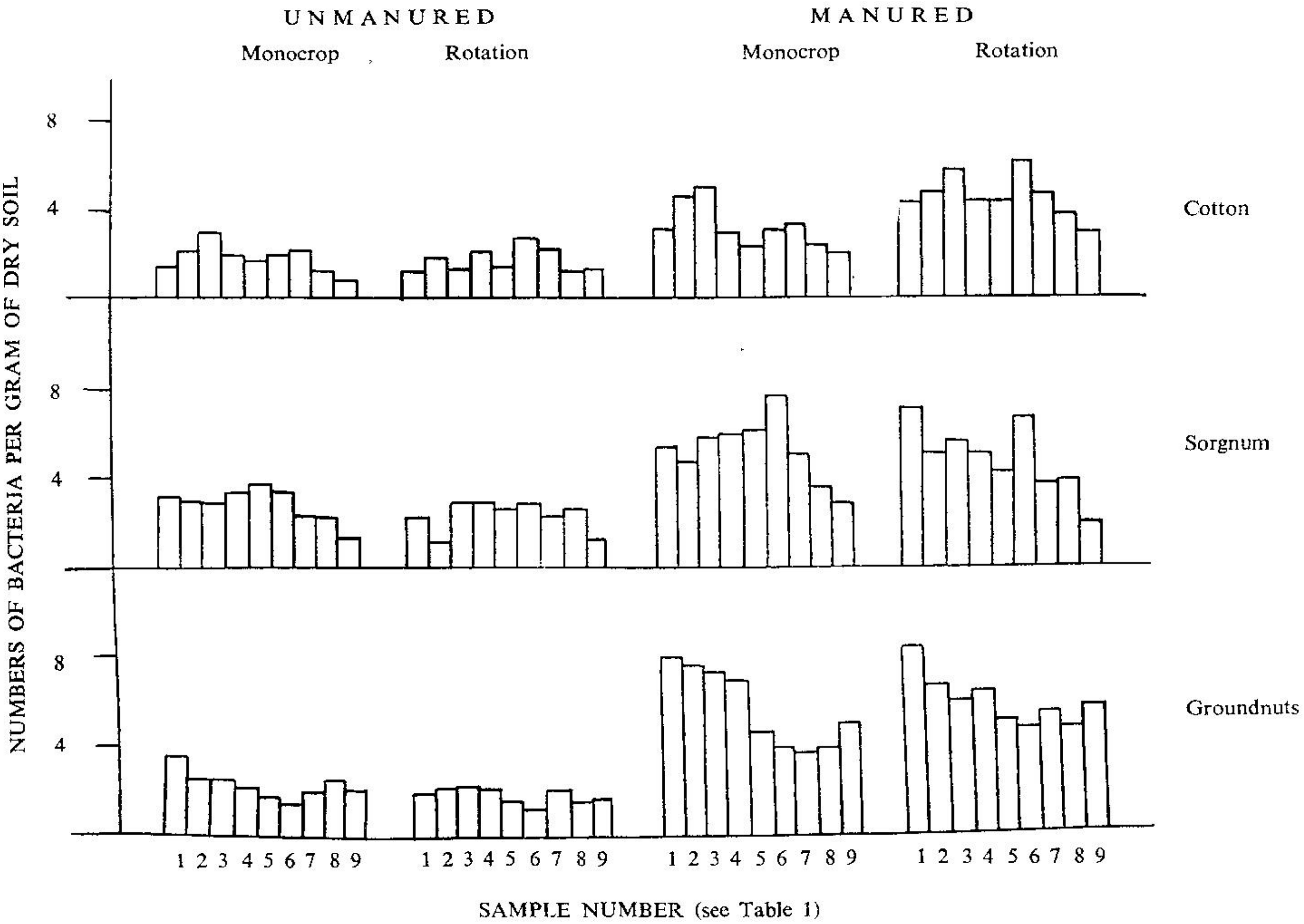

Fig. 4 Numbers of bacteria

From an examination of these four tables certain fungi are deemed worthy of more detailed mention. These are now considered below.

3. Notes on individual species affected by various treatments

Absidia spinosa: never common, appeared most often with manured, monocropped sorghum.

Acrostalagmus spp.: not isolated by either method until end of July; always infrequent.

Arthrobotrys, *Dactylaria* and *Dactylella* spp.: all predacious on nematodes; more frequent July-September when nematodes abundant in soil.

Aspergillus spp.: 14 groups identified on dilution plates; 10 groups on Warcup plates. Numbers fairly constant throughout season; some species influenced by soil fertility, but total *Aspergillus* reasonably constant throughout.

Aspergillus candidus: common only on dilution plates; twice as frequent in unmanured soil.

Aspergillus flavipes: sporadic, but increased towards end of season.

Aspergillus flavus: commonest on groundnut plots, especially at harvest.

Aspergillus fumigatus: very common; no seasonal variation; less frequent on manured soil.

Aspergillus nidulans: showed a tenfold increase with manure (dilution plates) and a 47-fold increase with manure (Warcup plates); most common with monocropped cotton; became rarer in all plots after end of June.

Aspergillus niger: favoured by less fertile soils; incidence fell in August and September when soil temperature was low and soil moisture high.

