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THE OCCURRENCE OF MICROMYCOFLORA IN THE STEM BASE AND ROOTS OF CEREALS IN SOUTHERN FINLAND

KAIHO MÄKELÄ and LEENA MÄKI

MÄKELÄ, K. & MÄKI, L. **The occurrence of micromycoflora in the stem base and roots of cereals in southern Finland.** Ann. Agric. Fenn. 19: 187—222. (Agric. Res. Centre, Inst. Pl. Path. SF-01300 Vantaa 30, Finland).

About 1035 samples of mature cereals from 119 localities and 1029 shoot samples from 91 localities in southern Finland were examined in moist chamber cultures. Microfungi were determined in the stem base and roots of five cereals in 1975—1978. The total numbers of fungal species found were about 130 belonging to 100 genera. Of these the majority (70 genera) belonged to the group *Deuteromycotina* and of these, 62 genera to the order *Hyphomycetes*. The group *Ascomycotina* had 15 genera and *Zygomycotina* 7 genera. In the mature cereal samples the amounts of fungi were nearly 15 % greater than in the shoots. The highest numbers of fungi among the samples were found in wheat and barley, the fewest species in oats. The number of fungal species in individual mature cereal samples showed relatively small variations between the different cereal species, being on the average 3—6 with the total variation 0—12. In the individual shoot samples the number of fungal species fluctuated more than in the mature plants. Also the annual fluctuations in the shoots were greater than in the mature cereals.

The majority of the fungi determined were saprophytes. In the mature cereals and in the shoots of winter cereals in autumn an average of 20—30 % of the fungi were parasites. In the spring the proportion of parasites varied from 15 to 40 %. The most common parasitic fungi were *Fusarium culmorum* (W. G. Smith) Sacc., *F. avenaceum* (Corda ex Fr.) Sacc., *Gaeumannomyces graminis* (Sacc.) v. Arx et Olivier, *Rhizoctonia solani* Kühn and *Septoria nodorum* Berkeley. The most prevalent saprophytic micromycophlora were *Cladosporium*-, *Alternaria*-, *Penicillium*- and *Acremonium*-species, *Gliocladium roseum* Bainier as well as *Streptomyces*-species.

Some of the fungi appeared similarly in all the cereals. Many of the fungi preferred some particular cereal instead of the others. The age of the cereal stand and the time of sample collection had an effect on the incidence of many of the fungi. There were large differences in their prevalence according to the year.

Index words: Microflora in the stem base and roots of cereals.

INTRODUCTION

Interest in the micromycoflora of cultivated soils has increased greatly during the past two decades in all parts of the world (BARRON 1968, DOMSCH and GAMS 1970, SCHIPPERS and GAMS 1979). This increased interest is due in large part to the intensified methods now employed in agriculture as well as to the ever increasing use of monoculture, i.e. the growing of only one type of cereal, with its associated drawbacks. It has therefore been considered important to

investigate the species of fungi occurring in cereals, the relationships between the different species as well as the variations in fungal incidence and the factors causing these fluctuations (PARKINSON and PEARSON 1965, STETTER and LEROUL 1979). In recent years much emphasis has been given to questions relating to biological control of plant pathogens (BAKER and COOK 1974).

In Finland there have been made only a few studies on soil microfungi. Some investigations have been made on the microfungi occurring in forests (FEHÉR 1933, SVINHUFVUD 1937, MIKOLA and HINTIKKA 1956). Other studies have been carried out on the metabolism of fungi in agricultural soil (VARTIOVAARA 1935). The fungi causing root rot decline of red clover in leys have also been investigated (YLIMÄKI 1967). The soil fungi inhabiting cereal fields have been discussed only briefly in connection with studies on foot rot of cereals. In a study on shrivelhead of spring wheat carried out in the years 1946—1953, HÅRDH (1953) isolated from the eyespots of stembreak-infected plants a total of 16 species belonging to 11 genera. Among these were *Cercosporella herpotrichoides* Fron, *Fusarium avenaceum* (Fr.) Sacc. and *F. culmorum* (W. G. Sm.) Sacc. In the year 1958 the additional species *Ophiobolus graminis* Sacc. was isolated for the first time in Finland from the stem base of spring wheat (IKÄHEIMO 1959).

In the years 1962—1964 TOIVIAINEN (1974) investigated the distribution of foot and root rot of cereals on the basis of material comprising different cereal species from 142 farms. The most common fungus was *Gaeumannomyces graminis* (Sacc.) v. Arx et. Olivier, and also *Cercosporella herpotrichoides* occasionally appeared in large amounts. *Fusarium culmorum* was incountered to some extent, while *Rhizoctonia solani* occurred only sparsely.

TOIVIAINEN (1974) also studied spring wheat and barley material which had been grown for 10 consecutive years in a monoculture experimental area. In this material he isolated from the stem base of the plants a total of 26 species of fungi belonging to 21 genera.

The importance of cereal growing in Finland has increased during the past two decades, while the area devoted to grasslands has correspondingly decreased. In 1976, for example, cereals comprised 50 % of the total arable land (2 640 million hectares) as contrasted with only 34 % in 1955. Barley (18 % of the arable land area) and oats (22 %) grow well throughout the whole country. Rye (1,4 %) is grown in the southern and central parts of the country. The areas devoted to winter wheat (1,4 %) and spring wheat (7 %) are found in southwest and southern Finland. In recent years the area grown to barley has increased whereas wheat and rye have diminished (ANON. 1955, 1976).

The purpose of this investigation was to study during the three-year period 1975—1978 the species of microfungi occurring in the stem base and roots of cereals, the quantitative relationships between the different species, and the incidence of these fungi in relation to different cereal species, different times of the growing season as well as different ages of the stands. The location of this study was southern Finland, which is the best area in the country for growing cereals.

The original intention of this study was to determine only the occurrence of foot and root rot of cereals. However, it was soon discovered that the fungal material was so interesting and abundant that it was decided to investigate the fungi in their entirety. This decision was made because the knowledge of many of these fungi is so incomplete that one could not with certainty omit any species as being unnecessary. Also included were all those fungi, such as *Drechslera* and *Septoria* species as well as *Rhynchosporium secalis* (Oud.) J. J. Davis, which cause root and base damage to yong shoots. The causal agents of foot and root rots in cereals are discussed in greater detail in a separate paper (MÄKELÄ and PARIKKA 1980).

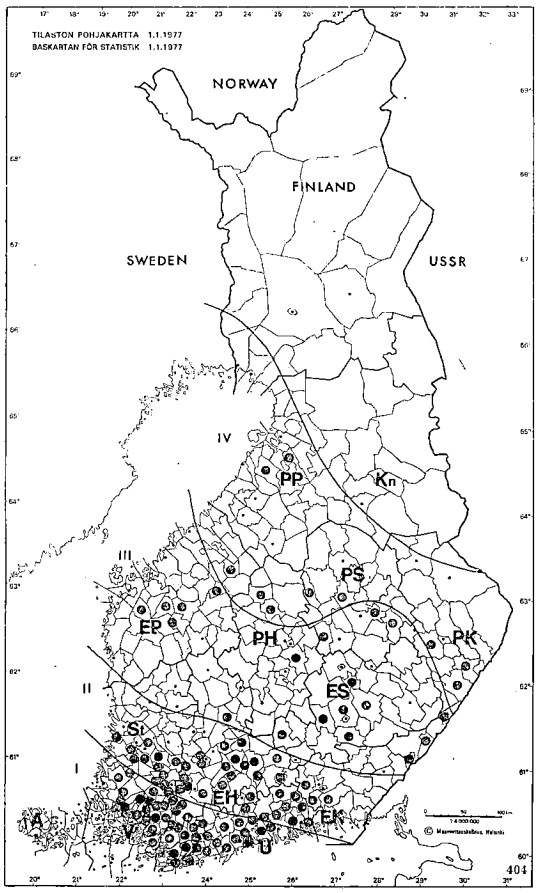

Fig. 1. Origin of the mature cereal samples by localities in Finnisch cultivation zones (I—IV) in 1975—1977.

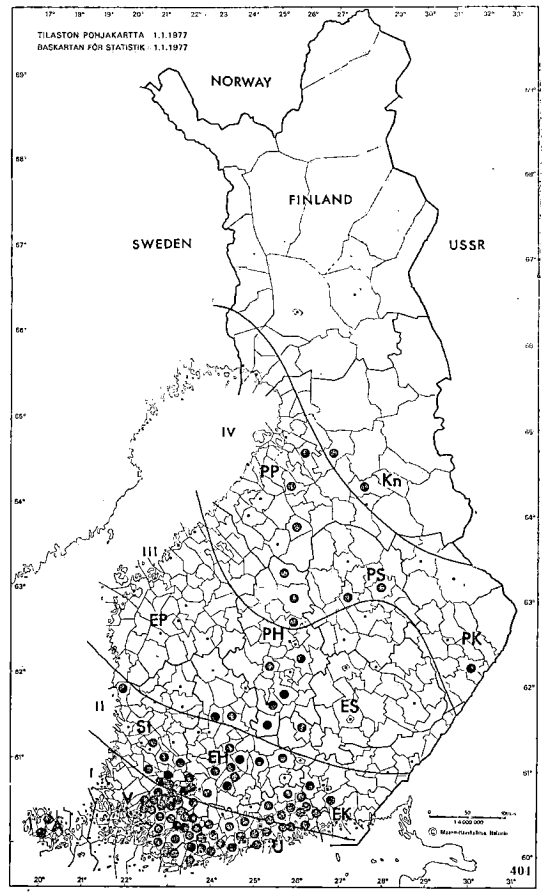

Fig. 2. Origin of the shoot samples of cereals by localities in Finnish cultivation zones (I—IV) in 1976—1978.

MATERIAL AND METHODS

Region

The region of this study comprised mainly the southwestern and southern parts of the country, in the cultivation zones I and II (Figs. 1 and 2). This region makes up ⅓ of the total arable land in Finland (2,6 million hectares). It is especially the production district for bread grains, and in this district continuous cropping (monoculture) of cereals has been practiced since the 1960's. During the years of this investigation the above-mentioned region included over 90 % of the winter wheat area of the country, nearly 80 % of the spring wheat area, 60 % of the rye and 40 % of both barley and oats (ANON. 1975, 1976, 1977).

The soil type in the region of the study is principally clay, especially in Varsinais-Suomi. In Uusimaa fine sand and silt also occur in some places in addition to clay. In South Häme and Satakunta the proportion of clay soils is considerably less while silt, fine sand and light mineral soils are correspondingly greater (KURKI 1979). The cereal samples were collected chiefly from clay and silt soils, to some extent also from sandy soils.

Weather conditions

The weather conditions in this region are the most advantageous in the country. The length of the growing season (+5 °—+5 °C) is 170—180 days and the average temperature is 12—13 ° C. The precipitation averages 40—80 mm per month and 550—650 mm per year. The latter part of the growing season has normally more rainfall than the early part. The average depth of snow in southern Finland is 20—40 cm. The snow cover protects the overwintering plants from extreme temperature fluctuations and it also retards the freezing of the soil. The length of the growing season, the temperature conditions and the precipitation can show considerable annual variations (KOLKKI 1966, SUOMELA 1976).

During the years of this investigation there were large variations in the weather conditions. In addition regional differences also occurred. As a whole 1975 had a warm growing season with low rainfall. The year 1976 was cool with low rainfall, while 1977 was cool with high rainfall. The amount of rain was greater in the coastal area than in the interior of the country.

The growing season in 1975 was, except for frost nights in May and a cool June, generally warm and long, extending late into the autumn. Long periods of dry weather occurred in Kymenlaakso and South Häme. In contrast there were many local rain showers, especially in the coastal areas. The yields of grain were somewhat smaller than normal. The winter was mild with little snow.

In 1976 the growing season was generally cool. Only May and the beginning of August were warm. This season was also somewhat drier than normal, although local rain showers occurred. The autumn was cool and the growing season came to an early end. The grain yields were record large.

The growing season in 1977 began unfavourably. The winter had been long and very snowy, and the fall-sown cereals suffered from winter damage. Spring sowing was delayed because of rains. With the exception of short warm periods, the summer was cool and rainy. The autumn was warm and wet. The grain yields were low and of poor quality.

The winter of 1977—1978 had little snow and the ground frost was deep. Dry winds in the spring of 1978 caused damage to the shoots of the winter cereals. Spring ploughing was delayed as a result of the deep ground frost. The month of May was very dry, while June had heavy rains. (ANON. 1975, 1976, 1977, 1978).

Samples

The samples were collected principally from farmers' fields, and to a minor extent from the experimental stations of the Agricultural Research Centre. They were gathered every year from the same localities and partly from the same fields. The samples comprised both mature grains at the milky development stage (stage 11, LARGE 1954) and young shoots (stages 1 and 2, LARGE 1954). The mature samples were collected from a total of 1035 fields in 119 localities, and the shoot samples were taken both in the autumn and spring from a total of 1029 fields in 91 localities (Table 1). All cereal species were represented in the material. Most abundant were samples of winter and spring wheat and barley, while oats had the fewest samples. The numbers of samples varied from year to year. Despite this, relative proportions of the cereals represented in the total material remained similar, especially in the mature samples. In 1975 and 1976 there were fewer rye samples than usual, while in 1976 the numbers of spring cereal shoots were smaller than usual. Especially numerous were the samples of spring wheat in 1977.

In the districts where the samples were gathered, the most common cereal varieties grown during the years of this investigation were Finnish, namely the following: rye: Voima, Toivo and Pekka; winter wheat: Vakka, Nisu

Table 1. The number of field samples investigated and localities of collections in 1975—1978.

Cereals	Year	Mature cereals in autumn		Shoots			
				in autumn		in spring	
		No. of localities	No. of fields	No. of localities	No. of fields	No. of localities	No. of fields
Rye	1975	(6)	(6)	26	30	—	—
	1976	17	24	15	21	15	16
	1977	27	47	29	51	26	55
	1978	—	—	—	—	27	45
Total		35	77	48	102	42	116
Winter wheat	1975	31	83	37	84	—	—
	1976	32	72	19	55	35	80
	1977	45	94	33	77	40	83
	1978	—	—	—	—	35	104
Total		60	249	48	216	49	267
Spring wheat	1975	48	111	—	—	—	—
	1976	40	99	—	—	21	47
	1977	55	152	—	—	25	49
	1978	—	—	—	—	9	15
Total		84	362	—	—	37	111
Barley	1975	49	95	—	—	—	—
	1976	28	52	—	—	35	50
	1977	46	95	—	—	34	70
	1978	—	—	—	—	16	40
Total		83	242	—	—	60	160
Oats	1975	29	35	—	—	—	—
	1976	13	36	—	—	14	19
	1977	24	34	—	—	23	32
	1978	—	—	—	—	5	6
Total		54	105	—	—	40	57
All the cereals	1975	75	330	40	114	—	—
	1976	50	282	24	76	48	212
	1977	70	423	43	128	51	289
	1978	—	—	—	—	48	210
Total		119	1 035	61	318	80	711

and Linna; spring wheat: Ruso and Tähti; barley: Pomo, Otra (6-rowed), Karri and Ingrid (2-rowed); oats: Ryhti, Tiitus, Pendek and Hannes (Off. Statist. Finl. Agric. 1976).

Time of collection

The time of the season when the samples were collected varied considerably from year to year, depending on the weather (Table 2). In 1975

Table 2. Date of collection of samples researched in 1975—1978.

Year	Mature cereal samples gathered in autumn	Shoot samples		
		winter cereals gathered		spring cereals gathered in spring
		in autumn	in spring	
1975	23. 7.—19. 8.	9. 10.— 6. 11.	—	—
1976	1. 8.— 9. 9.	28. 10.—11. 11.	26. 4.—21. 5.	6. 6.—22. 6.
1977	10. 8.—22. 9.	8. 10.— 1. 11.	2. 5.—19. 5.	5. 6.—25. 6.
1978	—	—	13. 5.— 5. 6.	15. 6.—25. 6.

the grains ripened early. The collections were begun at the end of July and continued for nearly a month. In 1976 sample gathering was done in August and the first part of September, lasting more than a month. In 1977, due to the very late development, collections were made at the end of August for the winter cereals and as late as the end of September for the spring cereals, or a total of 1½ months. The shoot samples of the winter cereals were generally collected in October, but in 1976 this took place in late November and even in the following May. The shoots of spring cereals were usually taken in June. Exceptionally early was the spring of 1975 while 1978 was late.

Examination of the samples

All the samples, both of mature cereals and shoots, were taken from the fields with their roots. In order to facilitate visual examination, the roots were carefully rinsed under running water. The most typical of the mature plants were severed at about 10 cm above the base, and the basal part with its roots was placed in a Petri dish (Ø 15 cm) on moist filter paper for the purpose of culturing the fungal species. The shoot samples with their roots were put in Petri dishes and their upper leaves were removed. The dishes were initially kept for two weeks at room temperature (+20—+24 °C) followed by two weeks at +10 °C and subsequently another 1—2 weeks at room temperature. During this culture period the fungi were examined a few times with a stereomicroscope. In addition a light microscope was also used for measurements and microphotographs. Slides were prepared with lactic acid, and these also were measured and photographed.

The results are presented by cereal species and by years, and furthermore the totals for all years are listed separately for mature cereals and for shoots. The incidence of fungi is expressed as percentage by number of the examined samples or fields.

RESULTS

Total numbers of fungi

The total numbers of fungi varied depending on the cereal species, the stage of development and the year (Table 3). In the mature cereal samples (Fig. 3) the amounts of fungi were nearly 15 % greater than in the shoots (Fig. 4). The highest numbers of fungi among the mature plants were found in wheat and barley, while among the shoots it was the winter cereals, especially winter wheat, which were most infected. The fewest species of fungi were encountered in oats. In the winter cereals there were virtually no differences in numbers of fungal pathogens at the different stages of development. On the other hand, in the spring cereals there were 30—40 % fewer fungal species than in the corresponding mature plants. The

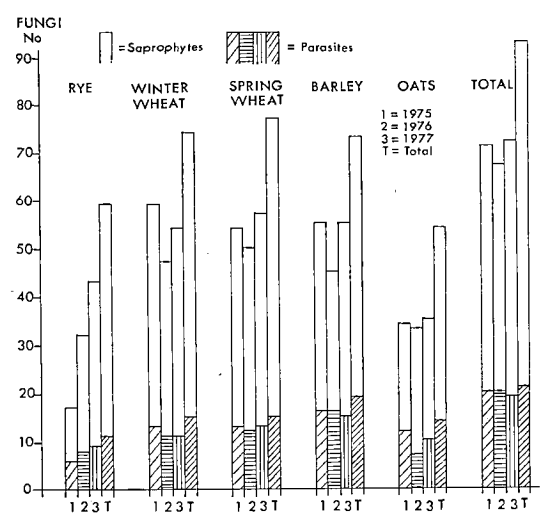

Fig. 3. Parasites and saprophytes, total no. per cereal in the stem base and roots of the mature cereals in 1975—1977.

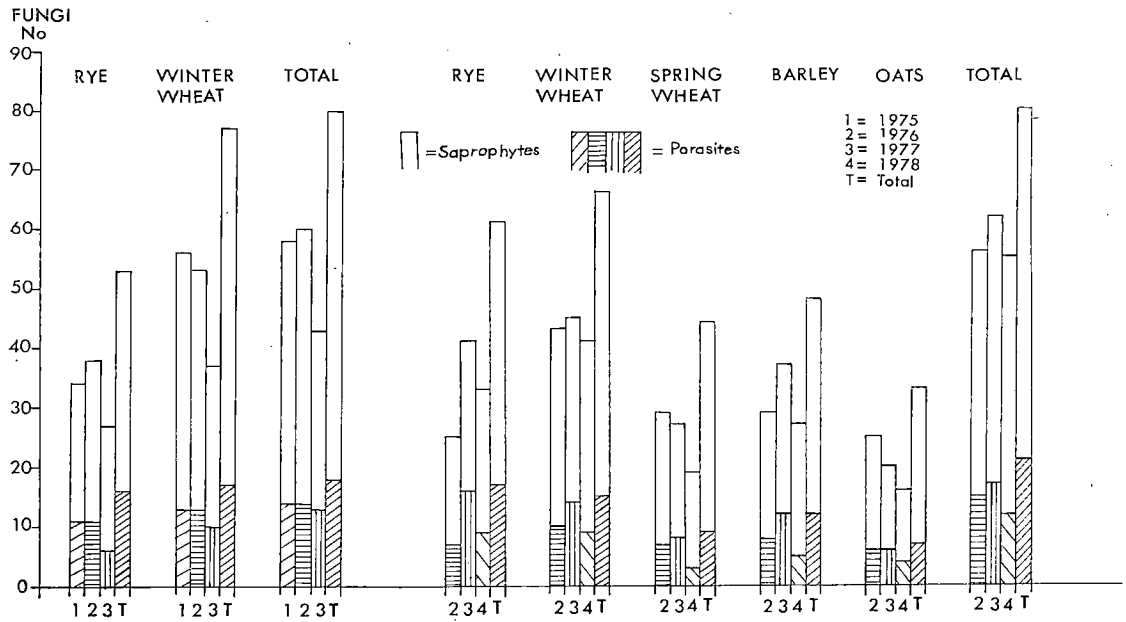

Fig. 4. Parasites and saprophytes, total no. per cereal in the shoot samples in autumn and in spring gathered.

bulk of the fungal species were common to all the different cereals. The total number of fungi averaged 1/5 greater for all the cereals combined than for each cereal species separately. Concerning the shoots the corresponding ratio was over 1/4. Thus the variation in mycoflora between the different cereal species was greater in the shoots than in the mature plants.

Similarly there were differences between the years investigated. The most sparse occurrence of fungi in mature plants was in 1976 while in the shoots it was autumn 1977 and spring 1978. The total numbers of fungi in the same cereal considering all the years combined were 1/3—1/4 greater than considering each individual year. Thus the annual variations were greater in the shoots than in the mature cereals.

Numbers of fungi in the individual samples

Although the total numbers of fungi in the different cereals during the experimental period could be very high, the species of fungi in individual samples on the individual fields were rather scanty.

The numbers of fungal species in individual mature cereal samples showed relatively small variations between the different cereal species, being on the average 3—6 with the total variation 0—12 (Fig. 5). The largest numbers of species occurred on wheat, averaging from 3,7 to 6,3 in the different years (range 0—12). The fewest species were found on barley, averaging 3,8—4,5 (range 0—10). The magnitude of microflora on barley remained about the same from year to year.

In the individual shoot samples the number of fungal species fluctuated more than in the mature plants (Fig. 6). The differences between the cereal species were also greater. The most fungal species, averaging 4,6—7,6 (range 0—14), were found in the shoots of winter wheat which were collected in the autumn. These figures were even greater than in the mature winter wheat plants. The fewest species were on oat shoots, averaging 3,2—4,7 (range 0—8). Barley

Table 3. Frequency of fungi on the cereal samples investigated in 1975—1978.