Table 3 Complete list of fungi isolated from the various treatments

Fungus Species	Dil'n or Warcup plate		Monocropping						Rotation					
			Cotton		G'nuts		S'ghum		Cotton		G'nuts		S'ghum	
			0	5	0	5	0	5	0	5	0	5	0	5
Absidia spinosa	D	W		+	+	+	+	+	+	+	+	+	+	+
Acrostalagmus albus	D	W		+		+		+	+		+			
Acrostalagmus cinnabarinus	D	W	+		+	+			+					
Alternaria humicola	D												+	
Arthrobotrys oligospora		W			+	+	+	+				+		
Aspergillus alliaceus	D				+	+						+		
Aspergillus candidus	D	W	+	+	+	+	+	+	+	+	+	+	+	+
Aspergillus flavipes	D	W	+		+	+	+	+	+	+	+	+	+	+
Aspergillus flavus	D	W	+	+	+	+	+	+	+	+	+	+	+	+
Aspergillus fumigatus	D	W	+	+	+	+	+	+	+	+	+	+	+	+
Aspergillus glaucus	D			+	+					+	+		+	+
Aspergillus humicola	D		+	+		+						+		
Aspergillus nidulans	D	W	+	+	+	+		+	+	+	+	+		+
Aspergillus niger	D	W	+	+	+	+	+	+	+	+	+	+	+	+
Aspergillus ochraceus	D	W	+	+	+	+	+	+	+	+	+	+	+	+
Aspergillus sydowi	D										+			+
Aspergillus terreus	D	W	+	+	+	+	+	+	+	+	+	+	+	+
Aspergillus ustus	D	W	+	+	+	+	+	+	+	+	+	+	+	+
Aspergillus versicolor	D	W	+	+	+	+	+	+	+	+	+	+	+	+
Botrytis cinerea		W									+			
Cephalosporium acremonium	D	W	+	+	+	+	+	+	+	+	+	+	+	+
Cephalosporium curtipes	D	W	+	+	+	+	+	+	+	+	+	+	+	+
Chaetomium globosum	D		+	+	+	+	+	+	+	+	+	+	+	+
Chaetomium homopilatum	D												+	
Chaetomium indicum	D									+				
Chaetomium sp.		W	+	+	+	+	+	+	+	+	+	+	+	+
Cladosporium herbarum	D	W	+	+	+	+	+	+	+	+	+	+	+	+
Coniothyrium fuckelii	D				+		+							
Coniothyrium sp.		W	+	+	+	+	+	+	+	+	+	+	+	+
Cunninghamella echinulata		W	+	+	+	+	+	+	+	+	+	+	+	+
Cunninghamella elegans	D						+		+			+	+	
Curvularia geniculata	D				+		+	+	+			+		
Curvularia lunata	D		+	+	+	+	+	+	+	+	+	+	+	+
Curvularia maculans	D		+	+	+		+		+	+			+	+
Curvularia pallescens	D				+		+	+		+		+		
Curvularia sp.	D	W	+	+	+	+	+	+	+	+	+	+	+	+
Cylindrocarpon candidum	D			+										
Cylindrocarpon didymum	D		+	+	+	+	+	+	+	+		+	+	+
Cylindrocarpon heteronemum	D		+	+	+	+	+	+	+	+	+	+	+	+
Cylindrocarpon radicicola	D		+	+	+	+	+	+	+	+	+	+	+	+
Cylindrocarpon sp.	D	W	+	+	+	+	+	+	+	+	+	+	+	+
Dactylaria sp.		W						+						+
Dactylella sp.		W				+		+	+	+	+	+		+
Dicoccum sp.	D	W	+	+		+	+	+	+		+	+	+	
Epicoccum sp.	D						+						+	
Fusarium avenaceum	D							+	+	+				
Fusarium culmorum	D	W	+	+	+	+		+	+	+		+	+	+
Fusarium equiseti	D			+						+			+	
Fusarium oxysporum	D	W	+	+	+	+	+	+	+	+	+	+	+	+
Fusarium semitectum	D				+	+					+			
Fusarium solani	D	W	+	+	+	+	+	+	+	+	+	+	+	+
Fusarium sp.	D	W	+	+	+	+	+	+	+	+	+	+	+	+
Gliocladium roseum	D	W	+	+	+	+	+	+	+	+	+	+	+	+
Gymnoascus sp.	D	W						+			+			+
Haplographium sp.	D							+						
Helminthosporium nodulosum	D	W	+					+	+		+	+	+	
Helminthosporium sativum	D	W	+	+	+	+	+	+	+	+	+	+	+	+
Humicola sp.	D		+	+	+	+	+	+	+	+	+	+	+	
Hyalopus ater	D						+		+					
Hyalopus sp.	D									+				
Macrophomina phaseoli	D			+		+							+	+
Malustela aeria	D				+	+	+	+	+	+	+	+	+	+
Masoniella grisea	D		+							+				
Monilia brunnea	D		+	+	+	+	+	+	+	+	+	+	+	+
Monilia humicola	D													+
Monilia implicata	D						+							+
Monotospora sp.	D	W	+	+	+	+	+		+	+	+	+		+
Mortierella sp.	D	W	+	+	+	+	+	+	+	+	+	+	+	+

Fungus Species	Dil'n or Warcup plate		Monocropping						Rotation					
			Cotton		G'nuts		S'ghum		Cotton		G'nuts		S'ghum	
			0	5	0	5	0	5	0	5	0	5	0	5
Mucor circinelloides	D	W	+	+	+	+	+	+	+	+	+	+	+	+
Mucor hiemalis		W	+	+			+		+	+				+
Mucor ramannianus	D						+	+					+	
Mucor spinosus		W	+		+		+							
Mucor sp.		W	+	+	+	+	+	+	+	+	+	+	+	+
Myrothecium roridum	D										+	+		
Myrothecium verrucaria	D		+	+	+	+	+		+	+	+	+	+	+
Necosmospora vasinfecta	D				+	+					+	+		
Nigrospora sphaerica	D	W	+	+			+	+	+	+		+	+	+
Oospora sulphurea	D		+	+		+			+					
Paecilomyces fusisporus	D		+							+	+			
Paecilomyces varioti	D	W	+	+	+	+	+	+	+	+	+	+	+	+
Papularia sphaerosperma	D								+					
Pellicularia filamentosa		W	+	+	+	+	+	+	+	+	+	+	+	+
Penicillium spp.	D	W	+	+	+	+	+	+	+	+	+	+	+	+
Periconia byssoides	D	W	+	+		+		+	+		+			+
Periconia felina		W		+			+	+	+					
Periconia sp.	D	W	+	+	+		+		+		+	+		
Phoma spp.	D	W	+	+	+	+	+	+	+	+	+	+	+	+
Piptocephalis sp.	D	W		+	+		+	+	+					+
Pullularia pullulans	D	W	+	+	+	+	+	+	+	+	+	+	+	+
Pyrenochaeta sp.	D	W	+	+	+	+	+	+	+	+	+	+	+	+
Phythium mamillatum		W				+					+	+	+	
Phythium ultimum		W	+	+				+	+	+			+	+
Phythium sp.	D	W	+	+	+	+	+	+	+	+	+	+	+	+
Rhizoctonia solani	D	W		+	+	+		+		+	+	+	+	+
Rhizopus stolonifer	D	W	+	+	+	+	+	+	+	+	+	+	+	+
Scopulariopsis brevicaulis	D	W	+	+	+	+	+	+	+	+	+	+	+	+
Sphaeronaema sp.		W	+		+			+					+	+
Spicaria divaricata	D							+					+	
Spicaria elegans	D	W	+	+	+	+	+	+			+	+		+
Spicaria griseola	D	W	+	+	+	+	+	+	+	+	+	+	+	+
Spicaria sp.	D	W	+	+	+	+	+	+	+	+	+	+	+	+
Sporotrichum chlorinum	D		+						+	+				
Sporotrichum olivaceum	D						+							+
Sporotrichum roseum	D	W	+	+	+	+	+	+	+	+	+	+	+	+
Sporotrichum sp.		W	+	+	+	+	+	+	+	+	+	+	+	+
Stachybotrys atra	D	W	+	+	+	+	+	+	+	+	+	+	+	+
Stemphylium verruculosum	D	W		+	+	+	+	+	+	+	+	+	+	+
Stemphylium sp.	D	W	+	+		+	+	+	+		+		+	+
Stysanus stemonites	D					+	+	+			+	+		
Syncephalastrum racemosum	D	W	+	+	+	+	+	+	+	+	+	+	+	+
Tetracoccosporium paxianum	D	W	+	+	+	+	+	+	+	+	+	+	+	+
Thielavia basicola	D	W	+	+	+	+	+	+	+	+	+	+	+	+
Thielavia sepedonium	D	W	+	+	+	+	+	+	+	+	+	+	+	
Torula allii	D	W		+	+	+	+	+	+	+	+	+	+	+
Trichoderma viride	D	W	+	+	+	+	+	+	+	+	+	+	+	+
Verticillium albo-atrum	D	W	+	+	+	+	+	+	+	+	+		+	+
Verticillium sp.		W		+	+	+			+			+	+	
Zygorhynchus moelleri	D	W	+	+	+	+	+	+	+	+	+	+	+	+
Dark sterile mycelia	D	W	+	+	+	+	+	+	+	+	+	+	+	+
Green sterile mycelia		W					+	+						
Pink sterile mycelia	D			+	+		+					+		+
White sterile mycelia	D	W	+	+	+	+	+	+	+	+	+	+	+	+
Number of species			77	82	81	81	84	85	85	78	80	81	80	81

KEY: 0 : No farmyard manure
5 : 5 tons per acre of farmyard manure

Table 4 Fungi isolated by dilution plate technique arranged by sample data (The numbers represent the percentage of each species out of the total colonies occurring on each sampling occasion)