Fungi	The mature cereal samples gathered in autumn									The shoot samples gathered in autumn						The shoot samples gathered in spring								
	Cereal					All the cereals		Total		Cereal		The both cereals		Total		Cereal					All the cereals			Total
	Rye	Winter wheat	Spring wheat	Barley	Oats					Rye	Winter wheat					Rye	Winter wheat	Spring wheat	Barley	Oats				
	Fields																							
	77	249	362	242	105	330	282	423	1 035	102	216	114	76	128	318	116	267	111	160	57	212	289	210	711
	Year																							
	mean in 1975—1977					1975	1976	1977	1975–1977	mean in 1975—1977		1975	1976	1977	1975–1977	mean in 1976—1978					1976	1977	1978	1976–1978
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Myxomycetes																								
Physarales																								
Didymium spp.	1	2	1	1	0	3	0,4	0,2	1		0,2		1		0,1									
Zygomycotina																								
Mucorales																								
Absicia glauca			0,3		0,1				+										0,6	0,1				+
Mucor spp.	3	1	2	0,4	2	0,3	1	2	1	9	19	28	13	6	15	6	7	13	4	9	9	5	9	7
Mycotypha microspora		0,8							0,2															
Rhizopus nigricans		1	3	1	1	1	3	1	2	3	5	7	8		4	1	0,4	8	6	5	5	2	1	3
Rhopalomyces spp.		1	0,3		1		0,4	1	0,5	1					0,3	1			0,6	2		0,3	2	0,7
Thamnidium elegans			0,3					0,2	0,1		0,5			0,8	0,3			1			0,5			0,1
Ascomycotina																								
Plectomycetes																								
Eurotiales																								
Gymnoascaceae	1	2	2	1	3	0,6	3	2	2															
Emericellopsis sp.	1	1	1	1	4	3	1		1	2	6		20	1	5		0,4		0,6	4	1	0,3	1	1
Pyrenomycetes																								
Sphaeriales																								
Apiosordaria verruculosa																								
Ceratocystis sp.	3	0,4	2	3	4	2	1	3	2															
Chaetomidium sp.										1		1			0,3	1			0,6					0,3
Chaetomium spp.	1	3	0,3	2	1	1	3	0,5	1	7	3	1	11	4	4	3	5	5	11	9	12	5	2	7
Gaeumannomyces graminis	23	23	24	15	2	4	11	36	19															
Gaeumannomyces sp.				0,8				0,5	0,3															
Gibberella zeae		2	0,6	0,4	1	2	0,4	0,5	1															
Melanospora spp.	18	16	21	11	31	24	24	10	18		3	1	3	3	2		0,4	5	3	2	0,5	0,3	5	2
Monographella nivalis																	0,4						0,5	0,1
Sphaeroderma episphaeria		1	1		1	0,6	0,4		0,4									1			0,5			0,1
Sordaria spp.				1	1	1		0,2	0,4															
Sporormia sp.				0,4		0,3			0,1															

Loculoascomycetes																									
Pleosporales																									
Leptosphaeria spp.	1	2		1	2	2		1	1							1	5		0,6		0,5	2	3	2
Pleospora spp.											0,5		1		0,3									
Pyrenophora sp.																		3	0,6		0,5	0,3		0,3
Basidiomycotina																									
Holobasidiomycetidae																									
Rhizoctonia spp.	34	23	25	21	17	1	48	24	23	9	12		45	2	11	14	13	17	12	16	23	15	1	14
Amphyllophorales																									
Sclerotium spp.	5	11	7	5	6	10	10	4	7	1	0,5	1	1		0,6	9	5		0,6		2	3	5	3
Typhula spp.										1	1		3	1	1	3	5					6	0,5	2
Mycelia sterilia		2	2	3		2	1	2	2															
Unidentified sclerotia	3	5	3	3	1	3	4	3	3															
Deuteromycotina																									
Hyphomycetes																									
Acremoniella atra	10	24	14	9	10	7	16	19	14	13	19	18	9	20	17	2	10	2	3		4	2	10	5
Acremoniella verrucosa		1					0,3	0,4	0,2															
Acremonium spp.	14	16	9	12	14	9	23	8	12	24	28	43	29	10	26	14	16	23	24	28	22	25	11	20
Alternaria spp.	13	9	9	6	1	4	16	6	8	51	65	82	88	26	61	23	26	32	19	11	21	30	9	24
Arthrinium spp.	7	3	2	1		1	4	2	2	1	0,5	1	1		0,6	1	0,4		2	2	0,5	1	1	1
Arthrobotrys sp.	4	2	1	1			1	2	1	2	0,5	1	3		1	2	2					2		1
Aspergillus spp.											2			3	1		2	1		2		1	2	1
Bipolaris sorokiniana		0,4	2	15		7	3	3	4	1	1	2		1	1	1		1	3		1	0,3	1	1
Botrytis cinerea		4	4	5	5	12	0,4	0,5	4	3	6	6	5	3	5	7	6	5	3	4	4	2	11	5
Chrysosporium sp.			2	0,4	1		2		0,3		3		3	3	2	4	4	1		2	0,5	6		2
Cladosporium spp.	23	19	12	15	15	7	28	14	16	72	83	91	96	58	79	86	93	43	48	47	59	71	36	57
Cylindrocarpon sp.			0,6					0,5	0,2															
Dendrodochium spp.	4	4	3	3		2	1	5	3	1	0,5				0,6				1		0,5		0,5	0,3
Dendryphion nanum	1	3	1				4		1		1		3		0,6	1							0,5	0,1
Dictyosporium elegans	4	1	0,3	0,4	1	1	1	1	1		0,5		1		0,3									
Dinemasporium gramineum	1	1	0,3				0,4	1	0,4															
Doratomyces spp.					1	0,3			0,1		2		4	1	1	1	1	3	5	5	3	3	1	3
Drechslera avenae					51																33			
D. gramineum				3						3	3	7	1		3			1			0,5			0,1
D. teres				5						2	3	7		1	3				5		1	1	1	1
D. tritici-repentis			0,6							7	3	10	4		4	1	1	1			1	1		1
Drechslera spp.	1	2	0,3	3	1	4	1		2	1	2	4	1		2	2	0,4		1		0,5	1		1
Eidamia acremonioides		0,4		1	2	1	1		0,5							2	1		1		1	1	1	1
Endophragmia hyalosperma	3	0,4	0,3		1	0,3	0,4	1	0,5															
Epicoccum purpurascens	1	2	3	2	2	2	3	2	2	22	36	51	36	11	31	3	11	2	3		9	0,3	9	6
Fusarium avenaceum	36	32	21	16	21	29	13	26	23	28	23	32	16	23	25	8	16	14	7	12	19	7	12	12
F. culmorum	56	66	74	60	70	82	70	52	66	64	68	81	53	62	66	35	49	81	74	65	72	67	34	59
F. graminearum		4	4	9	7	7	2	2	5	3	1	2	3	2	2	2	1	1	0,6	2		1	1	1
F. nivale																23	3					12	0,5	5
F. poae	1		1	1	3	2	1	1	2	2	3	1		2	0,6				2			1		0,4
F. semitectum	1	2	4	5	3	8	1	1	3	4	4	4	7	2	4	2	10	3	1	2	15	1	0,5	5
F. tricinctum	1		1	0,4			1	1	0,6							1		1	0,6			1		0,4
Fusarium spp.	8	11	9	9	17	13	12	6	10	17	25	33	18	15	22	26	33	14	21	28	20	19	41	26
Fusidium sp.	1	1	1	1	2		3	1	1		0,5		1		0,3	3	1	1	3			1	3	1

Table 3 (cont.)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Gliocladium roseum	35	39	50	28	29	28	35	51	39	3	6	7	3	5	5	4	5	16	15	2	9	8	9	8
Gliomastix murorum			0,3		0,3	0,3	0,4		0,1	2		1	1		0,6									
Gonathobotrys sp.	3	0,4	0,3		1	1	1		0,5		1	1	1		0,6									
Graphium sp.		1	0,3	0,4		1			0,4								3	1		0,6			1	1	1
Helicosporium sp.	7	4	3	7	4	0,6	1	10	5															
Heterosporium sp.											0,5	1			0,3	1	1	2	0,6		2	1		1
Humicola grisea					2	0,3		0,2	0,2	3	0,5		1	2	1	1	1	3	4		5	2	1	3
Melanconium sphaerospermum	4	3	4	7	1		1	9	4															
Metarrhizium anisopliae	3	1	0,3					1	0,5															
Monilia sp.										3				2	1									
Monacrosporium mutabilis	10	17	14	8	11	5	11	19	13	1	1	2	1	1	1									
Oedocephalum sp.		0,4				0,3			0,1															
Oidiodendron sp.																1					0,5			0,1
Ostracoderma sp.	1	0,4	0,3		2	0,3	1	0,5	0,5	6	3	6	4	2	4	1	1	3			3			1
Paecilomyces sp.	1		0,6			0,3	1		0,3								0,4	2						0,4
Papulaspora rubida	1	6	2	2	5	5	1	3	3	2	4	4	6		4	7	5	1	3	9	3	4	6	4
Papulaspora spp.	3	1		0,4		0,6	1	0,5	0,6		0,5	1			0,3	8	7		4	1		4	11	5
Penicillium spp.	4	4	7	4		4	6	4	5	15	54	28	65	39	41	7	9	31	21	10	16	15	15	15
Periconia hispidula		0,4						0,2	0,1															
Periconia macrospinosa	4	6	4	2	9	5	3	5	4															
Periconia spp.										2	1		4	1	1									
Phialophora sp.											0,5		1		0,3									
Pseudocercosporella herpotrichoides											4	6	1		2		0,4				0,5			0,1
Rhinocladiella spp.	12	8	9	7	5	0,3	15	10	8															
Rhynchosporium secalis				15						7						28			3		2	6	7	5
Scopulariopsis brevicaulis																1		0,6				1	0,5	0,4
Spegazzinia sp.			0,3				0,4		0,1															
Stachybotrus atra			1			1			0,3															
Stachybotrus aurantia		0,4	3	0,3		3	0,4	0,2		1														
Staphylotrichum coccosporum	4	1						1	0,5															
Stemphylium botryosum										3		3			1									
Torula herbarum	20	16	6	8	1	2	18	9	9		2	2	1	1	1			1			0,5			0,1
Tricellula aquatica										1	5	11			4									
Tricocladium asperum										1		1			0,3		0,4		1	4	1	1	0,5	1
Trichoderma viride	4	6	8	9	10	1	9	11	7	4	1		5	2	2	1	2	1			2	0,3	0,5	1
Trichothecium roseum	5	9	7	5	9	5	14	4	7	12	12	5	25	9	12	1	1			2	1	1	0,5	1
Ulocladium consortiale		1	1	1			2	1	1	5	7	11	7		5	4	3	6	4	7	3	1	8	4
Verticillium lateritium		2	0,6	1	1	2	1	0,5	1	7	2	2	3	6	4	3	2	4	8		2	2	6	3
Verticillium spp.		4	2	2	6	3	5	1	3	2	4	2	11		3	1	3	1	0,6		1	1	2	1
Volucrispora graminicola											1	2			0,6									
Volutella spp.	1	1	1	2	2	0,6	2	1	1		0,5	1			0,3	2	0,4					1		0,4
Unidentified aquatic *Hyphomycetes*											1		1	1	0,6	2	0,4					1		0,4
Coelomycetes																								
Melanconiales																								
Colletotrichum craminicola	0,6	1	3	8	26	4	5	10	6	1	1	3			1	1	1		0,6	2	0,4	1		0,1

Sphaeropsidales												
Ascochyta sorghi										2	1	3
A. hordei											3	1
Ascochyta spp.		0,4	2	2	2	4	0,4		2			
Coniothyrium spp.	3	1	1	1	1	2	1	0,2	1		0,5	1
Hendersonia crastophila											1	2
H. culmicola												
Hendersonia spp.										1	0,5	2
Phaeoseptoria festucae	3	3	1	2	2	4		1	2	2	1	3
Phoma spp.	5	7	4	7	8	6	5	7	6	4	5	9
Pyrenochaeta spp.	3	5	5	2	6	2	8	4	4	2	2	2
Septoria nodorum	3	17	9	5		11	4	10	8	4	30	36
S. tritici		0,4				0,3			0,1	1	2	4
Septoria spp.	1	5	4	3		4	1	4	3	1	4	6
Wojnowicia graminis	3	4	1	1			3	3	2			
Bacteria												
Actinomycetales												
Streptomyces spp.	21	27	11	17	13	18	23	13	17	59	66	71

Sphaeropsidales												
Ascochyta sorghi	3		2	1	3				1	4		1
A. hordei	7	1	2	4	29		1		9	8	20	12
Ascochyta spp.												
Coniothyrium spp.			0,3		0,4	1					1	0,3
Hendersonia crastophila			0,6		2						2	1
H. culmicola				1	5				2		4	2
Hendersonia spp.			0,6		2		0,6		0,5		2	1
Phaeoseptoria festucae			1	1	1	1					2	0,6
Phoma spp.	3	2	4	2	2	3	1	2	2	2	0,5	2
Pyrenochaeta spp.	7		2				0,6	2	1			0,3
Septoria nodorum	21	9	22	3	32	1			5	9	26	13
S. tritici	1	1	2	3	24				15	6	9	9
Septoria spp.	3	1	3	3	4				1	4		2
Wojnowicia graminis												
Bacteria												
Actinomycetales												
Streptomyces spp.	65	57	64	46	58	45	39	35	57	44	44	48

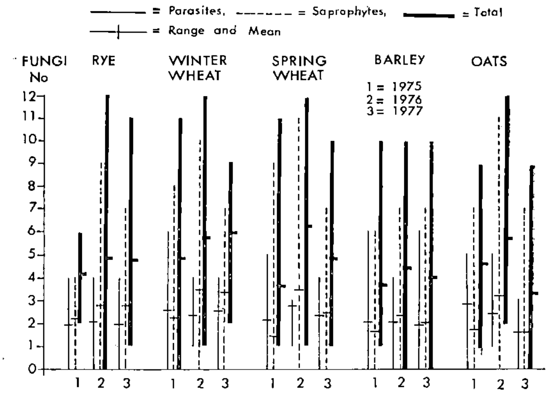

Fig. 5. The mean no. and the range no. of parasite and saprophyte in the individual sample of the mature cereals.

had nearly as few. The incidence of fungi in barley shoots remained virtually the same from year to year just as in the case of the mature plants.

There were also differences between the years of the investigation. The highest number of fungal species in mature plants for all the cereals occurred in 1976; it averaged 4,5—6,3 (range 1—12). In contrast, the fewest species were found in 1975, the corresponding figures being 3,7—4,9 (range 0—11). In the shoot samples the annual variations were even greater. The highest figures for winter cereal shoots were recorded in autumn 1976, averaging 7,1—7,6 (range 2—14) and for spring cereals in 1978, averaging 4,7—5,7 (range 1—12). In autumn 1977 and spring 1978 the fungal species in shoots of winter cereals were less than in the other years. Among the spring cereals the annual variations were smaller.

Parasites and saprophytes

It is very difficult to make an absolute distinction between parasites and saprophytes. Nevertheless in this investigation parasites have been considered to include the following fungi which are generally known to cause foot and root rot in cereals: *Ascochyta* spp., *Bipolaris sorokiniana*, *Colletotrichum* spp., *Drechslera* spp., *Fusarium*

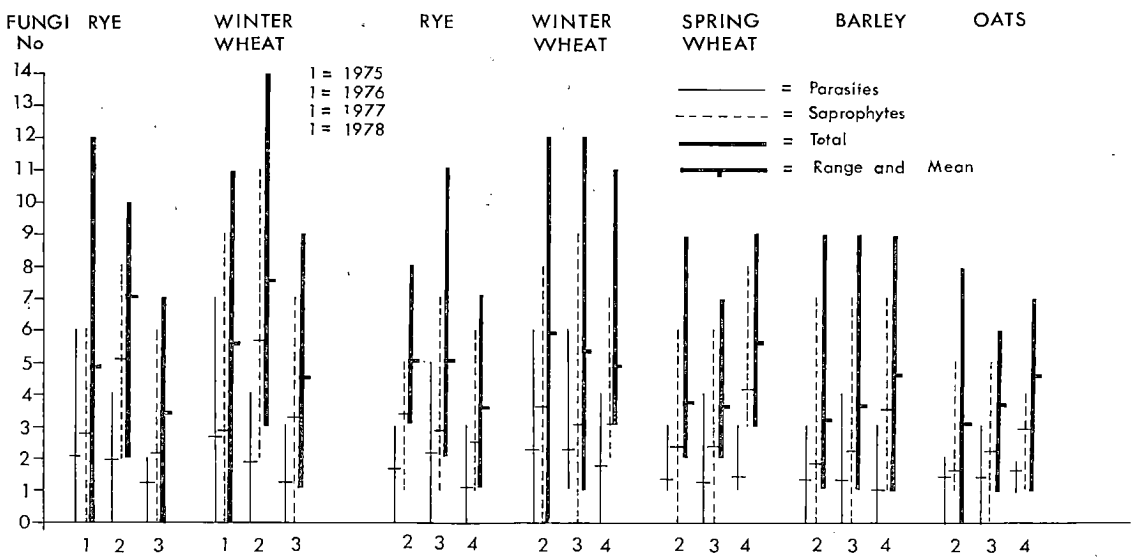

Fig. 6. The mean no. and the range no. of parasites and saprophytes in the individual shoot sample of cereal in autumn and in spring gathered.

spp., *Gaeumannomyces graminis*, *Gibberella zeae*, *Pseudocercosporella herpotrichoides*, *Rhizoctonia solani*, *Rhynchosporium secalis*, *Septoria* spp. and *Typhula* spp. (Table 4). These fungi are treated in more detail in a separate paper (MÄKELÄ and PARIKKA 1980).

The major part of the fungi found in the samples were saprophytes (Figs. 3 and 4). In the mature cereals parasites made up only 20—30 % (average figures) of the total numbers of fungi. This proportion remained approximately constant both in regard to the different cereals and

Table 4. The most common parasitic fungi, causing the foot and root rot diseases of cereals in the samples studied in 1975—1978.

Fungi	Parasitic fungi, % of samples researched											
	Mature cereals, in autumn 1975—1977					Shoots, in autumn 1975—1977		Shoots, in spring 1976—1978				
	Rye	Winter wheat	Spring wheat	Barley	Oats	Rye	Winter wheat	Rye	Winter wheat	Spring wheat	Barley	Oats
Ascochyta spp.	0	0,4	2	2	2	2	5	5	32	0	1	0
Bipolaris sorokiniana	0	0,4	2	15	0	1	1	1	0	1	3	0
Colletotrichum graminicola	0,6	1	3	8	26	0	1	1	1	0	0	0
Drechslera spp.	1	2	1	12	52	13	12	3	2	2	6	33
Fusarium avenaceum	36	32	21	16	21	28	23	8	16	14	7	12
F. culmorum	56	66	74	60	70	64	68	35	49	81	74	65
F. graminicola	0	4	4	9	7	3	1	2	1	1	0,6	2
F. nivale	0	0	0	0	0	0	0	23	3	0	0	0
Fusarium spp.	12	13	15	15	23	23	31	28	43	17	24	30
Gaeumannomyces graminis	23	23	24	15	2	0	0	0	0	0	0	0
Gibberella zeae	0	2	0,6	0,4	1	0	0	0	0	0	0	0
Pseudocercosporella herpotrichoides	0	0	0	0	0	0	4	0	0,4	0	0	0
Rhizoctonia solani	34	23	25	21	17	9	13	9	5	15	11	16
Rhynchosporium secalis	0	0	0	15	0	7	0	28	0	0	3	0
Septoria nodorum	3	17	9	5	0	4	30	3	32	1	0	0
S. tritici	0	0,4	0	0	0	1	2	2	24	0	0	0
Typhula spp.	0	0	0	0	0	1	1	3	5	0	0	0

in the different years (Fig. 3). In the shoots the proportions of parasites in the autumn-collected samples varied from 22 to 30 % of the total numbers of fungi. In the spring-collected samples the proportions were 15—40 % on the average. The annual fluctuations were greater in the shoots than in the mature plants (Fig. 4).

The numbers of parasites per mature sample and per field, considering the different years and the different cereals, were on the average 1,7—2,9 (range 0—6). These figures are smaller than for the saprophytes, which had corresponding results of 1,5—3,4 (range 0—11) (Fig. 5). In the individual shoot samples there were likewise fewer parasites than saprophytes. For all the years and cereals the numbers of parasitic fungi averaged 1,3—2,7 (range 0—7) and saprophytes correspondingly 1,7—5,7 (range 0—11) (Fig. 6). There were fewer parasites in the shoots than in the mature plants per field, whereas for the saprophytes they were more abundant in the shoots than in the mature samples.

Species of fungi

The species of fungi encountered in the samples (Table 5) varied, as has been mentioned above, according to several factors, namely the cereal species, the year, the stage of development and the time of collecting. The total number of fungal species found in all the samples, belonging to 100 genera, was about 25 % greater than the number in the individual mature samples and about 40 % greater than in the individual shoot samples. The bulk of the fungi, however, were common to all the cereals.

Over 2/3 of the fungal genera belonged to the class *Deuteromycotina*, and of these the majority were members of the order *Hyphomycetes*. Also *Sphaeropsidales* was well represented. Approximately 15 % of the genera belonged to the class *Ascomycotina*, most of them being *Pyrenomycetes* fungi. The proportion of ascomycetes was somewhat greater in the mature plants than in the shoots. On the other hand it is noteworthy that some genera of ascomycetes, such as *Gaeumannomyces*, do not appear in the shoots using the method employed in this study. In contrast, *Fungi imperfecti* were more abundant in the shoots than in the mature plants.

Table 5. The systematic distribution of the fungi on the cereal and shoot samples investigated.

	Mature cereal samples in autumn	Shoot samples		All the samples total
		in autumn	in spring	
Myxomycetes	2	0	0	2
Zygomycotina				
Mucorales	6	4	4	7
Ascomycotina				
Plectomycetes				
Eurotiales	2	1	1	2
Pyrenomycetes				
Sphaeriales	8	2	4	10
Loculoascomycetes				
Pleosporales	2	1	2	3
Basidiomycotina	3	4	3	5
Deuteromycotina				
Hyphomycetes	46	42	40	62
Coelomycetes				
Melanconiales ...	1	1	1	1
Sphaeropsidales ..	7	7	7	8
Total	77	62	62	100
Bacteria				
Actinomycetales	1	1	1	1

Effect of cereal species

Some of the fungi appeared similarly in all the cereals. These were e.g. *Acremonium*-, *Alternaria*-species, *Botrytis cinerea*, *Rhizoctonia solani* and *Fusarium* species with the exception of *F. nivale*, which was specialized only on winter cereals, particularly rye, and *Cladosporium* species, whose abundance varied according to the time of collection.

Most of the fungi preferred some particular cereal instead of the others. For instance, *Ascochyta hordei*, *Septoria tritici* and *Typhula incarnata* appeared generally only in spring in the shoots of winter wheat. Likewise *Acremoniella atra* and *Septoria nodorum* were encountered mainly in wheat. The same can be said about *Gaeumannomyces graminis*, which occurred on other

cereals but very rarely on oats. *Rhynchosporium secalis* was specialized on barley and rye. *Colletotrichum graminicola* and *Melanospora* spp. were more common on oats than on the other cereals.