Fungus species	Sample number (see Table 1)									Mean
	1	2	3	4	5	6	7	8	9	
Absidia spinosa								0.1		0.01
Acrostalagmus albus						0.1		0.1		0.02
Acrostalagmus cinnabarinus							0.1			0.01
Alternaria humicola								0.1		0.01
Aspergillus alliaceus		0.9								0.10
Aspergillus candidus	1.6	0.2	1.2	1.0	1.2	1.1	1.9	1.6	0.5	1.14
Aspergillus flavipes		0.1		0.1	0.1	0.1	0.1	0.2	0.2	0.09
Aspergillus flavus	0.5	0.1	0.3	0.4	1.1	0.8	3.3	1.4	0.2	0.89
Aspergillus fumigatus	13.9	6.2	8.5	8.6	7.6	8.2	7.8	7.4	8.1	8.47
Aspergillus glaucus	0.1	0.2					0.5			0.08
Aspergillus humicola	0.3	0.2								0.06
Aspergillus nidulans	3.2	8.0	6.0	2.8	1.1	1.2	0.8	1.3	1.4	2.86
Aspergillus niger	16.5	8.7	7.0	7.4	8.8	8.5	10.5	7.3	9.8	9.38
Aspergillus ochraceus	1.1	1.5	0.5	0.3	0.6	0.3	0.5	1.8	2.0	0.97
Aspergillus sydowi			0.2		0.1					0.03
Aspergillus terreus	2.6	0.6	0.7	0.5	0.5	0.4	1.5	0.8	0.2	0.88
Aspergillus ustus	3.0	2.9	6.4	6.6	6.2	5.2	5.8	4.9	3.7	4.96
Aspergillus versicolor	6.3	1.2	0.9	2.3	1.6	2.9	3.4	2.3	2.6	2.61
Cephalosporium acremonium		0.9	1.2	2.8	1.9	1.6	1.4	2.4	1.7	1.54
Cephalosporium curtipes	0.1	0.1		0.3	0.1	0.3	0.1	0.1	0.1	0.14
Chaetomium globosum		1.2	0.6	0.6	0.3	0.4	0.4	0.8	0.7	0.54
Chaetomium homopilatum								0.1		0.01
Chaetomium indicum		0.2								0.02
Cladosporium herbarum	0.7	5.1	4.6	3.8	3.1	3.5	2.5	3.9	5.4	3.62
Coniothyrium fuckellii				0.1					0.1	0.01
Cunninghamella elegans	0.1				0.1		0.1			0.03
Curvularia geniculata	0.1		0.2	0.1					0.2	0.06
Curvularia lunata	0.1	0.3	0.8	0.1	0.3	0.1	0.2	0.7	0.4	0.34
Curvularia maculans	0.1	0.3			0.1	0.1		0.2	0.2	0.11
Curvularia pallescens	0.1	0.3			0.1					0.06
Curvularia sp.	0.5									0.05
Cylindrocarpon candidum	0.1									0.01
Cylindrocarpon didymum	0.9	0.9	0.4	0.2	0.1	0.1	0.3	0.1		0.33
Cylindrocarpon heteronemum	0.3	0.2	1.7	0.6	0.4	0.3	0.2	0.4	0.3	0.49
Cylindrocarpon radicicola		0.6	0.4	0.5	1.0	0.2	0.3	0.1	0.5	0.40
Cylindrocarpon sp.				0.6						0.07
Dicoccum sp.			0.5	0.2		0.2				0.09
Epicoccum sp.								0.1		0.01
Fusarium avenaceum		0.1							0.1	0.02
Fusarium culmorum		0.7	0.7	0.4	0.8	0.6	0.5	0.5	0.2	0.48
Fusarium equiseti						0.1	0.1	0.1		0.03
Fusarium oxysporum	4.8	4.2	3.7	6.2	4.3	2.1	3.0	2.4	2.1	3.65
Fusarium semitectum		0.2								0.02
Fusarium solani			0.8	0.7	0.1	0.1	0.7	0.2	0.1	0.29
Fusarium sp.	1.1	0.2			0.5	0.4	0.2	0.2	1.0	0.39
Gliocladium roseum		0.2	0.4	0.4	0.5	0.4	0.4	0.3	0.2	0.32
Gymnoascus sp.				0.2				0.1		0.02
Haplographium sp.				0.1						0.01
Helminthosporium nodulosum		0.1	0.3							0.05
Helminthosporium sativum					0.1		0.1			0.02
Humicola sp.			0.2	1.0	0.1	1.8		0.4	0.3	0.43
Hyalopus ater								0.1	0.1	0.01
Macrophomina phaseoli	0.2					0.1				0.04
Malustela aeria		0.2	0.3		1.2	0.3	0.3	0.1	0.1	0.27
Masoniella grisea						0.4				0.04
Monilia brunnea		0.4	3.2	0.4	1.0	0.9	1.5	1.6	0.9	1.11
Monilia humicola								0.1		0.01
Monilia implicata						0.1				0.02
Monotospora sp.	0.2			0.2	0.1	0.4	0.1	0.1		0.11
Mortierella sp.	0.4	0.1		0.3		0.1		0.3	0.1	0.12
Mucor circinelloides	0.2									0.02
Mucor ramannianus			0.1	0.3						0.04
Myrothecium roridum						0.1				0.01
Myrothecium verrucaria	1.5	2.4	0.6	0.3	0.8	0.2	0.3	0.1	0.3	0.71
Neocosmospora vasinfecta					0.1	0.8		0.1		0.10
Nigrospora sphaerica				0.2		0.1		0.5	0.1	0.10
Oospora sulphurea						0.1	0.1			0.02
Paecilomyces fusisporus			0.1			0.1			0.1	0.03

Fungus species	*Sample number (see Table 1)*									*Mean*
	1	2	3	4	5	6	7	8	9	
Paecilomyces varioti	1.1	4.1	3.2	6.3	6.4	5.2	3.1	3.2	2.0	3.85
Papularia sphaerosperma								0.1		0.01
Penicillium spp.	27.5	27.2	33.4	25.5	35.6	38.3	36.5	40.6	38.3	33.65
Periconia byssoides					0.1				0.1	0.02
Periconia spp.	0.1	0.8	0.4	0.2					0.4	0.20
Phoma spp.	0.5	0.8	0.1	1.2	0.7	0.6	1.1	1.1	3.0	1.01
Piptocephalis sp.					0.1	0.1		0.1		0.02
Pullularia pullulans		0.5	0.2	0.4	0.1	0.2	0.6	1.1	0.3	0.38
Pyrenochaeta sp.	1.5	0.7	1.3	0.3	2.4	1.7	1.9	1.0	2.1	1.45
Pythium spp.		0.2				0.2	0.1			0.07
Rhizoctonia solani		0.1	0.2							0.03
Rhizopus stolonifer	0.6	1.0	0.3	0.7	0.8	0.4	0.4	0.2	0.6	0.56
Scopulariopsis brevicaulis	0.1	1.7	1.2	3.5	1.3	1.2	1.4	0.7	0.4	1.20
Spicaria divaricata				0.2						0.02
Spicaria elegans	0.3	0.2					0.1		0.1	0.07
Spicaria griseola		1.1	0.3	1.0	0.5					0.31
Spicaria sp.				0.1	0.1					0.02
Sporotrichum chlorinum		0.3								0.03
Sporotrichum olivaceum								0.2		0.02
Sporotrichum roseum		0.2					0.1		0.1	0.03
Stachybotrys atra			0.3	0.3	0.5	1.0	0.5	0.5	0.5	0.42
Stemphylium verruculosum	0.1	0.1	0.2	0.9				0.1		0.15
Stemphylium sp.			0.2	0.4						0.06
Stysanus stemonites		0.8			0.1					0.10
Stycephalastrum racemosum		0.1		0.1	0.3	0.1	0.3	0.2		0.14
Tetracoccosporium paxianum	1.0	0.7	0.7	0.1		0.5	0.2	0.1		0.40
Thielavia basicola	1.3	3.3	3.7	1.6	1.9	2.2	2.2	2.0	2.5	2.29
Thielavia sepedonium	0.1			0.2				0.7	0.7	0.18
Torula allii		0.8	0.3	0.4		0.5	0.1		0.1	0.24
Trichoderma viride	0.3	0.5	0.3	0.7	0.1	0.1	0.1	0.1	0.2	0.28
Verticillium albo-atrum						0.1				0.01
Zygorhynchus moelleri				0.1				0.1	0.1	0.03
Dark sterile mycelia	2.6	3.7	0.4	3.8	1.0	1.3	1.0	1.4	1.6	1.88
Pink sterile mycelia				0.1				0.3		0.04
White sterile mycelia	1.7	1.8	1.6	1.2	2.4	1.0	1.2	1.2	2.7	1.66
Total number of species	43	58	49	59	52	59	51	62	53	

Table 5 Fungi isolated by Warcup plate technique arranged by sample date (Data represent the number of plates on which each fungus was identified out of a maximum of 72.)

Fungus species	*Sample number (see Table 1)*								
	1	2	3	4	5	6	7	8	9
Absidia spinosa	0	9	7	6	7	3	2	3	0
Acrostalagmus albus	0	0	0	0	1	6	0	2	0
Acrostalagmus cinnabarinus	0	0	0	0	0	0	0	3	0
Arthrobotrys oligospora	0	0	0	2	0	0	3	1	0
Aspergillus candidus	0	3	3	6	1	3	2	2	8
Aspergillus flavipes	1	0	1	2	0	0	5	7	8
Aspergillus flavus	0	3	2	1	2	2	3	20	3
Aspergillus fumigatus	59	71	71	62	59	61	68	66	60
Aspergillus nidulans	4	9	9	13	4	0	3	3	3
Aspergillus niger	71	72	69	65	45	51	62	71	69
Aspergillus ochraceus	8	4	0	0	0	0	0	7	7
Aspergillus terreus	33	39	39	37	34	38	11	20	14
Aspergillus ustus	0	13	43	55	65	64	57	65	70
Aspergillus versicolor	22	11	6	6	8	14	32	17	8
Botrytis cinerea	0	0	1	0	0	0	0	0	0
Cephalosporium acremonium	39	61	65	58	58	50	50	62	60
Cephalosporium curtipes	15	39	58	40	32	28	22	51	43
Chaetomium spp.	27	16	25	13	20	23	15	16	17
Cladosporium herbarum	5	1	3	4	0	3	7	20	11
Coniothyrium sp.	1	8	0	13	6	4	3	3	14
Cunninghamella echinulata	8	19	17	29	28	20	23	8	3
Curvularia spp.	37	51	39	24	16	24	24	25	21

Fungus species	*Sample number (see Table 1)*								
	1	2	3	4	5	6	7	8	9
Cylindrocarpon spp.	23	31	36	29	28	17	10	33	36
Dactylaria sp.	0	0	0	0	0	6	3	0	0
Dactylella sp.	0	1	0	0	4	8	3	0	2
Dicoccum sp.	0	3	3	3	4	0	0	0	1
Fusarium culmorum	0	0	1	1	0	0	2	0	0
Fusarium oxysporum	43	35	40	6	0	0	14	36	8
Fusarium solani	0	0	1	0	0	0	2	0	0
Fusarium spp.	0	0	5	15	11	13	5	0	28
Gliocladium roseum	4	3	20	21	14	19	10	23	12
Gymnoascus sp.	0	0	0	0	0	0	0	2	0
Helminthosporium nodulosum	0	0	0	0	0	0	0	0	1
Helminthosporium sativum	1	6	4	6	3	2	0	0	2
Hyalopus sp.	0	0	0	0	0	0	0	0	1
Monilia spp.	0	0	0	0	0	0	1	6	2
Monotospora sp.	0	3	0	0	0	3	0	0	1
Mortierella spp.	13	18	28	53	57	55	31	12	6
Mucor circinelloides	30	2	3	19	5	3	9	15	12
Mucor hiemalis	1	17	6	1	0	0	0	0	0
Mucor spp.	8	6	11	35	50	54	49	41	31
Nigrospora sphaerica	2	6	1	0	0	0	2	7	0
Paecilomyces varioti	42	44	67	50	71	64	60	58	58
Pellicularia filamentosa	16	29	24	44	66	57	36	33	29
Penicillium spp.	70	72	71	71	70	68	68	70	71
Periconia byssoides	0	0	0	0	0	0	0	8	3
Periconia felina	0	4	0	0	0	0	4	0	2
Phoma spp.	13	33	42	59	54	56	43	63	64
Piptocephalis sp.	0	0	0	0	4	0	0	0	0
Pullularia pullulans	2	2	1	0	0	0	1	1	2
Pyrenochaeta sp.	3	0	0	4	1	14	9	13	12
Pythium mamillatum	0	0	4	0	0	0	0	0	2
Pythium ultimum	2	16	16	0	0	0	0	0	2
Pythium spp.	21	8	0	43	28	52	30	28	15
Rhizoctonia solani	0	0	2	5	21	10	4	7	5
Rhizopus stolonifer	46	56	53	55	48	60	56	55	62
Scopulariopsis brevicaulis	0	0	0	17	16	28	28	19	20
Sphaeronaema sp.	0	0	0	0	0	0	4	1	2
Spicaria elegans	0	2	0	0	0	0	0	0	0
Spicaria griseola	0	5	5	1	0	8	0	0	0
Spicaria spp.	0	0	2	3	14	5	6	5	14
Sporotrichum roseum	0	2	11	25	20	30	14	0	14
Sporotrichum sp.	0	0	2	10	33	15	21	29	10
Stachybotrys atra	0	0	0	0	0	0	7	2	10
Stemphylium verruculosum	0	0	0	1	0	3	0	10	3
Stemphylium sp.	0	0	0	1	2	0	0	0	10
Syncephalastrum racemosum	9	41	32	29	29	37	36	37	27
Tetracoccosporium paxianum	9	14	33	36	21	25	16	36	30
Thielavia basicola	0	56	58	37	23	28	22	40	35
Thielavia sepedonium	0	0	0	0	0	0	0	3	0
Torula allii	1	0	3	0	0	0	0	0	0
Trichoderma viride	16	15	10	6	7	13	16	16	16
Verticillium albo-atrum	0	1	7	6	10	4	0	1	2
Verticillium sp.	0	0	2	3	0	2	0	0	2
Zygorhynchus moelleri	10	23	15	15	13	7	6	23	37
Dark sterile mycelia	6	0	12	16	7	16	8	10	5
Green sterile mycelia	0	3	0	0	0	0	0	0	0
White sterile mycelia	8	1	0	2	0	0	0	0	0
Total number of species	40	49	52	53	46	48	53	54	60
No. plates with Nematodes	0	6	1	16	16	22	19	7	11

Table 6 The more common fungi isolated by the dilution plate technique arranged by treatment and crop (Numbers are expressed as a percentage of total colonies occurring in each crop treatment.)