Effect of stage of development and time of the year

The age of the cereal stand and the time of sample collection had an effect on the incidence of many of the fungi (Table 6).

The fungi found exclusively in mature cereal samples were the following: *Dinemasporium gramineum*, *Endophragmia sphaerospermum*, *Gaeumannomyces graminis*, *Gibberella zeae*, *Metarrhizium anisophiae*, *Periconia macrospinosa*, *Ceratocystis* sp., *Stachybotrus* spp. and *Wojnowicia graminis*. In addition, *Bipolaris sorokiniana*, *Gliocladium roseum*, *Melanospora* spp., *Monacrosporium* spp., *Rhizoctonia solani* and *Torula herbarum* were more common in the mature plants than in the shoots.

Table 6. The most common fungi on the cereal samples investigated in 1975—1978.

Fungi	Fungi, % of		
	mature cereal researched autumn 1975—77	shoots researched	
		autumn 1975—77	spring 1976—78
Acremoniella atra	14	17	5
Acremonium spp.	12	26	20
Alternaria spp.	8	61	24
Botrytis cinerea	4	5	5
Cladosporium spp.	16	79	57
Epicoccum purpurascens	2	31	4
Fusarium avenaceum	23	25	12
F. culmorum	66	66	59
Fusarium spp.	21	28	37
Gaeumannomyces graminis	19	0	0
Gliocladium roseum	39	5	8
Melanospora spp.	18	2	2
Monacrosporium spp.	13	1	0
Papulaspora spp.	4	4	9
Penicillium spp.	5	41	15
Phoma spp.	6	4	2
Rhizoctonia solani	23	11	10
Septoria nodorum	8	22	13
S. tritici	0,1	2	9
Trichodema viride	7	2	1
Trichothecium roseum	7	12	1
Verticillium spp.	4	7	5
Streptomyces spp.	17	64	48

Occurring only in the shoots were, among others, the following fungi: *Aspergillus*- and *Hendersonia*- species, *Monodictys levis*, *Stemphylium botryosum* and *Trichocladium asperum*. In addition, *Ascochyta hordei*, *Fusarium nivale*, *Pseudocercosporella herpotrichoides*, *Septoria* spp. and *Typhula* spp. appeared more frequently in shoots than in mature plants, specifically in the spring. Especially prevalent in the shoots of winter cereals in the autumn were *Acremonium*-, *Alternaria*- and *Penicillium* species as well as *Epicoccum purpurascens*. Also *Chaetomium*-, *Cladosporium*-, *Mucor*- and *Streptomyces* species were more common in shoots than in mature samples.

Effect of the years

For many of the fungi there were large differences in their prevalence according to the year. In 1975 many of the *Fusarium* species were more plentiful than in the other years of the study. Similarly, *Bipolaris sorokiniana* was more common in 1975 and 1978, *Rhizoctonia solani* and *Septoria nodorum* in 1976, *Colletotrichum graminicola*, *Fusarium nivale*, *Gaeumannomyces graminis*, *Helicosporium sp.*, *Melanconium sphaerospermum* and *Monacrosporium* spp. in 1977, and *Ascochyta hordei* and *Septoria nodorum* in 1978.

Microflora observed in the stem base and roots of cereals

The majority of the microflora examined were fungi, the number of determined genera exceeding 100. Of these about 70 genera belonged to the morphological division *Deuteromycotina*, and the main part of these, 62 genera, to the subdivision *Hyphomycetes*, 15 genera to the group *Ascomycotina*, 7 genera to the group *Zygomycotina* and five genera to the group *Basidiomycotina*. To the group *Myxomycotina* belonged one genus. On the other hand several undetermined *Streptomyces* species belonged to the *Actinomycetales* group (Table 5).

The following genera and species of fungi were determined.

Myxomycetes, Physarales. *Didymium difforme* (Pers.) S.F. Gray.

Infrequent on ripe cereals (*Hordeum vulgare*, *Secale cereale*, *Triticum aestivum*) in eight localities: U, V, St, PH. On shoots of spring wheat V: Pertteli 28. 10. 1976. Common on grains in Finland (HÄRKÖNEN and KOPONEN 1978). Widely distributed. Reported from all the Fennoscandian countries (cf. HÄRKÖNEN and KOPONEN 1978).

Didymium iridis (Ditmar) Fr.

Two specimens. On *Secale cereale* V: Lemu 19. 8. 1975, on *Triticum aestivum* St: Kokemäki 13. 8. 1975. Occassionally on grains in Finland (HÄRKÖNEN and KOPONEN 1978). Cosmopolitan. Reported from Sweden and Denmark (cf. HÄRKÖNEN and KOPONEN 1978).

Zygomycotina, Mucorales. *Absidia glauca* Hagem (ELLIS and HESSELTINE 1965) (Plate I 1).

Two specimens. On ripe *Avena sativa* U: Anjala 17. 8. 1975, on *Hordeum vulgare* U: Orimattila 14. 6. 1978. Cosmopolitan, world-wide (DOMSCH and GAMS 1970).

Mucor Mich. ex Fr. spp.

Fairly common on shoots of all the cereals, infrequent on ripe cereals. Found in Finland in forest soil (FEHÉR 1933, SVINHUFVUD 1937) and cereals (TOIVIAINEN 1974). Cosmopolitan. Reported on cereals, in soil (GILMAN 1957, DOMSCH and GAMS 1970, STETTER and LEROUL 1979), and as contaminants of seeds (MALONE and MUSKETT 1964).

Mycotypha microspora Fenner (FENNER 1932).

Two specimens. On ripe *Triticum aestivum* (winter wheat) V: Perniö 12. 8. 1975, U: Inkoo 12. 8. 1975.

Rhizopus nigricans Ehrenb.

Infrequent on shoots, most infrequent on ripe cereals. Found in Finland in forest soil (SVINHUFVUD 1937), leys (YLIMÄKI 1967) and cereals (TOIVIAINEN 1974). Cosmopolitan, world-wide. In rhizosphere soil of various plants, soil, decaying leaves (GILMAN 1957, CMI No 110) and as a contaminant of seeds (MALONE and MUSKETT 1964).

Rhopalomyces elegans Corda (ELLIS 1963) (Plate I 2, 3).

Two specimens. On *Avena sativa* U: Askola 15. 6. 1978, on *Secale cereale* V: 9. 5. 1977.

Rhopalomyces magnus Berlèse (WEBSTER and RIFAI 1965) (Plate I 4).

Infrequent on shoots and ripe cereals in 10 localities: U, V, EH.

Thamnidium elegans Link. ex S. F. Gray (HESSELTINE and ANDERSSON 1956). Sporadically on shoots and ripe cereals. Reported from Finland in forest soil (SVINHUFVUD 1937). Observed on a few occasion as a contaminant of seeds and in soil (GILMAN 1957, MALONE and MUSKETT 1964, DOMSCH and GAMS 1970).

Ascomycotina, Plectomycetes, Eurotiales. *Gymnoascaceae* (Plate I 5). Unidentified.

Infrequent on foot of ripe cereals of all the species. Mostly on *Avena sativa* in 1976. Found in 11 localities: U, V, St, EH. Chleistothecia on culm are mitelike, light skin colour, (160) 212 (258) × (124) 151 (193) μm including the spines and a sharp neck (46) 82 (138) × (16) 21 (23) μm (cf. ORR et al. 1963).

Emericellopsis van Beyma sp. (Plate I 6, 7) (Gams 1971).

Uncommon on all the cereals. Mostly on the shoots of winter wheat in the autumn 1976. Many species of the genus are world-wide in soil, but rare (GILMAN 1957, DOMSCH and GAMS 1970). Found in roots (STETTER and LEROUL 1979).

Ascomycotina, Pyrenomycetes, Sphaeriales. *Apiosordaria verruculosa* (Jensen) v. Arx & W. Gams (Plate I 8, 9).

One specimen. On *Secale cereale* U: Askola 26. 5. 1978. Very rarely mentioned (DOMSCH and GAMS 1970).

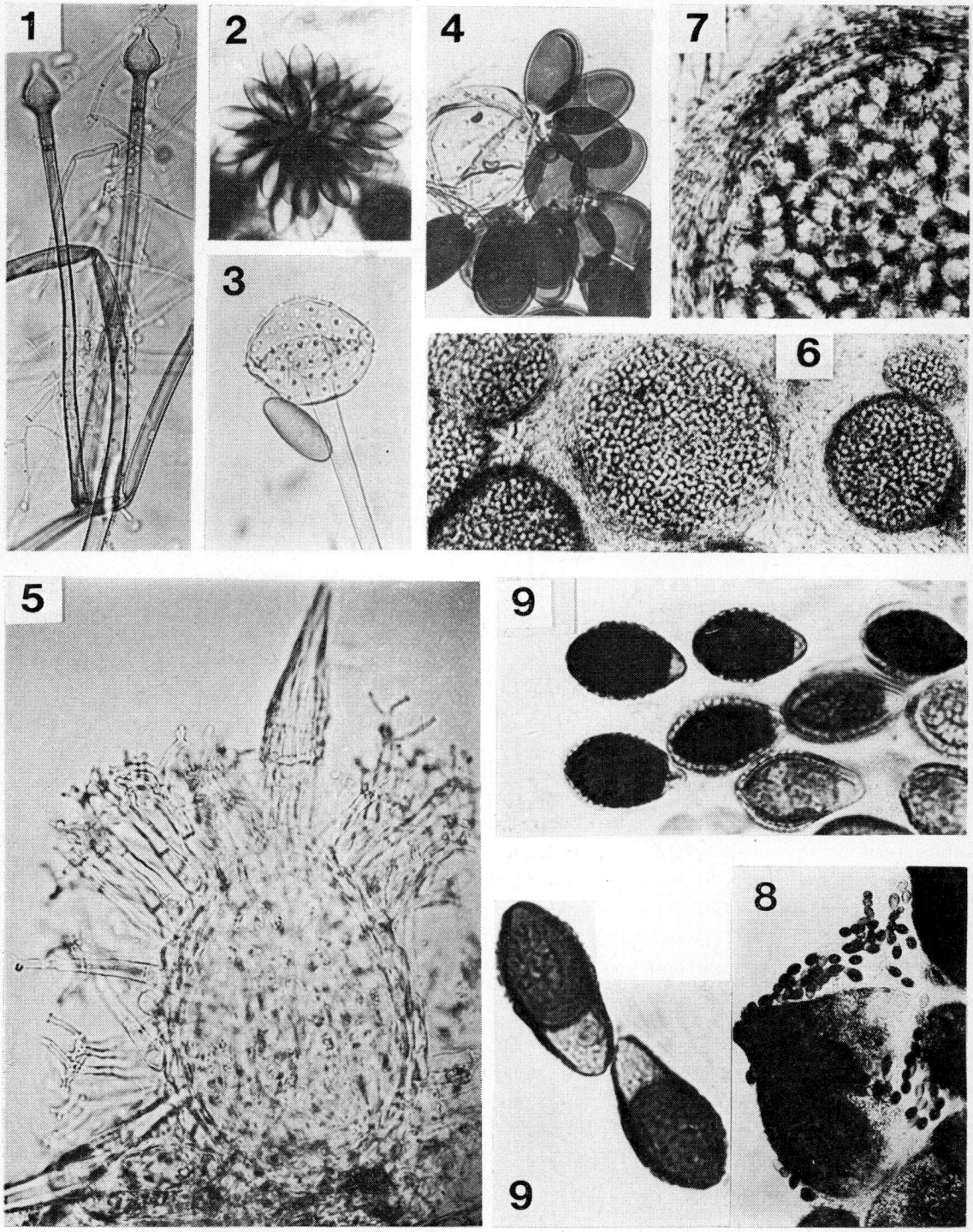

Plate I. 1—9. 1: *Absidia glauca* on spring wheat. 2, 3: *Rhopalomyces elegans* on rye. 4: *R. magnus* on winter wheat. 5: Unidentified ascomycetes on spring wheat. 6, 7: *Emericellopsis* sp. on oats. 8, 9: *Apiosordaria verruculosa* on rye.

Material: 1, 6, 7: U. Anjala 17. 8. 1975. 2, 3: U. Vihti 9. 5. 1977. 4: EH. Iitti 17. 8. 1976. 5: EH. Somero 17. 8. 1977. 8, 9: U. Askola 26. 5. 1978. 1, 4, 5: X 400. 2: X 200. 3: X 350. 6: X 300. 7, 9: X 1000. 8: X 100.

Ceratocystis Ellis & Halst. sp. (Olchowecki and Reid 1973) (Plate II 14, 15).

Very uncommon on all the ripe cereals. Found in 13 localities: V, U, St, EH, ES. Perithecia globose (120) 175 (240) μm in diameter light yellowish-brown (ochra) neck smooth, light yellowish-brown often bent (230) 320 (350) × 19 μm. Ascospores hyaline, one-called, oval (5) 6,7 (8) × (4) 4,8 (6) μm.

Chaetomidium (Fuckel) Zopf sp. (Cain 1961).

Three specimens. On *Hordeum vulgare* EH: Hämeenlinna 2. 6. 1975; ES: Puumala 22. 6. 1976. On *Secale cereale* V: Sauvo 20. 10. 1976. Little known on cultivated soil (Domsch and Gams 1970).

Chaetomium Kunze ex Fr. (Ames 1963, Seth 1970).

Fairly common on all the cereals. More common on shoots than in the ripe stands, mostly in 1976. Found in forest soil from Finland (Svinhufvud 1937). Many species found in soil (Gilman 1957) and as a contaminant of seeds (Malone and Muskett 1964).

Chaetomium elatum Kunze ex Fr. (Skolko and Groves 1948).

Three specimens. On *Secale cereale* EH: Pälkäne 14. 8. 1975, on *Triticum aestivum* (spring wheat) EH: Pälkäne 14. 8. 1975, on winter wheat EH: Ypäjä 17. 8. 1977. With *Ch. globosum* the most widespread *Chaetomium* species (Domsch and Gams 1970).

Chaetomium globosum Kunze ex Fr. (Skolko and Groves 1953).

Four specimens. On *Triticum aestivum* (spring wheat) V: Pertteli 12. 8. 1977; EH: Ypäjä 17. 8. 1977. Found in forest soil in Finland (Svinhufvud 1937). Most cosmopolitan and widespread *Chaetomium* species (Gilman 1957, Domsch and Gams 1970).

Chaetomium indicum Corda (Skolko and Groves 1948).

Four specimens. On *Hordeum vulgare* V: Mietoinen 12. 8. 1976, Pertteli 12. 8. 1977; EH: Hattula 29. 7. 1975. On *Triticum aestivum* (winter wheat) V: Tenhola 10. 8. 1977. Found rarely in soil (Gilman 1957).

Chaetomium olivaceum Cooke & Ellis (Skolko and Groves 1953).

Two specimens. On *Triticum aestivum* U: Inkoo 10. 8. 1977; EP: Ylistaro 8. 8. 1977. Found in soil (Gilman 1957).

Gaeumannomyces graminis (Sacc.) v. Arx et Olivier (Walker 1972, 1973, Cmi Nos 381—383).

Common on wheat, rye and barley, infrequent on oats. Most common in 1977. (Mäkelä and Parikka 1980). Widespread, especially in temperate zones (Sprague 1950, Cmi Map 334, 172, Domsch and Gams 1970).

Gaeumannomyces sp. (Plate II 10, 11, 12).

Two specimens. On *Hordeum vulgare* U: Kirkkonummi 8. 9. 1977; EH: Iitti 24. 8. 1977 (variety Paavo) (Mäkelä and Parikka 1980). Black ascomata with a long neck. Ascomata without a neck (381) 518 (653) μm × (367) 490 (612) μm, necks (354) 688 (952) μm × (68) 87 (122) μm. Ostiole a little expanded, yellow in colour, asci (40 asci) (49,5) 61,4 (69,3) × 9,8 μm, ascospores (50 spores) (39,6) 56,9 (69,3) × 1,7 μm. Asci and ascospores are hyaline — light yellowish in colour.

Gibberella zeae (Schw.) Petch. conidial state: *Fusarium graminearum* (CMI No 384). Sporadically on ripe cereals (barley, oats, wheat). Found in four localities, V, EH, EP, ES. Reported in Finland rarely on seeds of barley, oats and spring wheat (Jamalainen 1943 a, Mäkelä 1975 c). World-wide on cereals in temperate regions (Booth 1971, Neergaard 1977).

Melanospora Corda spp. (Doguet 1955).

Common on ripe cereals, more uncommon on shoots of cereals. Mostly on oats in 1976. Some *Melanospora* species found in soil (Gilman 1957).

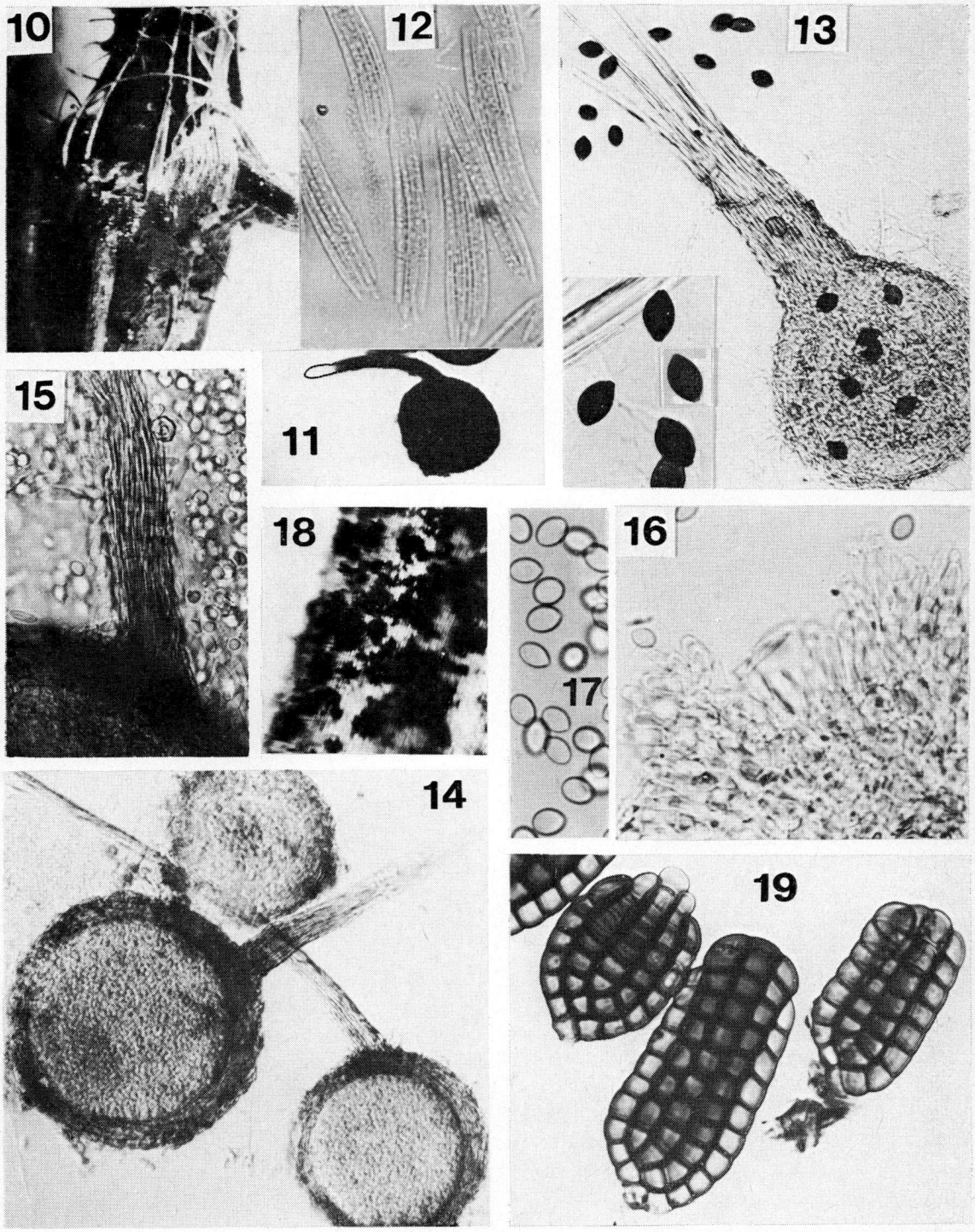

Plate II. 10—19. 10—12: *Gaeumannomyces* sp. on barley. 13: *Melanospora zamiae* on spring wheat. 14, 15: *Ceratocystis* sp. on rye. 16, 17: *Dendrodochium aurantiacum* on winter wheat. 18, 19: *Dictyosporium elegans* on spring wheat.

Material : 10—12: U. Kirkkonummi 8. 9. 1977. 13: V. Sauvo 19. 8. 1976. 14—15: EH. Iitti 17. 8. 1976. 16, 17: EH. Pälkäne 14. 8. 1978. 18, 19: EH. Pälkäne. 18: 14. 8. 1975. 19: 28. 9. 1975. 10: X 7. 11: X 30. 12, 15: X 500. 13, 14: X 200. 16, 19: X 700. 17: X 1000, 18: X 11.

Melanospora zamiae Corda (Plate II 13) (Winter 1887, MALONE and MUSKETT 1964) was the most common *Melanospora* species in the researched samples. Found frequently as a contaminant of seeds (MALONE and MUSKETT 1964).

Melanospora fallax Zukal.

Fairly common. Developed abundant bulbils like *Papulaspora* (MALONE and MUSKETT 1964, DOMSCH and GAMS 1970).

Monographella nivalis (Rehm) E. Müller (BOOTH 1971). Conidial state: *Fusarium nivale* Ces. ex Sacc.

Two specimens. On *Triticum aestivum* (winter wheat) V: Perniö 16. 5. 1978. On *Secale cereale* V: Vahto 3. 7. 1977. Found in Finland sporadically on rye and winter wheat (JAMALAINEN 1943 a). Widespread (CMI No 309).

Sordaria Ces. & de Not spp. (CAIN and GROVES 1948).

Four specimens. On *Avena sativa* V: Loimaa 4. 8. 1975. On *Hordeum vulgare* U: Sipoo 24. 8. 1977, EH: Pälkäne 14. 8. 1975, PP: Rovaniemi commune 9. 1975. Some *Sordaria* species have been found among soil fungi (GILMAN 1957, DOMSCH and GAMS 1970).

Sphaeroderma episphaeria (Phill. & Plowr.) Sacc. (MARTIN 1955).

Infrequent on spring wheat, winter wheat and oats in five localities: V, U, St, EH. Most common on ripe cereals.

Sporormia de Not. sp. (AHMED and CAIN 1972).

One specimen. On *Hordeum vulgare* V: Perniö 12. 8. 1975. Some *Sporormia* species found in soil (GILMAN 1957, DOMSCH and GAMS 1970).

Ascomycotina, Loculoascomycetes, Pleosporales. *Phaeosphaeria* Miyake, syn. *Leptosphaeria* Ces. & de Not. (MÜLLER 1950, HOLM 1957, ERIKSSON 1967 b).

Sporadically on shoots and ripe cereals. Many species were found.

Phaeosphaeria avenaria (G. F. Web.) O. Eriksss. f. sp. *triticea* Johnsson.