Fungal species	*Monocropping*			*Rotation*			*Without Manure*			*5 t.p.a. Manure*			*Mean*
	Cotton	*G'nuts*	*S'ghum*	*Cotton*	*G'nuts*	*S'ghum*	*Cotton*	*G'nuts*	*S'ghum*	*Cotton*	*G'nuts*	*S'ghum*	
Aspergillus [illegible]		0.36			0.18			0.13			0.41		0.09
Aspergillus candidus	1.19	1.43	0.83	0.87	1.65	1.53	1.72	1.64	1.44	0.34	1.44	0.91	1.25
Aspergillus flavus	0.71	0.98	0.65	0.80	1.41	1.08	0.96	1.13	1.15	0.56	1.26	0.58	0.94
Aspergillus fumigatus	12.95	8.39	7.79	9.19	8.38	9.90	12.68	12.91	9.83	9.44	3.86	7.86	9.43
Aspergillus nidulans	4.33	1.99	1.78	1.70	1.08	0.94	0.67	0.42		5.36	2.65	2.71	1.97
Aspergillus niger	12.43	5.66	10.31	12.61	8.40	9.88	14.56	8.29	10.99	10.53	5.77	9.21	9.88
Aspergillus ochraceus	0.63	1.11	0.41	0.68	2.01	0.66	0.50	1.45	0.58	0.81	1.68	0.49	0.92
Aspergillus terreus	1.49	0.30	0.50	0.48	0.93	0.73	0.73	0.12	0.10	1.24	1.12	1.13	0.74
Aspergillus ustus	4.80	6.40	3.11	5.23	3.41	3.59	3.31	2.56	2.28	6.71	7.25	4.42	4.42
Aspergillus versiscolor	2.43	1.19	2.77	1.80	1.90	3.08	1.39	0.51	1.84	2.85	2.58	4.01	2.19
Cephalosporium spp.	1.36	2.53	1.69	1.15	1.90	1.72	1.48	1.93	1.55	1.04	2.50	1.86	1.73
Chaetomium spp.	0.58	1.77	0.47	0.50	0.41	0.64	0.41	1.59	0.76	0.66	0.58	0.35	0.73
Cladosporium herbarum	5.36	2.49	2.58	7.87	2.36	3.59	9.59	1.89	3.24	3.64	2.95	2.93	4.04
Curvularia spp.	0.51	0.81	0.61	0.89	0.73	0.74	0.89	1.04	0.88	0.51	0.50	0.46	0.71
Cylindrocarpon spp.	1.48	1.13	1.01	1.74	0.98	1.59	1.56	0.84	1.42	1.67	1.27	1.18	1.32
Fusarium spp.	3.35	5.58	4.85	5.14	4.13	6.16	4.49	3.09	4.74	3.99	6.61	6.27	4.87
Gliocladium roseum		0.14	0.68	0.12	0.18	0.47	0.04	0.13	0.33	0.08	0.18	0.82	0.26
Helminthosporium spp.			0.11	0.11		0.41	0.06		0.41	0.04		0.11	0.10
Humicola spp.	0.81	0.12	0.21	1.32	0.29	0.05	1.24	0.23	0.20	0.89	0.17	0.06	0.47
Malustela aeria		0.50	0.06	0.46	0.78	0.14	0.34	0.54	0.11	0.11	0.74	0.09	0.32
Monilia spp.	0.80	2.16	1.03	1.27	0.73	0.79	1.24	0.97	0.82	0.83	1.92	1.00	1.13
Monotospora sp.	0.16	0.18	0.16	0.26	0.09	0.05	0.36	0.24	0.16	0.06	0.04	0.05	0.15
Morticrella spp.	0.12	0.07	0.25	0.43	0.06	0.11	0.52	0.12	0.25	0.03		0.11	0.17
Myrothecium spp.	0.21	1.84	0.75	0.94	0.70	0.26	0.74	1.72	0.96	0.41	0.82	0.05	0.78
Neocosmospora vasinfecta		0.62			0.11	0.06		0.39	0.06		0.34		0.13
Paecilomyces spp.	2.64	6.14	3.22	3.92	4.23	3.47	3.44	6.08	3.28	3.12	4.29	3.42	3.91
Penicillium spp.	30.75	30.84	42.79	26.57	35.26	33.61	24.14	34.49	38.03	33.17	31.61	38.37	33.30
Periconia spp.	0.46	0.08	0.22	0.34	0.55		0.74	0.59	0.12	0.06	0.04	0.10	0.28
Phoma spp.	1.32	0.85	1.07	0.88	1.84	1.23	1.45	1.98	1.42	0.75	0.71	0.88	1.20
Pullularia pullulans	0.41	0.27	0.24	0.50	0.49	0.79	0.57	0.34	0.51	0.34	0.42	0.51	0.45
Pyrenochaeta sp.	2.33	1.16	0.49	1.11	2.61	0.92	1.23	1.01	0.91	2.20	2.76	0.50	1.44
Rhizopus stolonifer	0.18	0.74	0.27	0.56	0.92	0.17	0.20	0.52	0.36	0.54	1.14	0.08	0.47
Scopulariopsis brevicaulis	1.00	0.84	0.80	1.69	0.43	1.96	0.70	0.01	1.66	1.98	1.25	1.10	1.12
Spicaria spp.	0.11	0.45	0.68	0.43	0.37	0.85	0.28	0.52	0.70	0.27	0.30	0.83	0.48
Stachybotrys atra	0.18	0.22	0.68	0.40	0.13	0.44		0.09	0.21	0.58	0.26	0.91	0.34
Stemphylium spp.	0.19	0.40	0.09	0.42	0.38	0.09	0.52	0.48	0.03	0.09	0.30	0.15	0.26
Syncephalastrum racemosum	0.19	0.14	0.14	0.03	0.31	0.21	0.19	0.30	0.22	0.03	0.14	0.12	0.17
Tetracoccosporium paxianum	0.43	0.67	0.08	0.81	0.19	0.57	0.87	0.36	0.44	0.37	0.50	0.21	0.46
Thielavia spp.	2.29	4.00	1.93	1.80	2.88	2.66	2.24	4.36	3.20	1.85	2.51	1.38	2.59
Torula allii	0.07	0.42	0.15	0.14	0.33	0.57	0.08	0.16	0.51	0.13	0.59	0.21	0.28
Trichoderma viride		0.19	0.57	0.14	0.29	0.42	0.08	0.16	0.48	0.06	0.32	0.53	0.27
Dark sterile mycelia	2.24	1.32	1.53	2.26	1.66	1.84	2.98	1.34	1.53	1.53	1.65	1.85	1.81
White sterile mycelia	1.56	2.76	1.32	1.30	3.52	1.14	1.58	2.62	1.03	1.28	3.66	1.43	1.93