Two specimens. On *Triticum aestivum* (winter wheat) V: Perniö 11. 5. 1976. PS: Maaninka 26. 4. 1976. Reported in Finland infrequently on barley, rye and wheat (KOPONEN and MÄKELÄ 1975).

Phaeosphaeria herpotrichoides (de Not.) L. Holm.

Four specimens. On *Avena sativa* EH: Hauho 17. 9. 1977. On *Secale cereale* St: Huittinen 17. 8. 1977. On *Triticum aestivum* (spring wheat) EH: Pälkäne 29. 7. 1975, the overwintered culm of winter wheat V: Koski 19. 5. 1977. Found in Finland very commonly throughout the country on all the cereals, mostly on oats (KOPONEN and MÄKELÄ 1975).

Phaeosphaeria microscopica (P. Karst.) O. Eriksss.

One specimen. On *Triticum aestivum* (winter wheat) U: Snappertuna 12. 8. 1975. Found in Finland on 26 grass species, but not found on the cereals (KOPONEN and MÄKELÄ 1975).

Phaeosphaeria nigrans (Rob.) L. Holm.

One specimen. On *Triticum aestivum* (winter wheat) V: Sauvo 18. 5. 1978. Reported in Finland sporadically on the cereals (KOPONEN and MÄKELÄ 1975).

Phaeosphaeria nodorum (E. Müll.) Hedjaroude (CMI No 86).

Five specimens. On *Hordeum vulgare* St: Kokemäki 13. 8. 1975. On *Triticum aestivum* (winter wheat) V: Piikkiö 28. 5. 1975, St: Kokemäki 13. 8. 1975, (spring wheat) St: Kokemäki 13. 8. 1975. Found in Finland sporadically on overwintered stubble of cereals (barley, rye, wheat) (KOPONEN and MÄKELÄ 1975).

Phaeosphaeria vagans (Niessl.) O. Eriksss.

Two specimens. On *Avena sativa* St: Kiukainen 13. 8. 1975. On *Triticum aestivum* (spring wheat) EH: Hattula 29. 7. 1975, Hauho 29. 7. 1975. Found in Finland uncommonly on overwintered cereals stubble (oats, barley, wheat) (KOPONEN and MÄKELÄ 1975).

Phaeosphaeria sp.

One specimen. On *Triticum aestivum* (spring wheat) EH: Iitti 19. 6. 1977.

Pleospora herbarum (Pers.) Rabenh. (MÜLLER 1951).

Two specimens. On *Triticum aestivum* (winter wheat) V: Perniö, 12. 8. 1975, (spring wheat) U: Lapinjärvi 15. 6. 1976.

Pleospora vagans Niessl. (ERIKSSON 1967 a).

One specimen. On *Triticum aestivum* (winter wheat) U: Siuntio 16. 5. 1978.

Pyrenophora Fr. sp. (MÜLLER 1951).

One specimen. On *Triticum aestivum* (winter wheat) V: Sauvo 18. 5. 1978.

Basidiomycotina, Aphyllophorales. *Typhula* (Pers.) Fr.

Infrequent on shoots of winter cereals (rye, wheat). Most common in 1977 (MÄKELÄ and PARIKKA 1980). Widely distributed on winter cereals and several grass species in the cooler temperate zones (SPRAGUE 1950, JAMALAINEN 1957, ÅRSVOLL 1975).

Typhula incarnata Lasch ex Fr. was the most common *Typhula* species.

Found as a major disease cause on overwintering cereals and grasses in regions having a stable, cold winter climate with prolonged, deep snow cover (JAMALAINEN 1957, ÅRSVOLL 1975).

Rhizoctonia DC. ex Fr. spp.

Common on all the cereals, mostly in 1976, very rare in 1975 (MÄKELÄ and PARIKKA 1980). Cosmopolitan and world-wide, takes many forms, many strains (races) (ELNUR and CHESTERS 1967, PARMETER et al. 1967, DOMSCH and GAMS 1970).

Rhizoctonia solani Kühn is the most common *Rhizoctonia* species (DOMSCH and GAMS 1970). Found in cereals throughout Scandinavia (HANSEN 1963, PETERSEN 1963, NILSSON 1969, TOIVIAINEN 1970, STETTER and LEROUL 1979).

Sclerotium Tode ex Fr. spp. (WERESUB and LE CLAIR 1971).

Fairly common on all the ripe cereals, more uncommon on shoots. Some of the sclerotia are similar to the bulbils of *Papulaspora*, light brown, nut-brown, yellow-green or black in colour. They differ greatly in size (NEERGAARD 1977).

Clavariaceae (PETERSEN 1973).

Unidentified. The fruiting bodies light, long, threadlike, basidia in abundance. Sporadically on the ripe spring wheat and winter wheat. Found in eight localities: V, U, St, EH.

Deuteromycotina, Hyphomycetes. *Acremoniella atra* (Corda) Sacc. (GROVES and SKOLKO 1946 a).

Common on all the cereals (cf. MÄKELÄ 1975 c). Most uncommon on shoots of cereals gathered in spring. *Acremoniella* is infrequently reported from soil (GILMAN 1957, BARRON 1968) and as a contaminant of seeds (MALONE and MUSKETT 1964).

Acremoniella verrucosa Fogn. (GROVES and SKOLKO 1946 a).

Three specimens. On *Triticum aestivum* (winter wheat) V: Paattinen 8. 8. 1975; EH: Pälkäne 14. 8. 1976, (spring wheat) EH: Pälkäne 14. 8. 1976. Found sporadically on cereals (MÄKELÄ 1975 c).

Acremonium Link ex Fr. spp. (GAMS 1971) syn. *Cephalosporium* Corda.

Common in all the cereals and in all the years. Most common on the shoots of winter cereals in autumn 1975 (cf. MÄKELÄ 1975 c). Many *Acremonium* species are isolated from soil (GILMAN 1957, DOMSCH and GAMS 1970) in roots (STETTER and LEROUL 1979) and as a contaminant of seeds (MALONE and MUSKETT 1964, NEERGAARD 1977).

Alternaria Nees ex Wallr. spp. (SIMMONS 1967).

Very common on the shoots of all cereals. More infrequent on ripe stands. World-wide. *Alternaria* species are frequently recorded from soil and

organic debris (NEERGAARD 1945, GILMAN 1957, BARRON 1968, DOMSCH and GAMS 1970) and as a contaminant of seeds (MALONE and MUSKETT 1964, NEERGAARD 1977).

Alternaria tenuis Nees (GROVES & SKOLKO 1944 b, SIMMONS 1967).

The most common *Alternaria* species in this study (MÄKELÄ 1975 c). Found in North Finland in soil (FEHÉR 1933). Cosmopolitan, world-wide (DOMSCH and GAMS 1970).

Arthrinium Kunze spp. (ELLIS 1965).

Sporadically on nearly all the cereals as well as on the shoots and the ripe stands (cf. MÄKELÄ 1975 c). World-wide. Few species of the genus have been found in soil (BARRON 1968).

Arthrinium phaeospermum (Corda) M. B. Ellis.

The most common *Arthrinium* species. Cosmopolitan, world-wide. Found in soil (GILMAN 1957, DOMSCH and GAMS 1970).

Arthrobotrys Corda sp.

Infrequent on the shoots and ripe cereals. The species most frequently isolated from soil are *A. olifospora* Fres. and *A. suberba* Corda (BARRON 1968, DOMSCH and GAMS 1970).

Aspergillus Link spp. (RAPER and FENNELL 1965).

Occasionally on shoots of cereals (cf. MÄKELÄ 1975 c). Found in soil, but less dominant in temperate regions (GILMAN 1957, BARRON 1968, STETTER and LEROUL 1979) and as a contaminant of seeds (MALONE and MUSKETT 1964, NEERGAARD 1977).

Bipolaris sorokiniana (Sacc. on Sorok.) Shoemaker. Syn. *Helminthosporium sativum* Pammel, King & Backe.

Very uncommon on the shoots and ripe stands but absent from oats. Fairly common on ripe barley stands in 1975 (MÄKELÄ and PARIKKA 1980). Found moderately common in spring barley fields in Finland (MÄKELÄ 1975 a). Cosmopolitan, world-wide (SPRAGUE 1950, CMI Map No 322). Common and particularly important in cereals (MALONE and MUSKETT 1964, OLOFSSON 1976, NEERGAARD 1977, STETTER and LEROUL 1979).

Botrytis cinerea Pers. ex Fr. (CMI No 431).

Uncommon, but occurred nevertheless on the shoots and ripe stands of all the cereals (MÄKELÄ 1975 c). Found in Scandinavia (FEHÉR 1933, STETTER and LEROUL 1979) also in Finland in forest soil (SVINHUFVUD 1937). Cosmopolitan (CMI Map No 169, GILMAN 1957, DOMSCH and GAMS 1970) *Botrytis* is prevalent in cool temperate areas, occasionally on Gramineae (SPRAGUE 1950), fairly common in soil, but it has a low sporulating capacity (BARRON 1968, DOMSCH and GAMS 1970) also as a contaminant of seeds (MALONE and MUSKETT 1964, NEERGAARD 1977).

Chrysosporium pannorum (Link) Hughes.

Infrequent on all the cereals. *Chrysosporium* species are common in soil, world-wide. The most frequently is *C. pannorum* (BARRON 1968, DOMSCH and GAMS 1970).

Cladosporium Link ex Fr. spp.

Common on the ripe cereals, very common on shoots. Found on cereals in Finland (HÅRDH 1953, TOIVIAINEN 1974, MÄKELÄ 1975 c). World-wide. Very common soil fungi (GILMAN 1957, DOMSCH and GAMS 1970) and as a contaminants of seed (MALONE and MUSKETT 1964, NEERGAARD 1977). *Cladosporium cladosporioides* (Fres.) de Vries and less frequently *C. herbarum* (Pers.) Link ex Fr. was the most common species (MÄKELÄ 1975 c), as also elsewhere (MALONE and MUSKETT 1964, DOMSH and GAMS 1970).

Cylindrocarpon destructans (Zins.) Schotten.

One specimen. On *Triricum aestivum* (winter wheat) 11. 5. 1976. Isolated from the root samples of red clover in Finland (YLIMÄKI 1967). The most common *Cylindrocarpon* species in soil. World-wide (BARRON 1968, DOMSCH and GAMS 1970).

Curvularia inaequalis (Shear) Boedijn (ELLIS 1966).

One specimen. On *Secale cereale* KP: Paavola 19. 5. 1975. Isolated from e.g. *Hordeum*, *Triticum* and sand dune soil in many countries (ELLIS 1970). Many *Curvularia* species reported from soil occasionally (GILMAN 1957), but it is seldom recorded in high frequencies (BARRON 1968).

Dendrodochium gracile Daszewska (Plate II 16, 17) (LINDAU 1910).

Infrequent mainly on ripe cereals. The genus is rarely reported from soil (GILMAN 1957, BARRON 1968).

Dendryphion nanum (Nees ex Fr.) Hughes (HUGHES 1958).

Sporadically on shoots and ripening cereals (rye, wheat). Only rarely isolated from soil (DOMSCH and GAMS 1970), also on dead stems of herbaceous plants (ELLIS 1971).

Dictyosporium elegans Corda (Plate II 18, 19) (LINDAU 1910).

Infrequent, mainly on ripe cereals. Ten specimens found in seven localities: V, U, St, EH, PH. Encountered several times on barley and oat stubble in Europe (ELLIS 1971). *Dictyosporium* species are rarely reported from soil (BARRON 1968).

Dinemasporium gramineum Lev. (ALLESCHER 1903, HUGHES 1958).

Four specimens. On *Secale cereale* V: Koski 17. 8. 1977, Sauvo 16. 8. 1977. On *Triticum aestivum* (winter wheat) U: Askola 17. 8. 1976, (spring wheat) V: Inkoo 10. 8. 1977. Found sporadically on grasses in Finland (MÄKELÄ 1972).

Doratomyces microsporus (Sacc.). Morton et G. Smith.

Uncommon on the shoots of all the cereals. World-wide, but is rarely recorded. On dead leaves of grasses also isolated from soil in Europe (DOMSCH and GAMS 1970, ELLIS 1971), and as a contaminant of seeds (MALONE and MUSKETT 1964).

Doratomyces purpureofuscus (Fr.) Morton et G. Smith (Plate III 20, 21).

One specimen. On *Avena sativa* EH: Pälkäne 14. 8. 1975. On dead herbaceous stems also isolated from soil etc. Europe and N. America (DOMSCH and GAMS 1970, ELLIS 1971), and occasionally as a contaminant of seeds (MALONE and MUSKETT 1964).

Doratomyces nanus (Ehrenb. ex Link) Morton & Smith.

One specimen. On *Triticum aestivum* (spring wheat) EH: Pälkäne 14. 8. 1975. On dead wood or bark, leaves, herbaceous stems, etc. Europe (DOMSCH and GAMS 1970, ELLIS 1971).

Drechslera Ito (SHOEMAKER 1959).

Infrequent, mainly on the shoots.
Many *Drechslera* species reported:
Drechslera avenae (Eidam) Scharif on *Avena sativa* very common both on the shoots and in the ripe stands (MÄKELÄ and PARIKKA 1980). Found very common on oat fields in Finland (MÄKELÄ 1975 a). Widespread and most important in cool and moist climates (SPRAGUE 1950, OLOFSSON 1976). Commonly transmitted from oat seeds (MALONE and MUSKETT 1964, NEERGAARD 1977).

Drechslera graminea (Rabenh. ex Schlecht) Shoem.

Uncommon, mostly on barley, also on the shoots of wheat and rye (MÄKELÄ and PARIKKA 1980). Found frequently on spring barley field in Finland (MÄKELÄ 1975 a). Cosmopolitan, world-wide (SPRAGUE 1950, OLOFSSON 1976), frequent in barley seeds (NEERGAARD 1977).

Drechslera teres (Sacc.) Shoem.

Infrequent, mostly on barley, also on the shoots of wheat and rye (MÄKELÄ and PARIKKA 1980). Found commonly in spring barley fields in Finland (MÄKELÄ 1975 a). Very common seed transmitted in barley (NEERGAARD 1977).

Eidamia acremonioides (Harz.) Lindau (Lindau 1907).

Infrequent on the shoots in spring and on the ripe stands. Found in eight localities: V, U, St, EH.

Endophragmia hyalosperma (Corda) Morgan-Jones and Cole (1964) (Plate III 22, 23).

Uncommon on ripe cereals, absent from barley. Five specimens. On *Avena sativa* U: Siuntio 8. 9. 1977. On *Secale cereale* V: Mietoinen 12. 8. 1976, Sauvo 16. 8. 1977. On *Triticum aestivum* (winter wheat) EH: Pälkäne 18. 8. 1975, (spring wheat) EH: Iitti 4. 9. 1977. Conidia (18,2) 24,0 (29,9) × (8,3) 9,8 (11,6) μm. Conidiaphores 103,4 × 5 μm. Found on many herbaceous plants and arboreal plants in Europe (Ellis 1971).

Epicoccum purpurascens Ehrenb. ex Schlecht (Hughes 1958).

Very common on winter cereals (wheat, rye) in spring, mostly on winter wheat in 1975. Sporadically on ripe cereals. Found commonly on cereals in Finland (Mäkelä 1975 c). Cosmopolitan. Frequent on all sorts of plants, also common in soil (Gilman 1957, Barron 1968, Domsch and Gams 1970), in roots (Stetter and Leroul 1979) and as a contaminant of seeds (Malone and Muskett 1964, Neergaard 1977).

Fusarium Link ex Fr. (Booth 1971).

The genus *Fusarium* has been represented with many species, most commonly in 1975 (Mäkelä and Parikka 1980).

F. avenaceum (Corda ex Fr.) Sacc.

Prevalent on all the cereals, most rare on the shoots in the spring 1977. Found in Finland commonly on the foot of spring wheat (Hårdh 1953, Toiviainen 1974). Occurred moderately common on cereals as a foliicolous fungus (Mäkelä 1975 c) and on red clover as a causal agent of root rot (Ylimäki 1967). World-wide distribution. This species has a very wide host range, also on cereals, found in soil (Sprague 1950, Domsch and Gams 1970, Booth 1971, Neergaard 1977).

F. culmorum (W. G. Smith) Sacc.

The most common fungi on the specimens of all the cereals. Found in Finland common on the foot of wheat (Hårdh 1953, Toiviainen 1974), moderately common on all the cereals as a foliicolous fungus (Mäkelä 1975 c), and infrequently on red clover as a causal agent of root rot (Ylimäki 1967). World-wide (Cmi Map No 440). The species has a very wide graminicolous host range. Isolated from soil (Sprague 1950, Domsch and Gams 1970, Booth 1979), and seeds (Malone and Muskett 1964, Neergaard 1977).

F. graminearum Schwabe, Perfect state: *Gibberella zeae* (Schw.) Petch (cf.p.).

Uncommon on ripe cereals, sporadically on shoots. Found on the foot of spring wheat in Finland (Hårdh 1953), and infrequent on cereals as a foliicolous fungus (Jamalainen 1943 a, Mäkelä 1975 c). World-wide. This species occurs predominantly on cereals and other gramineous hosts. (Sprague 1950, Booth 1971, Neergaard 1977, Stetter and Leroul 1979).

F. nivale (Fr.) Ces. Perfect state: *Monographella nivalis* (Schaffn.) E. Müll. (cf. p.).

Common on the shoots of rye only in spring 1977. At other times very sporadically. Found on rye and wheat in Finland (Jamalainen 1943 a). Is the major pathogen of Gramineae, particularly on cereals in cool temperature regions (Cmi Map No 432, Sprague 1950, Booth 1971, Stetter and Leroul 1979), common in seeds (Neergaard 1977).

F. semitectum Berk. & Rav.

Uncommon. Found on all the cereals and in all the years (cf. Mäkelä 1975 c). Rather common and widespread (Booth 1971).

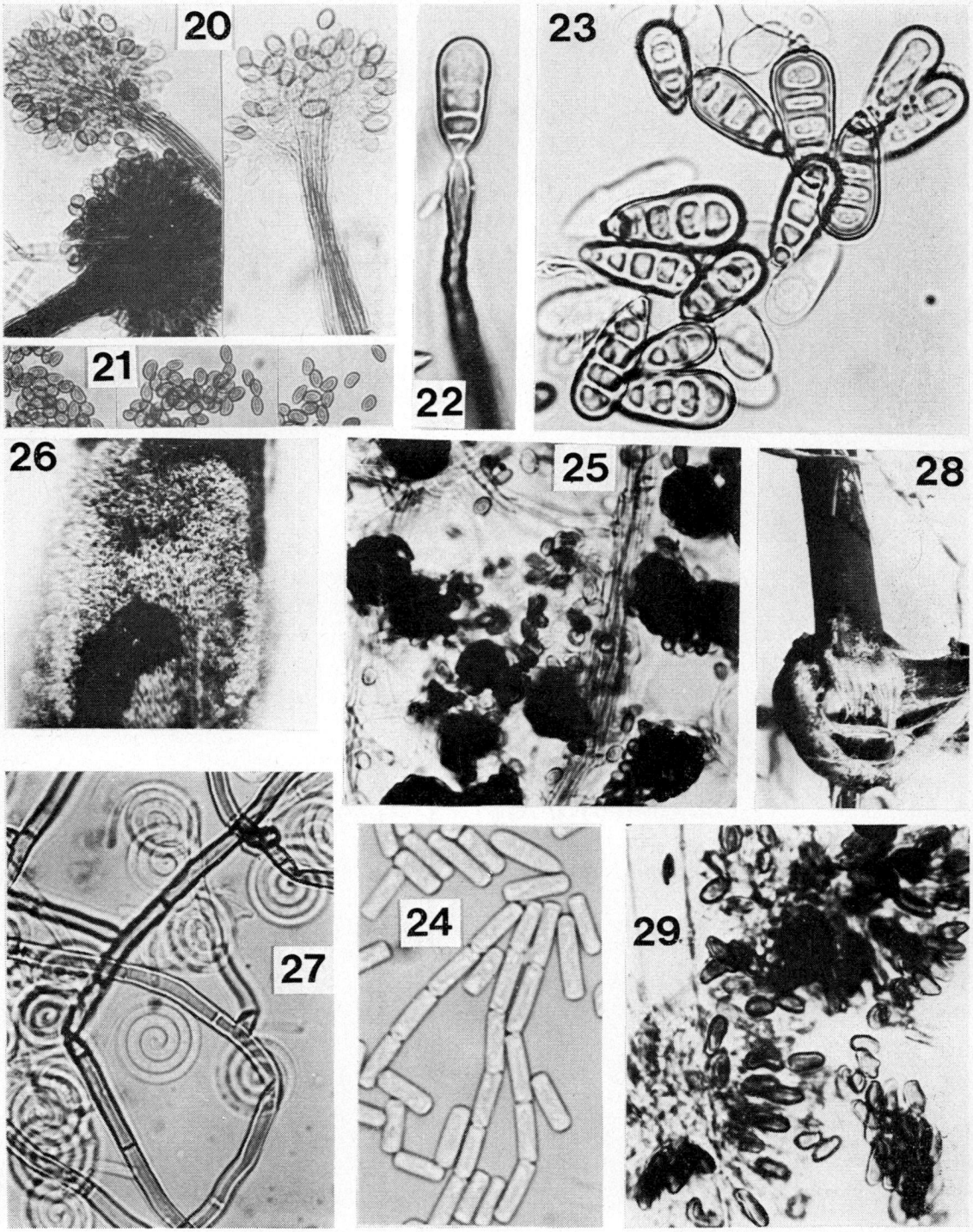

Plate III. 20—29. 20, 21: *Doratomyces purpureofusca* on oats. 22, 23: *Endophragmia hyalosperma* on winter wheat. 24: *Geotrichum candidum* on barley. 25: *Gliomastix murorum* on oats. 26, 27: *Helicosporium* sp. on winter wheat. 28, 29: *Melanconium sphaerospermum* on wheat.

Material: 20—29. 20, 21, 25: EH. Pälkäne 14. 8. 1975. 22, 23, 26, 27: EH. Pälkäne 18. 8. 1975. 24: V. Pertteli 16. 8. 1977. 28: St. Peipohja 30. 8. 1977. 29: EH. Pälkäne 14. 8. 1976. 20, 21: X 300. 22, 23, 24, 27: X 700. 26: X 10. 25: X 800. 28: X 3. 29: X 600.

In addition to these *Fusarium* species, other were found sporadically e.g. *F. moniliforme* Sheldon, *F. poae* (Peck) Wollenweber, *F. tricinctum* (Corda) Sacc. and some other unidentified *Fusarium* species. Together these *Fusarium* species were found rather frequently.

Fusidium Link spp. (LINDAU 1907, HUGHES 1958).

Infrequent on all the cereals. Found in soil (GILMAN 1957, BARRON 1968).

Geotrichum candidum Link. (CARMICHAEL 1957), (Plate III 24).

Four specimens. On *Hordeum vulgare* V: Kiikala 22. 9. 1977, Pertteli 18. 8. 1977. On *Secale cereale* U: Kirkkonummi 16. 5. 1978, EH: Pälkäne 14. 8. 1975. Widespread. Is frequently isolated from soil (GILMAN 1957, BARRON 1968, STETTER and LEROUL 1979).

Gliocladium Corda spp.

Very common on the ripe cereals, sporadically on the shoots. Many species of *Gliocladium* have been found in soil (GILMAN 1957).

G. roseum Bainier.

The most common series of *Gliocladium* species. World-wide. Very common in soil in cultivated land on roots of barley, wheat and oats (DOMSCH and GAMS 1970), occasionally as a contaminant of seeds (MALONE and MUSKETT 1964).

Gliomastix murorum (Corda) Hughes (GAMS 1971) syn. *Acremonium murorum* (Corda) W. Gams (Plate III 25).

Three specimens. On *Avena sativa* EH: Pälkäne 14. 8. 1975, Ypäjä 9. 9. 1975. On *Secale cereale* U: Artjärvi 21. 10. 1975. World-wide. The species is isolated commonly from soil (BARRON 1968, DOMSCH and GAMS 1970), and in roots (STETTER and LEROUL 1979).

Gonathobotrys Corda spp. (LINDAU 1907).

Sporadically. Seven specimens found in oats, rye and wheat in six localities; V, U, St, EH. Found in soil (BARRON 1968).

Graphium Corda spp. (LINDAU 1910).

Sporadically. Ten specimens found in all the cereals, barley, oats, rye and wheat in seven localities: V, U, EH. Found commonly on plant debris or woody substrata, also in soil (GILMAN 1957, BARRON 1968, DOMSCH and GAMS 1970, ELLIS 1971).

Helicosporium state of *Tubeufia helicomyces* Höhnel (Plate III 26, 27).

Fairly common on the ripe cereals, mostly on barley 1977. On the foot of culms grey violet, pilelike layers of the fungus. Conidia (80 conidia) (14,9) 22,1 (31,6) μm in diam., hyaline, pink in mass filaments multiseptate, hygroscopic, 1,7 μm in wide. According to MOORE (1955) conidial diameter is 12—20 μm, conidial filaments 1,5—2,5 μm thick.

Humicola Traaen ssp. ELLIS 1971.
H. grisea Traaen.

Sporadically, mainly on the shoots of cereals *Humicola* species are apparently very common in soils (BARRON 1968, DOMSCH and GAMS 1970).

Melanconium sphaerospermum (Pers.) Link. (Plate III 28, 29) ALLESCHER 1903, SUTTON 1964.

Fairly infrequent on ripe cereals, mostly on barley in 1977. Found in 23 localities: V, U, St, EH. On the foot of culms, black layers of the fungus. Conidia oval black brown (8,0) 9,1 (11,5) × (3,4) 4,2 (5,7) μm.

Metarrhizium anisopliae (Metsch.) Sorok. (BARRON 1968).

Five specimens. On *Secale cereale* V: Mietoinen 16. 8. 1977, EH: Somero 17. 8. 1977. On *Triticum aestivum* (winter wheat) V: Eura 16. 8. 1977, Koski 17. 8. 1977, (spring wheat) V: Tenhola 8. 9. 1979. One of the most important fungi for the biological control of insect pests (BARRON 1968, DOMSCH and GAMS 1970).

Monilia Pers. spp.

Three specimens. On *Secale cereale*, U: Siuntio 16. 5. 1978. On *Triticum aestivum* (winter wheat),

V: Perniö 21. 6. 1978, U: Helsinki 23. 5. 1978. Many *Monilia* species are isolated infrequently from soil (GILMAN 1957), and in roots (STETTER and LEROUL 1979).

Monacrosporium Oudem. spp.

Common on ripe cereals, very sporadically on winter cereals in autumn. Many species of this genus are known on the nematophagous fungi, also in cultivated soil (COOKE and DICKINSON 1965, COOKE 1969).

Monodictys levis (Wiltsh.) Hughes (HUGHES 1958).

One specimen. On *Hordeum vulgare* PP: Muhos 23. 6. 1976. Reported rarely in soil (BARRON 1968, DOMSCH and GAMS 1970).

Oedocephalum Preuss sp. (LINDAU 1907).

Two specimens. On *Secale cereale* U: Myrskylä 14. 6. 1977. On *Triticum aestivum* (winter wheat) St: Loimaa commune 4. 8. 1975. Species of this genus are reported infrequently from soil (GILMAN 1957).

Oidiodendron Robak sp.

One specimen. On secale cereale PH: Viitasaari 28. 6. 1976.

Oidiodendron is apparently widespread in its occurrence in soils, and there are frequent reports in the literature (BARRON 1962 b, 1968, DOMSCH and GAMS 1970).

Ostracoderma state of *Peziza ostracoderma* Korf (KORF 1960).

Sporadically, mostly on the shoots of winter cereals in autumn. Perhaps one of the most commonly encountered but least known of fungi from soil in Europe and North America (BARRON 1968, ELLIS 1976).

Paecilomyces Bainier spp. (BROWN and SMITH 1957).

Four specimens. On *Triticum aestivum* (spring wheat) V: Perniö 8. 9. 1977, U: Liljendal 17. 5. 1977, Askola 14. 6. 1977, (winter wheat) EH: Jokioinen 4. 8. 1975. Many species of the genus *Paecilomyces* found in soil (GILMAN 1957, BARRON 1968, DOMSCH and GAMS 1970).

Papulaspora Preuss.

Infrequent, mostly on the shoots of winter cereals (rye, wheat) in 1978. Some species of *Papulaspora* are reported infrequently from soil (BARRON 1968, DOMSCH and GAMS 1970), and in roots (STETTER and LEROUL 1979).

P. rubida Hotson (MALONE and MUSKETT 1964).

Fairly common, mostly on the shoots of oats and rye in spring. Found rarely on seeds of the grasses in Finland (MÄKELÄ 1972 b) and on seeds of the cereals (MALONE and MUSKETT 1964).

Penicillium Link ex Fr. spp. (RAPER and THOM 1949).

Common on the shoots of all the cereals, mostly on winter cereals in autumn. Very sporadically on ripe cereals. In particular many *Penicillium* species are reported in soil (GILMAN 1957, DOMSCH and GAMS 1970).

Periconia atra Corda (Plate IV 30).

One specimen. On *Triticum aestivum* (winter wheat) V: Tenhola 12. 8. 1975. On dead leaves of grasses (ELLIS 1971).

Periconia hispidula (Pers. ex Pers.) Mason & M. B. Ellis. (MASON and ELLIS 1953).

Two specimens. On *Triticum aestivum* (winter wheat) St: Kokemäki 30. 8. 1977; EH: Pälkäne 14. 8. 1978. Found on e.g. many Graminae, Carex (ELLIS 1971).

Periconia macrospinosa Lefebvre et Johnson (Plate IV 31, 32), (MASON and ELLIS 1953).

Uncommon on ripe cereals, mostly on oats in 1977. Widespread (CMI No 168), the most common species of this genus in soil (GILMAN 1957, DOMSCH and GAMS 1970, ELLIS 1971).

Phialophora Medlar sp. (HUGHES 1953).

Very sporadically on ripe cereals and the shoots of cereals (wheat, barley). Found in nine specimens from seven localities: V, U, St, EH (MÄKELÄ and PARIKKA 1980). *Phialophora* species are relatively common in soils, especially forest soils (BARRON 1968, DOMSCH and GAMS 1970).

Pseudocercosporella herpotrichoides (Fron) Deighton (BOOTH and WALLER 1969, CMI No 386).

Infrequent on the shoots of cereals (rye, wheat) in eight localities: V, U, EH. (cf. MÄKELÄ and PARIKKA 1980). Widespread throughout Europe also occurs in N. America (CMI Map No 74), (SPRAGUE 1950, BOOTH and WALLER 1969).

Rhinocladiella Nannf. spp.

Fairly common on ripe cereals, mostly on rye in 1976. Isolates from soil (BARRON 1968, ELLIS 1971).

Rhynchosporium secalis (Oud.) J. J. Davis (OWEN 1973, CMI No 387).

Common on ripe oats and the shoots of rye, sporadically on the shoots of barley (cf. MÄKELÄ and PARIKKA 1980). Observed commonly on spring barley and winter rye in Finland (MÄKELÄ 1974). Widespread (CALDWELL 1937, SPRAGUE 1950). Overwintering is largely on infected barley stubble, remains and volunteer plants (OWEN 1973), found also in seed of barley (NEERGAARD 1977).

Scopulariopsis brevicaulis (Sacc.) Bain.

Two specimens. On *Hordeum vulgare* V: Muurla 8. 6. 1977. On *Triticum aestivum* (winter wheat) A: Jomala 26. 5. 1977. Common and widespread (CMI No 100), isolated e.g. from soil and various plants (GILMAN 1957, BARRON 1968, DOMSCH and GAMS 1970, ELLIS 1971).

Spegazzinia Sacc. sp. (Plate IV 33), (HUGHES 1953, COLE 1974).

One specimen. On *Triticum aestivum* (spring wheat) St: Punkalaidun 9. 9. 1976. Reported rarely from soil (BARRON 1968, ELLIS 1971, 1976).

Stachybotrys atra Corda (cf. KORPINEN and YLIMÄKI 1972).

One specimen. On *Hordeum vulgare* V: Kiikala 17. 8. 1977. Cosmopolitan, very commonly isolated from soil and dead plants (GILMAN 1957, BARRON 1968, DOMSCH and GAMS 1970, ELLIS 1971).

Stachybotrys aurantia Barron (BARRON 1962 a) (Plate IV 34).

Sporadically on ripe cereals, mainly spring wheat. Found in five localities: V, St, EH, PK. Isolated very rarely from soil (BARRON 1962).

Stemphylium botryosum Simmons (SIMMONS 1967).

Sporadically on shoots and also ripe cereals. Found in six localities: V, St, EH. Cosmopolitan. Common on dead herbaceous plants, also isolated from soil (GILMAN 1957, BARRON 1968, ELLIS 1971).

Torula herbarum (Pers.) Link ex S. F. Gray (HUGHES 1953, 1958).

Common on ripe winter cereals (rye, wheat), sporadically on the shoots of cereals. Reported infrequently from soil (GILMAN 1957, BARRON 1968, DOMSCH and GAMS 1970) and in roots (STETTER and LEROUL 1979).

Tricellula aquatia WEBSTER (1959).

Sporadically on the shoots of winter cereals, mainly on winter wheat in 1975. Reported in minor amounts on 13 grass species in Finland (MÄKELÄ 1972). Found infrequently in moist soil (NILSSON 1964, DOMSCH and GAMS 1970).

Trichocladium asperum Harz (HUGHES 1958).

Sporadically, mainly on the shoots of cereals. World-wide. Recovered from soil (GILMAN 1957, BARRON 1968, DOMSCH and GAMS 1970).

Trichoderma viride Pers. ex Fr.

Fairly common on some ripe cereals, more sporadically on shoots. World-wide. One the most widespread soil fungi. It has been exten-

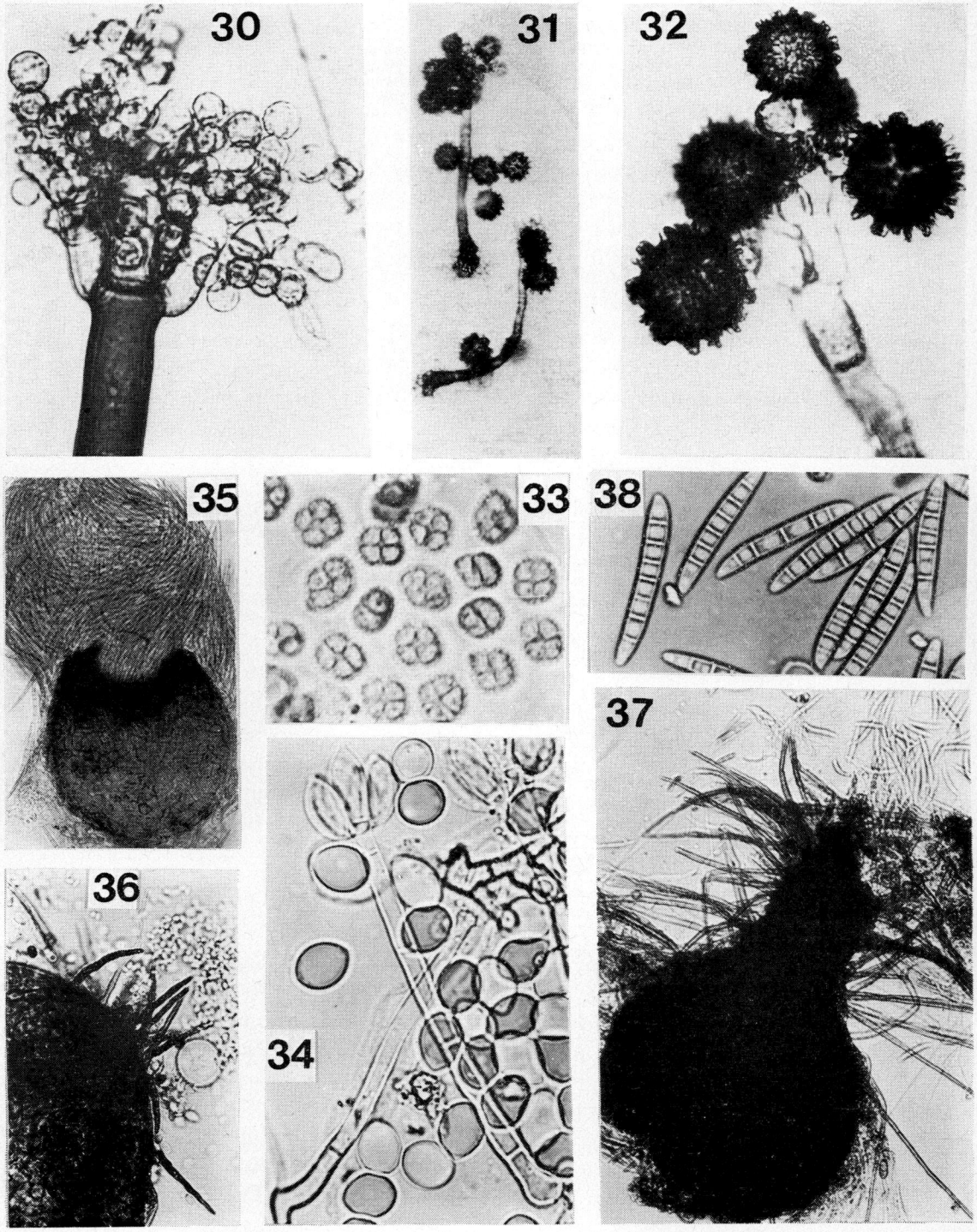

Plate IV. 30—38. 30: *Periconia atra* on winter wheat. 31, 32: *P. macrospinosa* on winter wheat. 33: *Spegazzinia* sp. on spring wheat. 34: *Stachybotrus aurantia* on spring wheat. 35: *Phaeoseptoria festucae* on barley. 36: *Pyrenochaeta* sp. on oats. 37, 38: *Wojnowicia graminis* on wheat.

Material: 30—38. 30: V. Tenhola 12. 8. 1975. 31, 32: V. Perniö 12. 8. 1975. 33: St. Punkalaidun 9. 9. 1976. 34, 36: V. Mietoinen 19. 8. 1975. 35: V. Koski Tl 4. 7. 1975. 30: X 800. 31: X 150. 32: X 800. 33: X 500. 34: X 1000. 35: X 200. 36: X 400. 37: X 150. 38: X 750.

sively studied because of its antagonism and parasitism against other fungi (GILMAN 1957, BARRON 1968, DOMSCH and GAMS 1970).

Trichothecium roseum Link ex Fr.

Fairly common on ripe cereals, mostly on the shoots of winter cereals in the autumn 1976. Reported from soil with high frequence (GILMAN 1957, BARRON 1968).

Ulocladium consortiale (Thüm.) Simmons (SIMMONS 1967).

Fairly infrequent on shoots, most rare on ripe cereals. Isolated from leaf litter, roots, soil and seeds (GILMAN 1957, DOMSCH and GAMS 1970, ELLIS 1976, NEERGAARD 1977, STETTER and LEROUL 1979).

Verticillium tenerum (Nees ex Pers.) Link Syn. *Verticillium lateritium* (Ehrenb. ex Fr.) Rabenh. (GAMS 1971).

Sporadically on nearly all the specimens, mostly on the shoots of barley and rye. World-wide. One of the most common *Verticillium* species in soil (GILMAN 1957, BARRON 1968, DOMSCH and GAMS 1970).

Also the other *Verticillium* species were found. They are extremely common in soil (BARRON 1968, GAMS 1971).

Volucrispora graminicola (Webster) Ingold (INGOLD et al. 1968). One specimen. On *Triticum aestivum* (winter wheat) V: Salo 9. 10. 1975.

Found on some grasses (WEBSTER 1954, MÄKELÄ 1972) and also in non-aquatic habitants (Park 1974).

An unidentified aquatic Hyphomycetes, like *Acaulopage tetraceras* Drechsler (cf. NILSSON 1964, INGOLD 1975).

Five specimens. On *Triticum aestivum* (winter wheat) U: Sipoo 1. 11. 1977; EH: Pälkäne 7. 6. 1976, 14. 8. 1976, (spring wheat) St: Kokemäki 5. 8. 1976. On *Secale cereale* V: Vihti 9. 5. 1977.

Volutella ciliata (Alb. et Schw.) Fr. (LINDAU 1910).

Sporadically, mostly on ripe cereals. Widespread, isolated from soil (BARRON 1968, DOMSCH and GAMS 1970) and in roots (STETTER and LEROUL 1979).

Also some other unidentified *Volutella* species were found.

Deuteromycotina, Coelomycetes, Melanconiales. *Colletotrichum garminicola* (Ces.) Wils. (von ARX 1957).

Common on ripe oats in 1977, fairly common on ripe barley, sporadically on other specimens. Found infrequently on spring cereals in Finland (MÄKELÄ 1975 c). World-wide on cereals and grasses (SPRAGUE 1950, MORDUE 1967, CMI No 132). *Colletotrichum* is frequently recovered from soil (BARRON 1968, DOMSCH and GAMS 1970).

Deuteromycotina, Coelomycetes, Sphaeropsidales. *Ascochyta sorghi* Sacc. (SPRAGUE 1950, PUNITHALINGAM 1979).

Infrequent on the shoots of winter cereals (MÄKELÄ and PARIKKA 1980). Found sporadically on spring cereals in Finland (MÄKELÄ 1975 c). General in North America, Europe and Asia, at least in the cool temperature parts. Found on cereals (SPRAGUE 1950).

Ascochyta hordei Hara (SPRAGUE 1950, PUNITHALINGAM 1979).

Infrequent on the shoots of cereals, common only on the shoots of winter wheat in 1978 (MÄKELÄ and PARIKKA 1980). Found sporadically on spring cereals in Finland (MÄKELÄ 1975 c). Reported from *Hordeum* species in USA (SPRAGUE 1950).

Ascochyta Corda spp.

Uncommon on ripe cereals, mostly in 1975. Found fairly infrequent also on many species of grass in Finland (MÄKELÄ 1972 a).

Coniothyrium Corda spp.

Sporadically on ripe cereals and on the shoots of wheat and barley, mostly on rye in 1975. Some species of *Coniothyrium* found in soil (GILMAN 1957, DOMSCH and GAMS 1970).

Coniothyrium cerealis E. Müller in Zogg is found to be the only *Coniothyrium* species on the dead culms of *Triticum vulgare*, *Hordeum vulgare* and *Secale cereale* (ZOGG 1951).

Hendersonia crastophila Sacc.

Infrequent. Found on the shoots of wheat in five localities: V, U. The fungus is found fairly common in Finland on cereals and very common on 39 grass species (MÄKELÄ 1977). Reported on many graminicolous hosts (SPRAGUE 1950, JØRSTAD 1967).

Hendersonia culmicola Sacc.

Uncommon. Found on winter wheat and rye in eleven localities: V, U, St, EH. The fungus is found very infrequently on nine grass species (MÄKELÄ 1977). Reported on grass in Europe and USA (SPRAGUE 1950, JØRSTAD 1967, ÅRSVOLL 1975).

Hendersonia sp.

Sporadically on the shoots of winter cereals.

Phaeoseptoria festucae Sprag. (Plate IV 35).

Sporadically on all the cereals. Found in Finland rare but moderately common on barley, rye and wheat (mostly on spring wheat) and also on 12 grass species (MÄKELÄ 1977). Reported on many grass species (SPRAGUE 1943, WEBSTER 1955, JØRSTAD 1967).

Phoma sensu Sacc. spp. (GROVE 1935, DORENBOSCH 1970, BOEREMA 1976).

Fairly common, mostly on ripe cereals. Many species of the *Phoma* have been found in soil (GILMAN 1957, DOMSCH and GAMS 1970, STETTER and LEROUL 1979).

Pyrenochaeta de Not sp. (GROVE 1935, Plate IV 36).

Fairly common, mostly on ripe cereals in 1976. Some species of the *Pyrenochaeta* have been found in soil (GILMAN 1957, DOMSCH and GAMS 1970).

Septoria nodorum Berkeley.

Common on wheat in 1975 and 1978. Fairly sporadically on barley and rye (cf. MÄKELÄ and PARIKKA 1980). *S. nodorum* has been found in recent years mainly on cereals mostly on wheat and moderately common on tworowed barley. Besides this the fungus was found on 27 grass species throughout the country (MÄKELÄ 1977). World-wide (SPRAGUE 1950, CMI Map 283).

Septoria tritici Roberge.

Found on the shoots of winter wheat in spring, mostly in 1976 (cf. MÄKELÄ and PARIKKA 1980). The fungus has occurred commonly in recent years on winter wheat in the south-western parts of Finland (MÄKELÄ 1977). Widespread and important, particularly in moist conditions (SPRAGUE 1950).

Septoria Sacc. spp.

Sporadically on the cereals except oats (cf. MÄKELÄ and PARIKKA 1980).

Wojnowicia graminis (McAlp.) Sacc. & D. Sacc. (Plate IV 37, 38).

Found fairly commonly on *Triticum aestivum* (winter wheat), infrequent on *Secale cereale* and *Hordeum vulgare* and absent from *Avena sativa*. Found in 22 localities: V, U, EH, PH (MÄKELÄ 1979).

Bacteria, Actinomycetales. *Streptomyces* spp. (WAKSMAN 1967).

Very common on the shoots of all the cereals. Common on ripe cereals, in roots (STETTER and LEROUL 1979).

DISCUSSION

The method of investigation used in this study, in which the stem base and roots of cereal plants are kept in moist Petri dishes (moist chamber culture) brings forth those fungal species which are propagated by air-borne spores, as well as soil fungi in large numbers (cf. GILMAN 1957, BARRON 1968, DOMSCH and GAMS 1970). On the other hand, mildews, rusts and smuts are not revealed by this method. This procedure is likewise not suited for certain Phycomycetes.

The total number of fungi determined was about 130 species belonging to 100 genera. The majority of these fungi (70 genera) belonged to the group *Deuteromycotina* and of these, 62 genera to the order *Hyphomycetes*. The group *Ascomycotina* had 15 genera and *Zygomycotina* 7 genera (cf. MILLER et al. 1957, AL-DOORY et al. 1959, HODGES 1962, KŸRŸLENKO 1968 b, CHRZANOWSKI 1976, STETTER and LEROUL 1979).