Table 7. The more common fungi isolated by the Warcup soil plate technique, arranged by treatment and crop (Data represent the number of plates on which each fungus occurred.)

Fungus species	*Monocropping*			*Rotation*			*No Manure*			*With Manure*		
	C	*G*	*S*	*C*	*G*	*S*	*C*	*G*	*S*	*C*	*G*	*S*
Absidia spinosa	3	5	15	2	7	5	1	7	6	4	5	14
Aspergillus flavus	7	12	4	2	8	3	6	7	3	3	13	4
Aspergillus fumigatus	107	85	94	102	86	103	105	99	102	104	72	95
Aspergillus nidulans	10	3	11	11	4	9	0	1	0	21	6	20
Aspergillus niger	104	86	102	101	84	98	105	93	103	100	77	97
Aspergillus ochraceus	6	3	2	5	3	7	7	2	2	4	4	7
Aspergillus terreus	67	43	35	39	48	33	52	52	33	54	39	35
Aspergillus ustus	75	77	67	71	70	72	72	78	65	74	69	74
Aspergillus versicolor	39	10	11	31	11	22	38	8	11	32	13	22
Cephalosporium acremonium	86	76	83	89	85	84	88	87	83	87	74	84
Cephalosporium curtipes	49	57	55	47	55	65	50	60	53	46	52	67

Fungus species	*Monocropping*			*Rotation*			*No Manure*			*With Manure*		
	C	*G*	*S*	*C*	*G*	*S*	*C*	*G*	*S*	*C*	*G*	*S*
Chaetomium spp.	30	27	34	17	32	32	19	39	38	28	20	28
Cladosporium herbarum	10	5	14	8	3	14	8	7	14	10	2	13
Coniothyrium sp.	11	7	7	12	7	8	13	9	3	10	5	12
Cunninghamella echinulata	10	33	31	13	36	32	7	26	36	16	43	27
Curvularia spp.	44	41	49	52	28	47	47	43	52	49	26	44
Cylindrocarpon spp.	38	43	43	35	36	48	38	36	40	35	43	51
Fusarium oxysporum	34	29	27	31	22	39	35	25	27	30	26	39
Fusarium spp.	18	7	14	15	9	14	20	8	13	13	8	15
Gliocladium roseum	15	13	32	17	29	21	16	27	18	16	15	35
Helminthosporium sativum	3	8	3	3	4	3	2	5	2	4	7	4
Mortierella spp.	44	49	51	37	46	46	27	35	34	54	60	63
Mucor circinelloides	20	11	14	28	9	17	20	8	18	28	12	13
Mucor hiemalis	11	0	2	11	0	1	13	0	2	9	0	1
Mucor spp.	46	48	38	49	52	51	49	48	49	46	52	40
Paecilomyces varioti	87	88	80	94	84	81	94	85	86	87	87	75
Pellicularia filamentosa	50	70	46	53	55	60	36	44	47	67	81	59
Penicillium spp.	106	106	106	106	104	103	106	104	108	106	106	101
Phoma spp.	67	72	76	62	83	68	65	85	72	64	70	72
Pyrenochaeta spp.	7	9	8	9	16	7	7	9	5	9	16	10
Pythium ultimum	11	0	5	14	0	6	11	0	2	14	0	9
Pythium spp.	33	51	28	32	53	28	26	52	28	39	52	28
Rhizoctonia solani	4	14	6	11	9	10	0	5	2	15	18	14
Rhizopus stolonifer	77	90	62	91	88	83	74	90	82	94	88	63
Scopulariopsis brevicaulis	13	19	33	10	26	27	16	28	29	7	17	31
Spicaria griseola	7	7	10	12	7	5	10	6	9	9	8	6
Spicaria spp.	4	13	9	6	11	6	5	12	10	5	12	5
Sporotrichum roseum	29	6	26	27	3	25	31	4	24	25	5	27
Spotrichum sp.	13	32	16	10	38	13	10	35	14	13	35	15
Stachybotrys atra	3	4	1	5	4	3	6	2	2	2	6	2
Syncephalastrum racemosum	23	52	44	48	62	48	36	62	44	35	52	48
Tetracoccosporium paxianum	30	36	39	36	35	44	40	40	43	26	31	40
Thielavia basicola	44	49	52	51	44	59	42	47	59	53	46	52
Trichoderma viride	11	20	22	28	9	25	22	11	23	17	18	24
Verticillium albo-atrum	3	8	5	10	2	5	4	5	3	9	5	7
Zygorhynchus moelleri	29	11	34	30	22	23	34	14	21	25	19	36
Dark sterile mycelia	15	12	5	23	8	17	16	12	11	22	8	11

KEY: C = Cotton
G = Groundnuts
S = Sorghum

Aspergillus ochraceus: always uncommon; very rare during rains; mostly associated with cotton.