The total numbers of fungi in all the cereals were 20—25 % greater than in the individual cereal species. In winter cereals (rye and wheat) the incidence of fungi was almost the same in the different stages of cereal development. On the other hand, in spring cereals the shoots had 30—40 % fewer fungal species than in the corresponding mature plants. The effect of the developmental stage of cereals upon the abundance of fungi has been ascertained in many studies (HOES 1962, 1964, KŸRŸLENKO 1968 a, 1968 b, GAMS and DOMSCH 1969).

In the individual cereal samples the numbers of fungal species were rather low, averaging for all the trial years 3,7—6,3 (range 0—12) in mature plants and 3,2—7,6 (range 0—14) in the shoots. The highest numbers of fungi were found in wheat, the fewest in oats. In barley the amounts of fungi remained approximately the same from year to year.

There were definite differences between the different years of the study. The highest numbers of fungal species per mature sample occurred in the year 1976, when there was a record large grain yield. The growing season in this year was cool and dry. The fewest fungi were found in 1975 when the growing season was warm with low rainfall. In the shoot samples these annual differences were even greater (MÄKELÄ and PARIKKA 1980).

The majority of the fungi determined were saprophytes. In the mature grains and in the shoots of winter cereals in autumn an average of 20—30 % of the fungi were parasites. In the spring the proportion of parasites varied from 15 to 40 %. The most common parasitic fungi were *Fusarium culmorum*, *F. avenaceum*, *Gaeumannomycec graminis*, *Rhizoctonia solani* and *Septoria nodorum* (MÄKELÄ and PARIKKA 1980).

The most prevalent saprophytic fungi were *Cladosporium*-, *Alternaria*-, *Penicillium*- and *Acremonium* -species, *Gliocladium roseum* as well as *Streptomyces* -species.

Fungi which occurred with approximately equal frequency in all the samples were relatively few. Such fungi were some of the *Fusarium*-species such as *F. culmorum* and *Botrytis cinerea*. Many fungal species were found to be more common in mature cereals than in the shoots, such as e.g. *Gaeumannomyces graminis*, *Gliocladium roseum*, *Melanospora* spp., *Monacrosporium* spp., *Rhizoctonia solani*. Likewise in the shoots of winter cereals many fungi were common in the autumn e.g. *Acremoniella atra*, *Alternaria* spp., *Cladosporium* spp., *Acremonium* spp. *Epicoccum purpurascens*, *Septoria nodorum*, *Trichothecium roseum* and *Streptomyces* spp. This indicates the effect of the summer season in promoting fungal abundance and also the possible effect of air contamination. In addition the possibility of seed contamination should also be taken into consideration. This applies likewise to the shoots of spring cereals in the spring. But there was only on rare fungus (*Papulaspora* spp.) which in the shoots was more prevalent in the spring than at other times of the season. This indicates that the long winter in Finland, lasting

duration of the thermal winter (0°— 0°C) 110—145 days even in southern Finland (KOLKKI 1966) reduces the numbers of fungi. In addition, the moisture is also significant, since in autumn the conditions are generally much more moist than in the spring or summer (HELIMÄKI 1967).

Some of the fungi occurred similarly in all of the cereal species (e.g. *Acremonium* spp., *Alternaria* spp., *Rhizoctonia solani* and many *Fusarium* species). Many of the fungi, however, preferred one certain cereal instead of others. For example, species which appeared predominantly in the shoots of winter wheat in the spring were *Ascochyta hordei*, *Septoria tritici* and *Typhula incarnata*. Also *Septoria nodorum*, *Gaeumannomyces graminis* and *Acremoniella atra* were found more commonly on wheat. *Rhynchosporium secalis*, *Bipolaris sorokiniana*, *Drechslera graminea* and *D. teres* were specialized on barley, while *Fusarium nivale* was more prevalent on rye. *Drechslera avena*, *Colletotrichum graminicola* and *Melanospora* species were more common on oats than on the other cereals.

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Kaiho Mäkelä and Leena Mäki
Agricultural Research Centre
Institute of Plant Pathology
SF-01300 Vantaa 30, Finland

SELOSTUS

Viljan tyvissä ja juuristossa esiintyvä mikrosienistö Etelä-Suomen pelloilla

KAIHO MÄKELÄ ja LEENA MÄKI

Maatalouden tutkimuskeskus

Vuosina 1975—1978 kerättiin 1035 tuleentunutta viljanäytettä 119 paikkakunnalta ja 1029 orasnäytettä, 91 paikkakunnalta, Etelä-Suomesta, valtaosin viljelijäin pelloilta. Sienet kasvatettiin kosteakammiomenetelmällä ja määritettiin mikroskooppisesti.

Todettujen sienten kokonaismäärä oli n. 130 lajia, jotka edustivat 100 sukua. Valtaosa näistä sienistä (70 sukua) kuului luokkaan *Deuteromycotina* ja siinä ryhmään *Hyphomycetes* (62 sukua). Luokkaan *Ascomycotina* kuului 15 sukua ja luokkaan *Zygomycotina* 7 sukua.

Sienten kokonaismäärä oli 20—25 % suurempi kuin yksittäisellä viljalajilla todettu. Eri kehitysasteella olevissa syysviljoissa (ruis, vehnä) oli sienten lukumäärä miltei sama. Sen sijaan kevätviljan oraissa oli sienilajeja 30—40 % vähemmän kuin vastaavassa tuleentuneessa viljassa.

Yksityisissä viljanäytteissä oli sienilajeja melko vähän, tuleentuneessa viljassa eri vuosina keskim. 3,7—6,3 (vaihtelu 0—12) ja oraissa keskim. 3,2—7,6 (vaihtelu 0—14). Eniten sieniä oli vehnällä, vähiten kauralla. Ohralla sienilajisto pysyi jokseenkin samana vuodesta toiseen.

Eri koevuosien välillä oli eroavuuksia. Eniten sienilajeja oli tuleentunutta viljanäytettä kohti vuonna 1976, jolloin viljasatokin oli ennätyksellisen suuri. Kasvukausi oli viileä ja vähäsateinen. Vähiten sieniä oli vuonna 1975, jolloin kasvukausi oli lämmin ja vähäsateinen. Oraissa olivat vuosien väliset erot vielä suurempia.

Näytteissä todetuista sienistä oli valtaosa saprofyyttejä. Tuleentuneessa viljassa ja syysviljan oraissa syksyllä oli parasiitteja vain keskim. 20—30 %. Keväällä parasiittien osuus oraissa vaihteli 15—40 %. Yleisimmät parasiittiset sienet olivat *Fusarium culmorum*, *F. avenaceum*, *Gaeumannomyces graminis*, *Rhizoctonia solani* ja *Septoria nodorum*.

Yleisimmät saprofyyttiset sienet olivat *Cladosporium*-, *Alternaria*-, *Penicillium*- ja *Acremonium* -lajeja, *Gliocladium roseum* sekä *Streptomyces* -lajeja.

Sieniä, joita esiintyi jokseenkin yhtä yleisenä kaikissa näytteissä oli vähän. Tällaisia olivat mm. eräät *Fusarium* -lajit ja *Botrytis cinerea*. Useita sienilajeja, mm. *Gaeumannomyces graminis*, *Gliocladium roseum*, *Melanospora*- ja *Monacrosporium* -lajeja sekä *Rhizoctonia solani*, todettiin tuleentuneissa viljoissa yleisempinä kuin oraissa. Myös syysviljan oraissa oli syksyisin yleisenä monia sieniä kuten *Acremoniella atra*, *Alternaria*-, *Cladosporium*- ja *Acremonium* -lajeja, *Epicoccum purpurascens*, *Septoria nodorum* ja *Trichothecium roseum*. Tämä viittaa kesäkauden sieniä lisäävään vaikutukseen ja myös mahdolliseen ilmalevintään. Toisaalta on huomioitava oraitten siemensaastunnan mahdollisuus. Tämä koskee myös kevätviljan oraita keväällä. Mutta oli vain jokunen harva sieni, joka oli oraissa yleisempi keväällä kuin muulloin (*Papulaspora* spp.). Tämä viittaa siihen, että Suomen pitkä talvikausi, Etelä-Suomessakin keskim. 110—145 pv, vähentää sienten määrää. Myös kosteudella on merkitystä, sillä syksyisin on kosteus yleensä huomattavasti suurempi kuin keväisin.

Osa sienistä esiintyi samantapaisesti kaikilla viljalajeilla, mm. monet *Fusarium*-lajit. Useat sienet suosivat jotain viljaa toisten kustannuksella.

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ROOT AND FOOT ROT DISEASES OF CEREALS IN SOUTHERN FINLAND IN 1975—1978

KAIHO MÄKELÄ and PÄIVI PARIKKA

MÄKELÄ, K. & PARIKKA, P. 1980. **Root and foot rot diseases of cereals in southern Finland in 1975—1978.** Ann. Agric. Fenn. 19: 223—253. (Agric. Res. Centre, Inst. Pl. Path. SF-01300 Vantaa 30, Finland).

The experimental material comprised 1035 mature cereal samples from 119 localities and 1029 seedling samples from 91 localities in southern Finland. The samples were from five cereal species and were collected in the years 1975—1978. The extent of injury to the stem bases and roots (20 plants per sample) was judged visually. The fungi were determined microscopically using the moist chamber method.

At harvest time the numbers of healthy mature plants were least in barley and winter wheat (av. 7—23 %) and highest in oats (av. 30—38 %). Mild damage to the stem base and moderately healthy roots were found in about ½ of the samples. Severe damage, i.e. dark-coloured stem bases and roots occurred mostly in wheat and barley (av. 35—45 %) and to the least extent in oats (less than 10 %). The seedlings were generally healthier than the mature cereals. Seedlings of spring cereals were healthier than those of winter cereals. The winter cereal seedlings, particularly their leaves, were healthier in the autumn than in the spring. Oats showed less damage than the other cereals, both in the seedling stage and as a mature cereal. There were differences in the amount of damage from year to year.

There was only partial correspondence between the symptoms of root and foot rot and the occurrence of the fungi causing the diseases. The greatest numbers of fungi occurred in wheat and barley, the least in oats. There were more fungi in the mature cereals and the seedlings of winter cereals than in the seedlings of spring cereals. The most common fungi were *Fusarium culmorum* (W. G. Smith) Sacc., *Gaeumannomyces graminis* (Sacc.) v. Arx et Olivier, *Rhizoctonia solani* Kühn and *Septoria nodorum* Berkeley.

Fusarium culmorum occurred commonly in all the cereals and was most prevalent in the warm growing season 1975. Among the other *Fusarium* species, of which more than a dozen were determined, *F. avenaceum* (Corda ex Fr.) Sacc. was quite common while *F. graminearum* Schwabe was rarely found. Only in the spring 1977 was *F. nivale* (Fr.) Ces. prevalent in the seedlings of rye. Noteworthy was *Gaeumannomyces graminis*, which was most common in wheat, somewhat common also in rye and only infrequently found in barley. This fungus occurred mostly in the cool, rainy summer 1977. *Rhizoctonia solani* was more prevalent in the autumn than in the spring, and it was most abundant in the cool, dry season 1976. *Septoria nodorum* occurred predominantly in wheat, mainly in the seedlings during wet growing seasons and the following season. *Bipolaris sorokiniana* (Sacc. on Sorok). Shoemaker was found to some extent in certain fields of barley. *Pseudocercosporella herpotrichoides*

(Fron) Deighton occurred rarely in the seedlings of winter wheat during the autumn. *Colletotrichum graminicola* (Ces.) Wils. was common in mature oats and fairly common in barley.

Index words: Root and foot rot diseases, cereals.

INTRODUCTION

The structural alteration in Finnish agriculture during the past two decades has resulted in an increase in cereal growing and a corresponding decrease in grassland. In 1976 52,1 % of the arable land was grown to cereals as compared to only 34 % in 1955 (Off. Statist. Finl. Agric. 1955, 1976). This change was most pronounced in southern and southwestern Finland where cereals and especially food grains are concentrated (Raininko 1976).

Monoculture, or the continuous growing of one cereal species on the same field, usually results in a decline in the yields as compared with rotational culture. In Finnish studies (Talvia 1970, Teittinen 1974, 1977) the declines in yields were found to be greatest 3—5 years after the beginning of monoculture, after which the yield level became established at about 10—20 % lower than that of rotational cultivation. The reduction in yield was greater in fine sand than in clay soils. Among the different cereal species wheat showed a greater decline than barley. According to other studies (e.g. Airola 1975) barley suffered more than wheat. Similar results have been found in other Nordic countries (Jepsen and Jensen 1976, Nyström 1976, Olsson 1978), although considerable variations occurred in the results. Recent Danish investigations (Hjortsholm 1979) indicate that there are no great differences in the yield levels between continuous barley growing and rotational cultivation.

The causes of the decline in yields in monoculture are held to be e.g. changes in soil fertility, structure and nutrient proportions, accumulation of phenolic acids in the soil, as well as increases in numbers of weeds, pests and plant disease organisms (Bockman and Knoth 1965, 1971, Domsch and Gams 1968).

On the other hand, many workers have presented results indicating no noteworthy differences between continuous and rotational growing of cereals (Andersen 1979, Hjortsholm 1979, Stetter and Leroul 1979). The theme of monoculture has aroused great interest in last years (cf. Schippers and Gams 1979).

The practice of monoculture is nowadays generally considered to be associated with increased in root and foot rot diseases. The main cause of root and foot rot is the presence of soil fungi which damage the roots and stem bases of the cereal plants, thus diminishing water and nutrient uptake (Sprague 1950, Nilsson 1969). The plants are often infected already at the seedling stage. Germination is reduced or inhibited, and the injured seedlings grown slowly or die (Colhoun et al. 1968, Nilsson 1969, Weste 1975, Kurppa 1976, Jenkyn and King 1977, Voĭtova 1977). Winter cereals are especially susceptible (Kolk and Olsson 1975, Olvång 1978). As a result of the death of the seedlings, the numbers of living plants decrease and this may be partially responsible for the reduction in yield (Slope 1968, Haegemark and Olvång 1976). The depression in yield is mainly due to the fact that these diseases reduce the number of straws and consequently also the number of heads per plant. Also the 1000-grain weight is generally reduced (Teittinen 1977, Olsson 1978). The weather conditions and the culture methods are considered to be extremely important factors in the occurrence of root and

foot rot diseases (TALVIA 1970, TEITTINEN 1974, 1977, OLSSON 1978).

The most important causal agents of root and foot rot diseases are *Bipolaris sorokiniana* (Sacc. on Sorok.) Shoemaker, *Fusarium* species, especially *F. culmorum* (W. G. Smith) Sacc., *F. graminearum* Schwabe ja *F. avenaceum* (Corda ex Fr.) Sacc., *Gaeumannomyces graminis* (Sacc.) v. Arx et Olivier, *Pseudocercosporella herpotrichoides* (Fron) Deighton, *Rhizoctonia solani* Kühn (SPRAGUE 1950, MOORE 1959, KORSHUNOVA 1968, NILSSON 1969, FOCKE 1971). Also *Septoria nodorum* is a common parasite in the stem bases of cereals (REINECKE 1977) and causes the same type of damage to seedlings as do root and foot rot diseases (KIETREIBER 1961, MÄKELÄ and MÄKI 1980).

In addition there are a large number of dark-coloured fungi which inhabit the stem bases and roots of cereals as saprophytes or weak parasites and cause symptoms resembling those of root and foot rot diseases. Such fungi are e.g. certain species of *Arthrinium*, *Colletotrichium graminicola* (Ces.) Wils., *Dictyosporium* spp., *Gliomastix murorum* (Corda) Hughes, *Melanconium sphaerospermum* (Pers.) Link. *Melanospora* spp., *Ophiobolus herpotrichus* Sacc., *Periconia* spp., *Phoma* spp., *Torula herbarum* (Pers.) Link ex S. F. Gray, *Ulocladium consortiale* (Thüm). Simmons ja *Wojnowicia graminis* (McAlp.) Sacc. & D. Sacc. (SPRAGUE 1950, NILSSON 1969, SALT 1976, STETTER and LEROUL 1979, MÄKELÄ and MÄKI 1980).

In Finland there are reports dating back to the 1890's of cereal diseases with spotting of the plants resembling root and foot rot, for example from the provinces of Varsinais-Suomi and Savo (REUTER 1912). In 1910 REUTER (1912) observed at Hausjärvi in South Häme a disease in winter rye which he presumed to be caused by *Ophiobolus graminis* Sacc. and *O. herpotrichus* (Fr.) Sacc. As wheat cultivation expanded in the 1930's, increased attention was given to the crop damage caused by root and foot rot diseases (HILLI 1933). Investigations of »light heads» of wheat were begun in 1936, at which time the disease occurred abundantly in the provinces of Satakunta, South and Central Ostrobothnia and South Savo (JAMALAINEN 1946). These studies on »shrivelheads» of spring wheat were continued by HÅRDH (1953) in the years 1946—1953. He discovered *Cercosporella herpotrichoides* Fron to be the most common fungus, and he isolated it for the first time in Finland. According to his studies this fungus occurred in all parts of the country but most seriously in the coastal regions along the Gulf of Bothnia. In addition he isolated from diseased stems *Fusarium avenaceum* (Fr.) Sacc. and *F. culmorum* (W. G. Smith) Sacc. as well as certain other species of *Fusarium*. In 1958 the fungus *Ophiobolus graminis* was isolated from spring wheat in the province Uusimaa for the first time in Finland (IKÄHEIMO 1959). Root and foot rot, eyespot, take-all and shrivelheads are especially predominant in this area of the country (IKÄHEIMO 1960).

Because of the abundant occurrence of root and foot rot diseases, intensive studies were begun on these diseases in the 1960's. In the years 1964—1966 TOIVIAINEN (1966, 1970) investigated root and foot rot on 142 farms located in the provinces of West Uusimaa, South Satakunta and South Savo. The results showed that these diseases were common in the entire region of cereal growing in Finland. The most important host plants of take-all (*Gaeumannomyces graminis*) were spring and winter wheat as well as barley. From oats TOIVIAINEN (1966) isolated *Gaeumannomyces graminis* (Sacc.) v. Arx et Olivier var. *avenae* from Satakunta (Huittinen) in 1962.

Eyespot (*Pseudocercosporella herpotrichoides* (Fron) Deighton also occurred sometimes in large numbers. *Fusarium culmorum* was encountered to some extent, whereas *Rhizoctonia solani* Kühn was found only rarely.

In the years 1963—1965 extensive field trials were established at the 12 experimental stations of the Agricultural Research Centre in order to study the unfavourable effects of continuous

cereal cultivation. In the trials spring wheat and oats, or barley and oats, were grown both in continuous monoculture (1963—1977) and in rotation with grass leys (1970—1972). From the year 1973 all the plots were grown continuously with cereals. The soil types in the trials consisted of silt, fine sand and clay (VIRTANEN 1979). In the years 1963—1968 the most common stem diseases were take-all (*Ophiobolus graminis*) and eyespot (*Cercosporella herpotrichoides*). Take-all was most prevalent in spring wheat and oats, while eyespot occurred mostly in barley. Both diseases had generally a mild incidence. Stem damage caused by *Fusarium* species was most common in 1963. In the same year *Rhizoctonia solani* occurred to same extent (TALVIA 1970).

In the years 1975—1977 the most dominant causal agents of root and foot rot were *Fusarium culmorum* and *Gaeumannomyces graminis*, as well as to a certain extent *Rhizoctonia solani*. On the other hand *Pseudocercosporella herpotrichoides* was virtually not found at all (VIRTANEN 1979, MÄKELÄ and MÄKI 1980). When grown in monoculture, wheat thrived more poorly than in rotational culture. Also barley showed considerable yield losses in monoculture. On the other hand there were no appreciable differences in oats between continuous and rotational cropping (TEITTINEN 1974, 1977). According to VIRTANEN (1979) both wheat and oats thrived better in rotational than in continuous culture. The differences from year to year were very great (TALVIA 1970, TOIVIAINEN 1966, 1970, TEITTINEN 1974, 1977, VIRTANEN 1979).

The present study is based upon material collected in the years 1975—1978 from cereal fields in southern and southwestern Finland. The material comprised both mature cereal plants and seedlings gathered in the autumn and spring.

In this study attempts were made to ascertain the most common fungal species causing root and foot rot diseases, their occurrence in different cereal species and at different developmental stages, as well as the annual and regional differences. The same material was also used to determine all the other fungal species occurring in the stem bases and roots of cereals (MÄKELÄ and MÄKI 1980).

MATERIAL AND METHODS

Region

The region of this study comprised mainly the southwestern and southern parts of the country, in the cultivation zones I and II (Figs. 1 and 2). This region makes up 1/3 of the total arable land in Finland (2,6 million hectares). It is an area of cereal cultivation, especially bread grains. During the years of this investigation the above-mentioned region included over 90 % of the winter wheat area of the country, nearly 80 % of the spring wheat area, 60 % of the rye and 40 % of both barley and oats (OFF. STATIST. FINL., AGRIC. 1975, 1976, 1977).

Of all the cereal samples about 1/3 came from Varsinais-Suomi, 1/4 from Uusimaa and Häme, and 14 % from Satakunta. Of the winter wheat samples 44 % were collected in Varsinais-Suomi, while 1/3 of the rye samples came from Uusimaa and Varsinais-Suomi, and 1/3 of the barley samples from South Häme. Only 4 % of the total samples originated from areas outside of southern Finland.

The soil type in the region of the study is principally clay, especially in Varsinais-Suomi. In Uusimaa fine sand and silt also occur in some places in addition to clay. In South Häme and Satakunta the proportion of clay soils is considerably less, while silt, fine sand and light mineral soils are correspondingly greater (KURKI 1979). The cereal samples were collected chiefly from clay and silt soils, to some extent also from sandy soils.

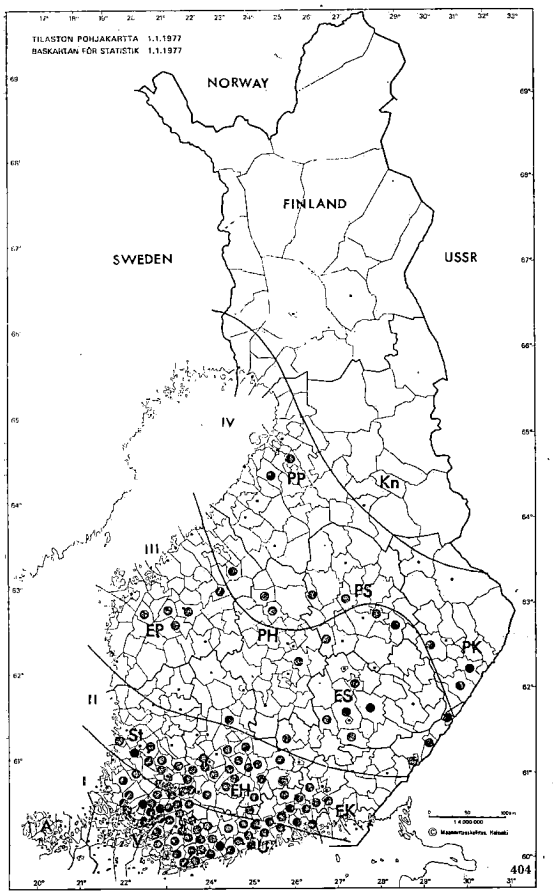


Fig. 1. Origin of the mature cereal samples by localities in Finnish cultivation zones (I—IV) in 1975—1977.

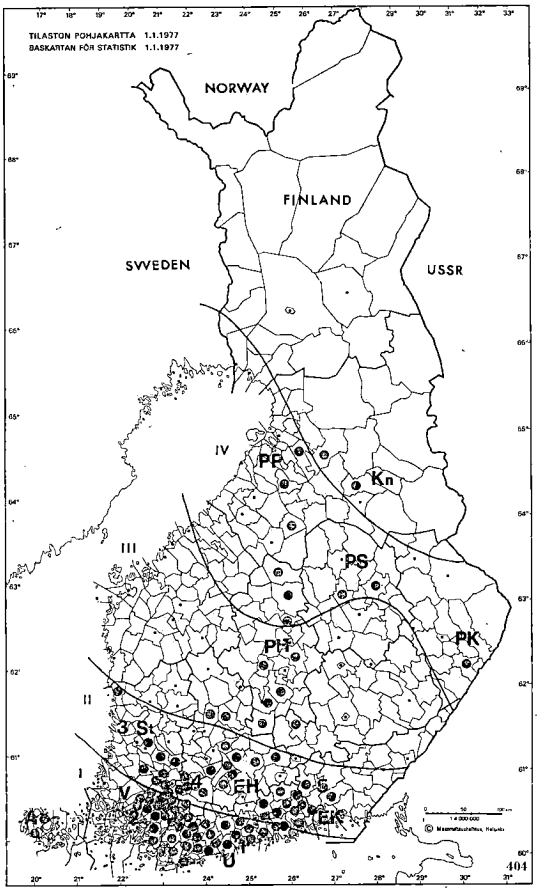


Fig. 2. Origin of the seedling samples of cereals by localities in Finnish cultivation zones (I—IV) in 1976—1978, as well as the meteorological observation stations: 1 Helsinki-Vantaa, 2 Turku, 3 Pori, 4 Jokioinen, 5 Utti.

Numbers of cereal samples

The cereal samples were collected principally from farmers' fields, and to a minor extent from the experimental stations of the Agricultural Research Centre. They were collected from a total of 1035 fields in 119 localities (Table 1). Seedling samples were originated in 1029 fields and in 91 localities (Table 2). All cereal species were represented in the material. Most abundant were samples of winter and spring wheat and barley, while rye had the fewest samples. The numbers of samples varied from year to year. Despite this, the relative proportions of the cereals represented in the total material remained almost the same. In 1975 and 1976 there were fewer rye samples than usual, in 1976 there were fewer barley samples, and in 1978 the numbers of spring cereal seedlings were less than usual. Especially numerous were the samples of spring wheat in 1977. In the different years most of the samples were taken from the same areas or even from the same fields. In the districts where the samples were gathered, the most common cereal varieties grown during the years of this study were: rye: Voima, Toivo and Pekka;

Table 1. Frequency of the parasitic soil fungi causing foot and root rot diseases of the mature cereal samples investigated in 1975—1977

Cereal	Year	The samples investigated		Parasitic fungi, % of the mature cereal samples investigated in the fields											
		No. of localities	No. of fields	*Bipolaris sorokiniana*	*Colletotrichum graminicola*	*Fusarium avenaceum*	*F. culmorum*	*F. graminearum*	*F. nivale*	*Fusarium* spp.	*Gaeumannomyces graminis*	*Gibberella zeae*	*Pseudocercosporella herpotrichoides*	*Rhizoctonia* spp.	*Septoria nodorum*
Rye	1975	(6)	(6)			50	67				17			17	17
	1976	17	24			29	67			13	13			50	
	1977	27	47		11	38	49			11	30			28	2
Total	1975—77	35	77												
Mean					0,6	36	56			12	23			34	3
Winter wheat	1975	31	83	1	1	37	89	7		19	11	2		2	23
	1976	32	72			17	57	3		10	14	1		53	4
	1977	45	94		1	38	51	2		11	40	1		18	20
Total	1975—77	60	249												
Mean				0,4	1	32	66	4		13	23	2		23	17
Spring wheat	1975	48	111	4	1	31	86	5		27	1	1			9
	1976	40	99	2	3	6	83	2		13	14			50	6
	1977	55	152		5	24	59	4		11	47	0,7		27	10
Total	1975—77	84	362												
Mean				2	3	21	74	4		15	24	0,6		25	9
Barley	1975	49	95	19	5	22	70	6		20	3	1		1	5
	1976	28	52	12	2	10	65	4		19	6			48	2
	1977	46	95	13	14	13	47			8	31			26	5
Total	1975—77	83	242												
Mean				15	8	16	60	9		15	15	0,4		21	5
Oats	1975	29	35		14	20	94	14		29		3			
	1976	13	36		25	22	69			31				33	
	1977	24	34		38	21	44	6		9	6			18	
Total	1975—77	54	105												
Mean					26	21	70	7		23	2	1		17	
All the cereals	1975	75	330	7	4	29	82	7		23	4	2		1	
	1976	50	282	3	5	13	70	2		16	11	0,4		48	
	1977	70	423	3	10	26	52	2		10	36	0,5		24	
Total	1975—77	119	1 035												
Mean				4	6	24	67	5		16	19	1		23	

winter wheat: Vakka, Nisu and Linna; spring wheat: Ruso and Tähti; 6-rowed barley: Pomo and Otra; and 2-rowed barley: Karri and Ingrid. Of the oat varieties, the most commonly grown were Ryhti, Tiitus and Pendek (Off. Statist. Finl., Agric. 1976).

Time of collection of the samples

The cereal samples were collected at the milky development stage (stage 11, Large 1954). The time of the season when the samples were collected varied considerably from year to year,

Table. 2. Frequency of the parasitic soil fungi causing foot and root rot diseases of the shoot samples, investigated in 1975—1978.

Cereal	Year	The samples investigated		Parasitic fungi, % of the shoot samples investigated in the fields											
		No. of localities	No. of fields	*Bipolaris sorokiniana*	*Colletotrichum graminicola*	*Fusarium avenaceum*	*F. culmorum*	*F. graminearum*	*F. nivale*	*Fusarium* spp.	*Gaeumannomyces graminis*	*Gibberella zeae*	*Pseudocercosporella herpotrichoides*	*Rhizoctonia* spp.	*Septoria nodorum*
Gathered in autumn															
Rye	1975	26	30	3		33	70			33					13
	1976	15	21			29	48	5		24				43	
	1977	29	51			26	67	4		16					
Total	1975—77	48	102												
Mean				1		28	64	3		23				9	4
Winter wheat	1975	37	84	2	2	31	85	2		46			8		44
	1976	19	55			11	55	2		26			2	46	29
	1977	33	77	1		22	58			18				3	16
Total	1975—77	48	216												
Mean				1	1	23	68	1		31			4	13	30
The both cereals ...	1975	40	114	2	2	32	81	2		38			6		36
	1976	24	76			16	53	3		25			1	45	21
	1977	43	128	1		23	62	2		17				2	9
Total	1975—77	61	318												
Mean				1	0,6	25	66	2		26			2	11	22
Gathered in spring															
Rye	1976	15	16			13	69			38					6
	1977	26	55		2	6	40	2	47	12				16	2
	1978	27	45	2		9	18	2	2	36				2	4
Total	1976—78	42	116												
Mean				1	1	8	35	2	23	29				9	3
Winter wheat	1976	35	80			25	78			54			1	1	11
	1977	40	83		2	11	59		11	24				15	29
	1978	35	104			13	18	2		50				1	51
Total	1976—78	49	267												
Mean					0,7	16	49	1	3	43			0,4	5	32
Spring wheat	1976	21	47	2		23	66			19				30	
	1977	25	49			4	92	2		14				6	2
	1978	9	15			20	93			20					
Total	1976—78	37	111												
Mean				1		14	81	1		17				15	1
Barley	1976	35	50	2		14	76			18				24	
	1977	34	70	1		3	64	1		27				9	
	1978	16	40	5		5	68			30					
Total	1976—78	60	160												
Mean				3		7	74	0,6		24				11	
Oats	1976	14	19			5	53			37				32	
	1977	23	32			9	75	3		22				9	
	1978	5	6			50	50			50					
Total	1976—78	40	57												
Mean						12	65	2		30				16	
All the cereals	1976	48	116	1		19	72			35				16	
	1977	51	151	0,3	1	7	67	1	12	22				11	
	1978	48	61	1		12	34	1	0,5	41				1	
Total	1976—78	80	711												
Mean				1	0,4	12	59	1	5	31				10	

depending on the weather. In 1975 the grains ripened early, both winter and spring cereals at almost the same time. The collections were begun at the end of July and continued for nearly a month (23. 7.—19. 8.). In 1976 the sample gathering was done in August and the first part of September, lasting more than a month (1. 8.—9. 9.). The autumn of 1977 was especially late. The samples of winter cereals were collected mainly in August (10. 8.—8. 9.) and those of spring cereals for nearly 1 ½ months, until the end of September (10. 8.—22. 9.).

The seedling samples (stages 1 and 2, LARGE 1954) of winter cereals were generally gathered in October, but in 1976 this took place late in November and even in the following May. The seedlings of spring cereals were usually collected in June. Exceptionally early was the spring of 1975 while 1978 was late.

Experimental Methods

The mature grain and seedling samples were taken from the fields with their roots. Twenty plants from each field were analyzed. In order to facilitate visual examination the roots were carefully rinsed under running water. For each mature sample an evaluation was made of the quality of the stem base (length 10 cm), the roots and the head. For the seedlings (1—4-leaf stage) the stem base and leaves were evaluated. The stem bases were classified into five categories: 1. pale, 2. mottled, 3. brown, 4. spotted, 5. black. The pale stems showed no colour at all. The mottled stems had indefinite streaking and spotting. In the spotted stems there were one or more distinct spots. In the brown and black stems the colour was uniform.

The roots of the plants were divided into three categories: 1. healthy, 2. moderate, 3. diseased. The healthy roots were pale and dense, whereas the diseased ones were discoloured, grey and sparse, and the moderate roots were intermediate in their symptoms. The heads were classified into healthy and shrivelled. Detailed analyses of the individual cereal samples were performed in the years 1976 and 1977.

Determination of the causal agents

The most typical of the mature samples were severed at about 10 cm above the base, rinsed under running water, and the basal part with its roots was placed in a Petri dish (Ø 15 cm) on moist fllter paper for the purpose of culturing and identifying the fungal species. In the diseased samples the heads were analyzed in the same way. The dishes were initially kept for two weeks at room temperature (+20—+24 °C) followed by two weeks at +10 °C and subsequently another 1—2 weeks at room temperature. The culture period was thus more than a month. During this period the fungi were examined a few times with a stereomicroscope. In addition most of the dishes were also studied with a light microscope for measurements and microphotographs. Slides were prepared with lactic acid, and these also were measured and photographed.

The results are presented by cereal species and by years, as well as totals for all the trial years. The incidence of fungi is expressed as percentage by number of the examined samples or fields.

Weather conditions

The weather conditions during the trial years fluctuated greatly. There were also considerable differences between the localities. The meteorological observations were taken from five stations of the Finnish Meteorological Service, namely Helsinki-Vantaa airport (Uusimaa), Turku (Varsinais-Suomi), Pori (Satakunta), Jokioinen (South Häme) and Utti (Kymenlaakso) (Fig. 2) (METEOROL. YEARB. FINL. 1975, 1976, 1977, 1978). The results are presented graphically from Helsinki, Turku and Jokioinen (Fig. 3).

The summer 1974 was rainy. The following winter 1974—1975 was mild with little snow.

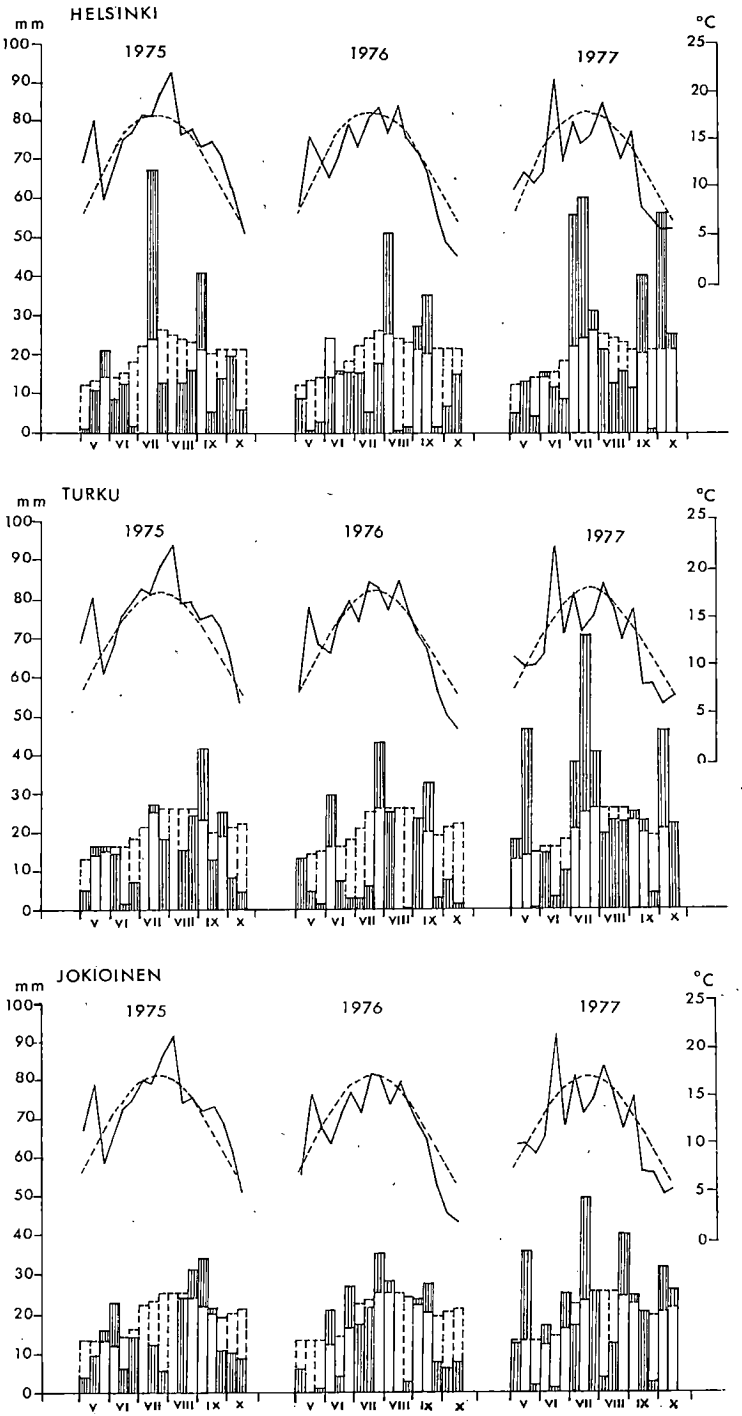


Fig. 3. Temperature °C (—— mean, ------ normal value in 1931—1960) and precipitation mm (ruled columns during the trial period, unruled columns normal value in 1931—1960) in the decade during the trial periods in 1975—1977 at Helsinki, Turku and Jokioinen.

Growing season 1975. Owing to warm weather early in the spring, the winter cereal seedlings began their growth rapidly. Likewise the spring cereals were sown early with subsequent good germination. Severe frost in late May and early June caused heavy damage, especially to rye. The growing season was, with the exception of a cool July, generally warm and dry. Long dry periods occurred particularly in Kymenlaakso and South Häme. On the other hand there were many local rain showers, especially in western Finland. The autumn was also warm and dry. In the southern parts of the country the winter 1975—1976 was mild with little snow.

Growing season 1976. The ground frost was deep and it melted slowly. Cold, dry conditions retarded plant growth. Seedlings of winter cereals, however, survived the winter quite well. Spring cereals were sown later than usual but the germination was good. The growing season as a whole was cool and somewhat drier than normal. Only May and the beginning of August were warm. Normal precipitation occurred only in June. Local showers in July increased the total rainfall considerably. Also in the beginning of August abundant rains fell in e.g. Helsinki, Pori and Utti. Harvest took place late, and the autumn sowings were likewise late. The autumn was cool and the growing season ended early.

Growing season 1977. Seedlings of winter cereals, especially rye, suffered from winter frost damage. The winter 1976—1977 was long with a deep snow cover and only little ground frost. Spring sowings took place 1—2 weeks later than normal. This was due to heavy rains which fell in the middle of May, principally in southwest Finland. In general the growing season was cool and rainy, with the exception of short warm periods in the beginning of June, August and September. The heaviest precipitation occurred at Turku, whereas the rainfall was close to normal at Utti and Jokioinen. In late autumn the weather was warm and rainy. The winter 1977—1978 had little snow and the ground froze to a great depth, especially in southwest Finland.

In late winter and early spring 1978 the weather was sunny and windy. As a result, the snow evaporated directly into the air and the plants were damaged by the drying wind and the ground frost. May was extremely dry, virtually without rain at all. Because of the deep ground frost, spring sowings were carried out late, particularly in southwest Finland. June was very cool and rainy.

As regards weather conditions, the growing seasons 1975 and 1976 were favourable, even though they were somewhat drier than normal. The least rainfall occurred in 1975 in Kymenlaakso and South Häme. This season was also quite dry in Varsinais-Suomi. The cool weather prevented excessive evaporation, so that the plants did not suffer from the drought. The growing season 1977, on the other hand, was unfavourable since it was both rainy and cool.

RESULTS

Injures in mature grain samples

At the time of the autumn harvest, the major part of the stem bases and roots of the grain samples were damaged in one way or another (Fig. 4). The degree of injury in the stem bases and roots was usually correlated, so that if the plant had many pale-coloured stems, then the roots were healthy; and the reverse was also true.

In winter cereals there was generally a correlation between pale (= healthy) stems and a good root system. In contrast, the spring cereals had more pale stems than good roots. In 1976 the numbers of pale stems in all the cereal species were double those found in the year 1977. In the roots no corresponding differences occurred with the exception of oats. In oats the amounts of pale stems and good roots were considerably

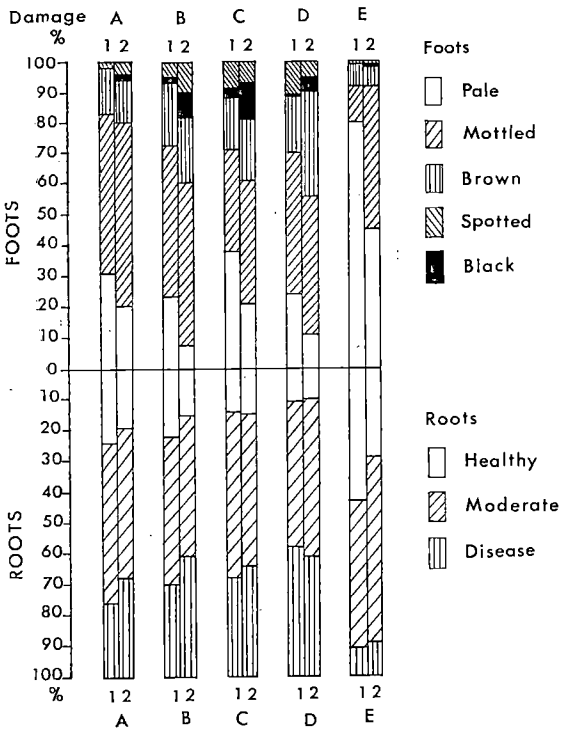


Fig. 4. Different lesions (%) in basal parts of stem and roots of the mature cereal samples researched in 1976 (1) and 1977 (2). (A = rye, B = winter wheat, C = spring wheat, D = barley, E = oats).

greater (30—80 %) than in the other cereals (10—35 %). Exceptionally low were the figures for barley and winter wheat (7—23 %).

Moderately damaged, mottled stems as well as moderately damaged roots occurred in almost equal numbers in both trial years and in all the cereal species, amounting to about ½ of the plants examined. Only in oats was the incidence of mottled stems considerably greater in 1977 than in 1976.

Obviously discoloured stem bases included the three categories brown, black and spotted. Their total numbers corresponded generally with the poor roots in all the cereals. The highest figures for this group were found in wheat and barley (35—45 %) and the lowest for oats (below 10 %). In rye this group represented about 20—30 % of the plants.

In both of the trial years the numbers of brown-stemmed samples were approximately the same, 15 % in rye, 20 % in wheat and 5 % in oats. Barley diverged from these other cereals. In 1977 more than 1/3 of the barley samples had brown stem bases, which was nearly twice as many as in 1976. Black-stemmed plants were very scarce in 1976, but in 1977 their numbers had increased many-fold, particularly in spring wheat but also in winter wheat and barley. In rye they amounted to only a few percent and were virtually non-existent in oats.

Spotted stem bases were likewise sparse in occurrence. Their maximum numbers were found in winter cereals in 1977, in spring cereals in 1976. The highest numbers occurred in wheat and barley, while oats had virtually no spotted stems at all.

There were distinct differences in the plant injuries between the two trial years. In 1977 there were clearly fewer pale stem bases and healthy roots than in 1976. In 1977 brown-stemmed barley and mottled-stemmed oats were much more numerous than in 1976. Similarly black-stemmed samples were more abundant in 1977 than in 1976, and this was most evident in wheat and barley.

Injuries in seedlings

The major part of the seedlings, both those collected in the autumn and in the spring, were healthy (Fig. 5). In this respect they differed clearly from the mature grain samples (Fig. 4). The rye and winter wheat samples gathered in the autumn had very similar amounts of injuries in the same years. Likewise the stems and leaves had similar injuries. The difference occurred only in the amounts of damage to the roots. In both cereal species such root damage was greater in the autumn 1977 than in 1976.