Aspergillus terreus: commonest on manured soil and with cotton.

Aspergillus ustus: very rare at start of season; more frequent with high soil moisture, becoming less common at start of dry season; not affected by manure or crop treatment.

Aspergillus versicolor: isolated throughout season; greatly increased by manuring; less common with groundnuts.

Curvularia spp.: incidence low during rains, but increased at start of dry season; less common on manured plots.

Cladosporium herbarum: seasonal periodicity similar to *Curvularia.*

Cunninghamella spp.: associated with soils of high moisture content; rare under cotton.

Cylindrocarpon spp.: commoner at start of season than at end.

Humicola spp.: markedly associated with soils carrying cotton.

Mortierella spp.: commonest with high soil moisture and low temperature; more abundant in manured soil.

Mucor spp.: commoner during rains; not much affected by manuring or crop sequence, but a slight increase with cotton.

Myrothecium spp.: common in unmanured, monocropped groundnut soils.

Neocosmospora vasinfecta: strongly associated with groundnuts.

Paecilomyces spp.: always abundant; slightly less common in drier soils.

Pellicularia filamentosa and *Rhizoctonia solani* (both segregates of *Corticium solani*): commoner with manure and with monocropped groundnuts; highest incidence in July-September.

Penicillium spp.: unaffected by crop, fertilizer or cropping sequence.

Phoma spp.: frequent throughout season; most common in unmanured soils.

Pyrenochaeta spp.: commoner in unmanured soil; isolated most often in latter half of sampling period.

Pythium spp.: commonest with high soil moisture and low temperature; more abundant with manure.

Rhizopus stolonifer: very common; most frequent with groundnuts.

Scopulariopsis brevicaulis: more common at end of season.

Sporotrichum spp.: most frequent during rains.

Syncephalastrum racemosum: slightly more common with rotation than with monocropping.

Tetracoccosporium paxianum: more frequent in unmanured soils.

Thielavia basicola: highest numbers found in May, June and October, coinciding with high soil temperatures.

Trichoderma viride: variable but never rare; incidence highest in sorghum plots; more common at start of season.

Verticillium spp.: incidence highest when soil temperature at minimum.

All the effects of external factors on the individual fungi mentioned above were observed both on dilution plates and on Warcup soil plates unless otherwise stated. Any apparent effects that occurred with one technique but not the other have not been mentioned, except for groups such as the Phycomycetes which are infrequently isolated by the dilution plate technique.

DISCUSSION AND CONCLUSIONS

Microbial inter-relationships in soil are very complex and only a proportion of the fungi present can be isolated by known techniques. In this experiment manuring greatly increased the numbers of soil fungi. In the unmanured soils the smaller numbers of fungi associated with monocropped cotton may have been due to the cotton stalks having been uprooted at the end of the season which left very little behind in the way of plant residues, whereas sorghum stumps remain in the soil until the land is ploughed the following season. Although groundnuts are also dug out, this crop does increase the nutrient status of the soil by nitrogen fixation.

Manuring also brought about minor qualitative differences. Some fungi were affected by the different crops and cropping sequences, but independent fluctuations within groups tended to cancel out. Therefore, it was only possible to demonstrate gross changes in the general composition of the mycoflora because of the limitations of the isolation techniques.

Penicillium and *Aspergillus* together made up about two-thirds of the isolates on the dilution plates and both genera appeared on almost every Warcup plate. The *Aspergillus/Penicillium* ratio did not deviate greatly from unity during the period of sampling; there was no tendency for *Aspergillus* to increase with higher temperatures at the expense of *Penicillium*. (*Aspergillus* is normally commoner in warmer soils, and *Penicillium* in cooler, but the range of soil temperatures experienced during this experiment was probably too narrow for such a trend to be observed.) *Aspergillus niger* was more frequent in unmanured soil in this trial. Other work in Northern Nigeria has shown that, as a contaminant of groundnut seeds, *A. niger* is commoner in the hot dry conditions of the northern provinces than in the cooler, wetter soils of the southern part of the country (McDonald, unpublished data). This species has also been shown to cause a collar rot of groundnuts grown in the light sandy soils in the north (Perry, 1966). *A. niger* would therefore appear to be a fungus associated with low fertility, low moisture and high temperature. *Aspergillus flavus* is now of great importance as it can produce a toxic carcinogen when growing on groundnuts; it is noteworthy that this species was more frequently associated with groundnuts than with the other two crops.

Although *Fusarium* is an important genus with many pathogenic species, accurate species determination is time-consuming and difficult. Therefore, not all isolates were identified down to species and it can only be concluded that *Fusarium* was favoured by manuring. The genus as a whole was not affected by crop or by time of sampling. *Curvularia* spp. and *Cladosporium herbarum* showed seasonal periodicity in soil which agreed closely with their fluctuations as components of the air-spora (Dransfield, 1966). *Verticillium* was associated in this trial with low soil temperatures. This genus is more important as a pathogen in temperate regions than in the tropics.

This general survey has indicated that each crop can affect[8] certain fungi, especially when the crop is grown in continuous monoculture. However, the effect was diluted by taking soil samples remote from the roots and application of organic manure introduced additional factors to alter the equilibrium. The effect of a particular crop on the mycoflora would be more clearly observed if only unmanured, monocropped plots were sampled; soil micro-organisms would then be entirely dependent on root exudates and crop residues. The effect would be still more concentrated if rhizosphere soil were used instead of soil more distant from the roots as in the present multi-factorial trial. Further experiments are in progress on these lines.

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