The injuries in winter cereal seedlings, particularly in the leaves, were considerably greater in the spring-collected samples (av. 45—60 %) than in the autumn-collected samples (av. 10—

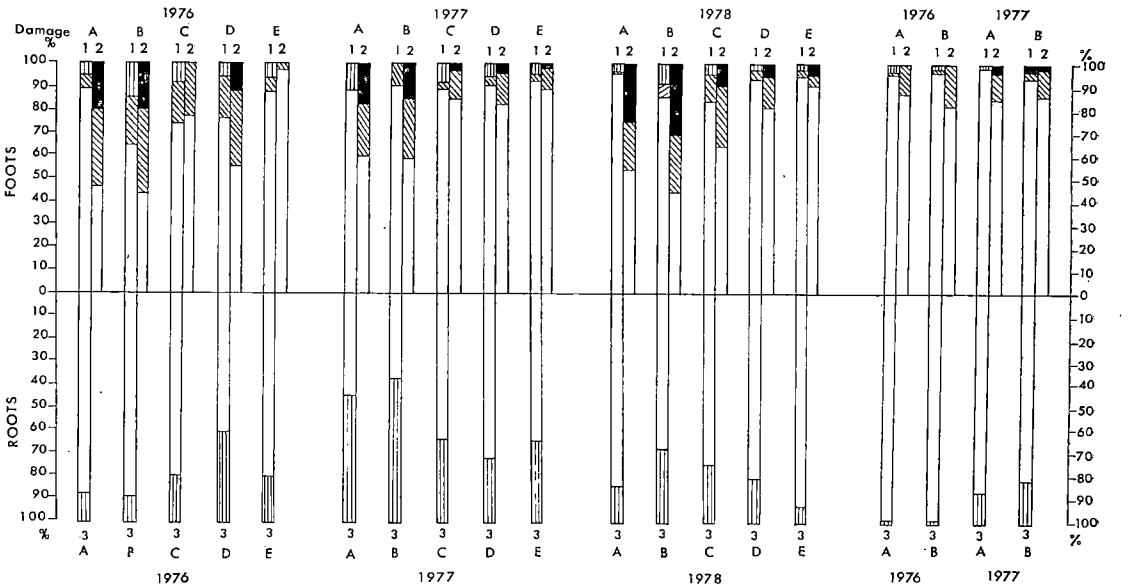


Fig. 5. Different lesions (%) in basal parts of stem (1), leaves (2) and roots (3) of the seedling samples researched in 1976—1978. (A = rye, B = winter wheat, C = spring wheat, D = barley, E = oats) (cf. Fig. 4).

15 %). Likewise the stems and roots showed more damage in the spring than in the autumn. Especially severe damage occurred in the roots in the spring 1977.

The seedlings of spring cereals had distinctly less injury than those of winter cereals. Concerning the different cereal species, oat seedlings were healthier than the others.

Numbers of shoots

The numbers of shoots per plant varied in the different cereal species and trial years (Table 3). The highest numbers of shoots were in rye, averaging 2,3 and 1,8 in the two trial years 1976 and 1977. The fewest occurred in spring wheat, with corresponding figures of 1,3 and 1,3. In winter cereals, especially rye, the number of shoots was greater in 1976 than in 1977.

Shrivelled heads

The incidence of shrivelled heads fluctuated widely according to the different cereal species and years (Tables 3 and 4). In 1976 there were considerably more shrivelled heads than in 1977. Only in oats was the relation reversed. The most shrivelled heads occurred in winter wheat, the fewest in oats and barley. The black-stemmed shoots had more shrivelled heads than the other categories of samples.

In 1975 wheat plants were observed with violet-shaded, metallic-appearing discolouration in the heads, of which some were shrivelled. This occurred in 1/3 of the winter wheat fields and over ½ of the spring wheat fields. In other years this phenomenon was not observed. It was apparently related to the unusually dry and warm weather in that year.

Fungi causing root and foot rot diseases

In the trial years 1975—1978 about 20 fungal species known to cause root and foot rot diseases were found in the cereal samples. This number represents about 20—30 % of all the 130 fungal species found in mature cereals and seedlings of winter cereals, and 15—40 % of the total fungi in spring-collected seedlings.

Table 3. Number of shoots per individual plant and extent of the shrivelled ears, % of the mature cereal samples investigated in 1976 and 1977.

Cereal	Year	Number of fields investigated	Number of shoots investigated	Number of shoots per individual plant		Shrivelled ears % of shoots investigated	
				mean	range	mean	range
Rye	1976	24	389	2,3	1—9	12,2	0—17
	1977	47	960	1,8	1—10	4,0	0—21
Total Mean	1976—1977	71	1 349	1,9		6,8	
Winter wheat	1976	72	1 340	1,6	1—7	19,7	0—55
	1977	94	1 840	1,5	1—7	5,9	0—56
Total Mean	1976—1977	166	3 180	1,5		12,0	
Spring wheat	1976	99	1 960	1,3	1—6	7,7	0—25
	1977	152	2 900	1,3	1—6	5,9	0—60
Total Mean	1976—1977	251	4 860	1,3		6,6	
Barley	1976	52	860	1,8	1—8	3,4	0—10
	1977	95	1 820	1,8	1—10	1,8	0—14
Total Mean	1976—1977	147	2 680	1,8		2,3	
Oats	1976	36	620	1,5	1—5	1,9	0—16
	1977	34	680	1,4	1—5	3,2	0—17
Total Mean	1976—1977	70	1 300	1,4		2,8	
All the cereals	1976	283	5 169	1,7	1—9	9,0	0—55
	1977	422	8 200	1,6	1—10	4,2	0—60
Total Mean	1976—1977	705	13 369	1,7	1—10	6,1	0—60

The majority of the fungi were saprophytes (MÄKELÄ and MÄKI 1980). The present study describes the twelve most important fungal species causing root and foot rot (Table 1).

Root and foot rot fungi occurred mostly in barley and wheat and least in oats. There were also differences between the trial years, with most fungi in 1976 and fewest in 1977. More fungi were found in mature grain samples and seedlings of winter cereals than in seedlings of spring cereals.

The most prevalent of the root and foot rot fungi were *Fusarium culmorum*, *F. avenaceum*, *Gaeumannomyces graminis*, *Rhizoctonia solani* and *Septoria nodorum*. Only small amounts of *Pseudocercosporella herpotrichoides* were found.

Fusarium species. During the trial years *Fusarium* species occurred commonly in all the cereals and in nearly all of the samples. More than a dozen of them were determined, of which the most common were *Fusarium avenaceum* and *F. culmorum*. Appearing infrequently were *F. graminearum*, *F. poae* and *F. semitectum*. Only sporadically were the following found: *F. acuminatum*, *F. arthrosporioides*, *F. coeruleum*, *F. tricinctum* and *F. oxysporum*. *F. nivale* occurred only in the seedlings of winter cereals in the spring.

There were virtually no differences between the cereal species in regard to the incidence of *Fusarium* species. In contrast, there were differences between the years. In 1975 *Fusarium*

Table 4. Frequency of the parasitic soil fungi in the ears of the mature cereal samples (cf. Table 1).

Cereal	Year	No. of fields investigated	Parasitic fungi, % in the ears								
			Bipolaris sorokiniana	*Colletotrichum graminicola*	*Fusarium avenaceum*	*F. culmorum*	*F. graminearum*	*F. nivale*	*Fusarium* spp.	*Rhizoctonia* spp.	*Septoria nodorum*
Rye	1975	—	—	—	—	—	—	—	—	—	—
	1976	15			27	13			40	7	
	1977	46			57	26		2	35	2	4
Total Mean	1975—77	61			49	23		1,7	36	3	3
Winter wheat	1975	44	2		11	27			20		
	1976	61			3	21	2		21	2	3
	1977	92	1	2	9	23			24	1	34
Total Mean	1975—77	197	1	1,7	8	23	0,5		22	1	17
Spring wheat	1975	38			18	40	3		29		
	1976	75			7	69			12	1	1
	1977	152	1		23	40	2		29	1	22
Total Mean	1975—77	265	0,7		18	48	2		24	1	13
Barley	1975	16			25	19			19		
	1976	29	3		3	28	3		35		
	1977	94	15		18	21	6		37		13
Total Mean	1975—77	139	11		16	22	5		35		9
Oats	1975	—	—	—	—	—	—	—	—	—	—
	1976	9				33			22		
	1977	34	6	9	18	18	3		21		
Total Mean	1975—77	43	5	7	14	21	2		21		
All the cereal	1975	98	1		16	31	1		23		
	1976	189	0,5		6	41	1		21	2	2
	1977	418	5	1	22	29	2	0,2	30	1	19
Total Mean	1975—77	705	3	0,6	17	32	2	0,1	27	1	12

was more common and in 1977 less common than in the other years. An exception to the other *Fusarium* species was *F. nivale*, which appeared abundantly only in the spring 1977 in rye seedlings (Table 2).

Fusarium culmorum (W. G. Smith) Sacc. *Fusarium culmorum* was very common in all the cereals and at all stages of growth. In the mature samples it was found at 101 localities. There were no appreciable differences between the different localities. On the other hand, the years showed considerable differences. This fungus was most prevalent in the year 1975 (Table 1, Fig. 6).

The stem bases which were infected with *Fusarium culmorum* were, up to their first node, uniform brown in colour or were mottled or spotted brownish in varying degrees (Fig. 7, Plate III). Pale red discolouration also could be seen. Under moist conditions a reddish mycelium developed between the leaf sheath and the stem, and in addition sprodochia

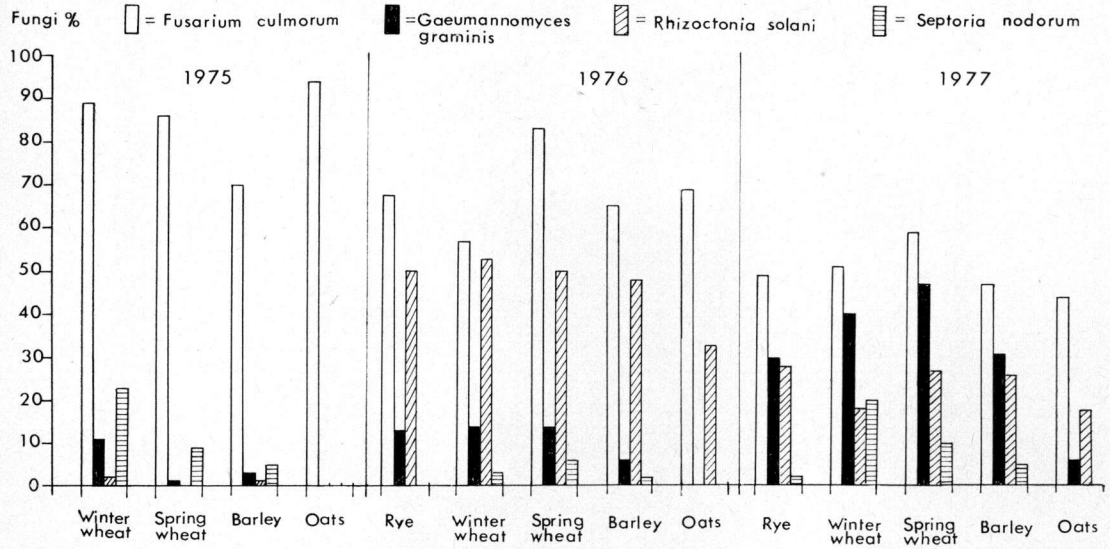


Fig. 6. Frequency (%) of some most important parasitic fungi on mature cereal samples researched in the different growing season 1975, 1976 and 1977.

appeared in the roots and stems, especially at the nodes. The infected stem bases were more brittle than healthy ones and thus were easily broken. This was especially clear in the late summer and autumn 1975 when diseased plants were abundant and the weather at ripening time was dry for along period. The roots of plants infected by *F. culmorum* were coloured brown in varying degrees and were to some extent weakened (Fig. 7, Plate III). In seedlings the disease was manifested as a darkening and rotting of the stem bases and roots. Oats differed from the other cereals in the fact that even though the fungus occurred commonly, the disease symptoms did not appear.

In comparing the incidence of dark stem bases in the cereal samples with the amounts of *Fusarium culmorum* determined in the fungal cultures, it was ascertained that they did not always correspond with one another. In the years 1975 and 1976, however, there was a positive correlation, whereas in 1977 no such correlation was found.

Fusarium avenaceum (Corda ex Fr.) Sacc. *Fusarium avenaceum* was considerable less common than *F. culmorum;* these two fungi often occurred together. The greatest amounts of this fungus were found in mature plants of winter cereals, and the least in the seedlings collected in the spring.

Fusarium graminearum Schwabe, perfect stage *Gibberella zeae* (Schw.) Petch occurred rarely. The perfect stage was encountered only in mature cereals. These fungi were relatively more common in oats in 1975. Oat plants infected by *Gibberella zeae* occasionally had roots which were poorly developed, a dark stem base and shrivelled heads. In the tissue of the stem bases the fungus produced black ascocarps and from them exuded great masses of salmon-coloured ascospores (Plate III).

Fusarium nivale (Fr.) Ces. *Fusarium nivale* occurred commonly in rye seedlings only in the spring 1977. At this same time the fungus was much less prevalent in winter wheat. The injuries to the seedlings varied widely according to the intensity of infection. If the leaves are damaged, the plant usually recovers, but root damage results in stunted growth or death of the plant with a subsequent sparse stand (Fig. 8).

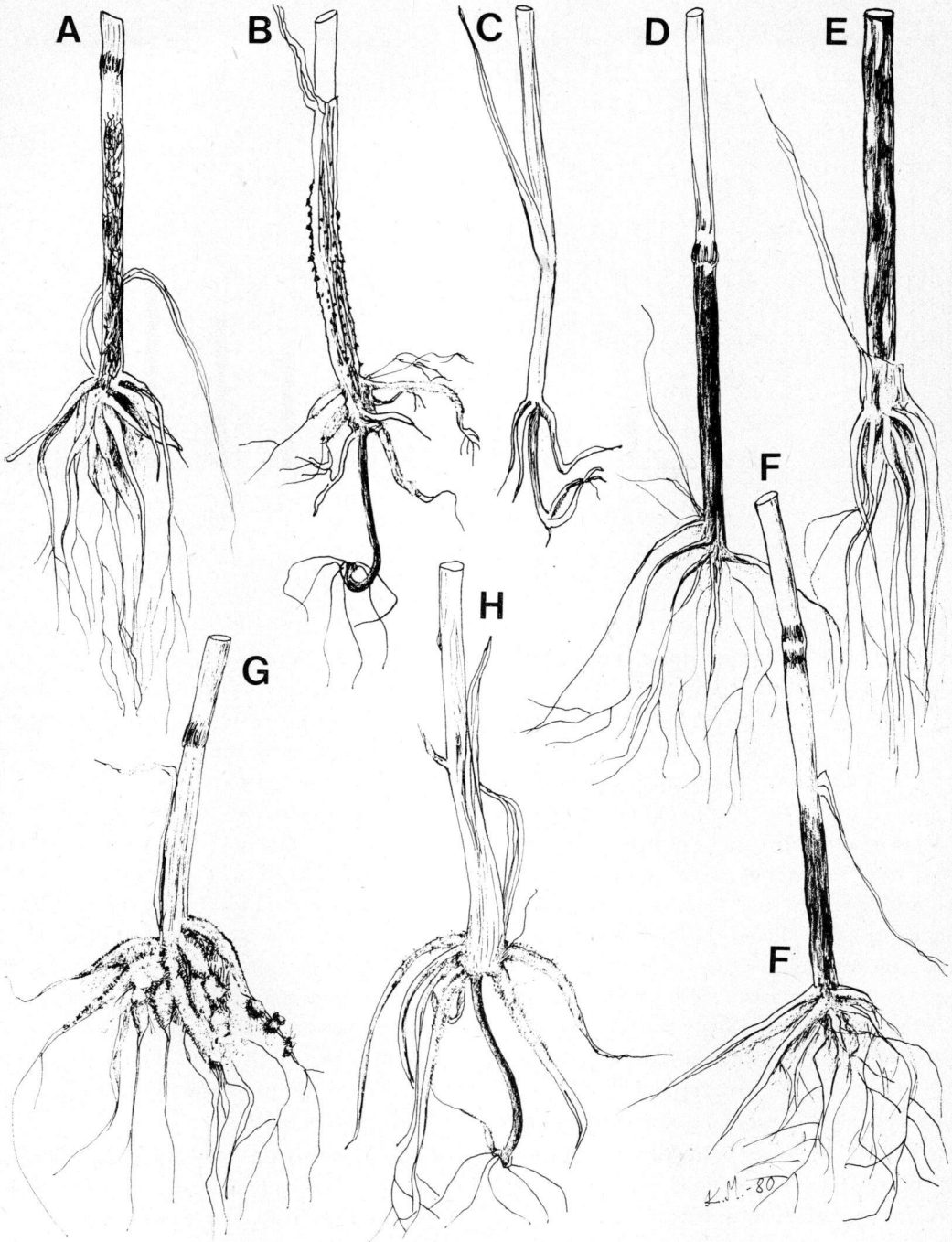


Fig. 7. A—F: Diseased roots and basal parts of stem of cereals. A, B, C: *Gaeumannomyces graminis*. D, E, F: *Fusarium culmorum*. G, H: *Rhizoctonia solani*. A: on rye. B, D, E, F, H: on spring wheat. C: on barley. A: Brown hyphae on culm. B: Leaf sheath pulled aside with necks of numerous perithecia breaking through the surface of leaf sheath. D, F: Brown coloured basal parts of stem. E: Multi-coloured basal parts of stem. G: Young white sclerotia and mature brown sclerotia of *R. solani* on roots.

Material: A: U. Siuntio 12. 8. 1977. B: EH. Iitti 6. 9. 1977. C: U. Tuusula 7. 9. 1977. D: U. Anjala 17. 8. 1976. E, G: EH. Pälkäne 14. 8. 1976. F: V. Mietoinen 8. 8. 1975. H: U. Elimäki 17. 8. 1976.

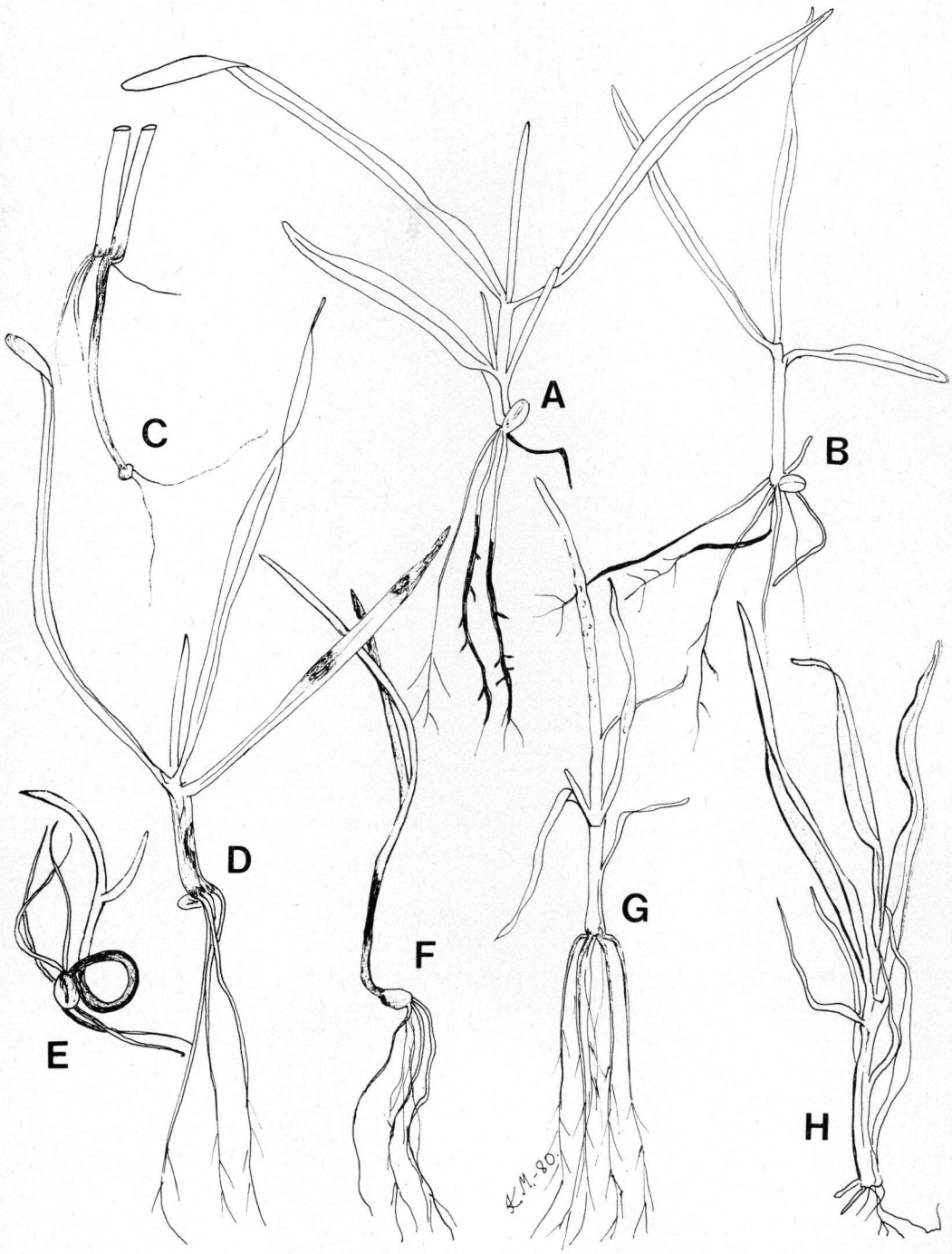


Fig. 8. A—H: Diseases of seedlings. A, B, C: *Gaeumannomyces graminis*. D, E, F: *Septoria nodorum*. G, H: *Fusarium nivale*. A, B, D: on winter wheat. C: on barley. E. F: on spring wheat. G, H: on rye. A, B, C: Dead and black parts of roots infected by *G. graminis*. D: Brown spots on leaves and sheath. E, F, H: Dying seedling, G: Diseased seedling with sporodochia of *F. nivale*.

Materia: A: V. Kiikala 19. 10. 1977. B: EH. Hattula 7. 5. 1977. C: Ypäjä 22. 6. 1976. D: U. Artjärvi 11. 11. 1976. E, F: EH. Pälkäne 20. 6. 1978. G: U. Vihti 9. 5. 1977. H: EH. Somero 19. 5. 1977.

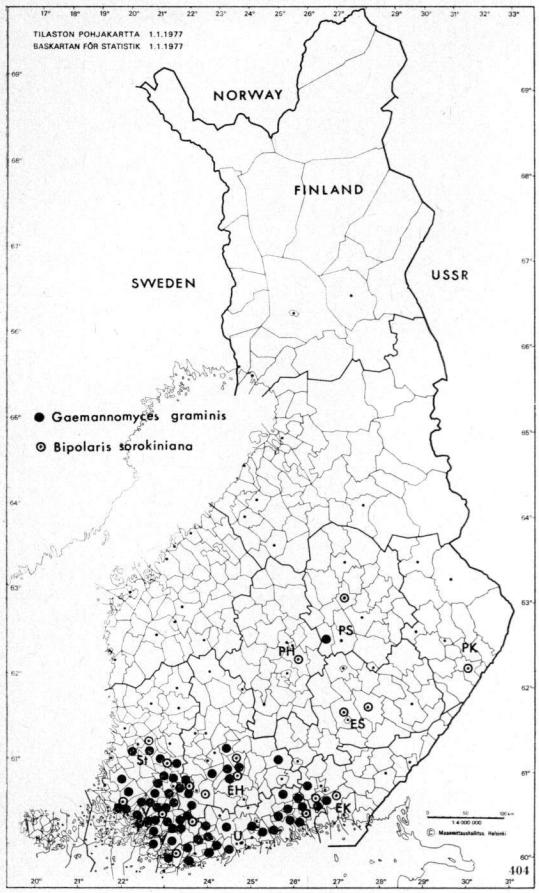


Fig. 9. The occurrence of *Gaeumannomyces graminis* and *Bipolaris sorokiniana* on the mature cereals by localities in 1975—1977.

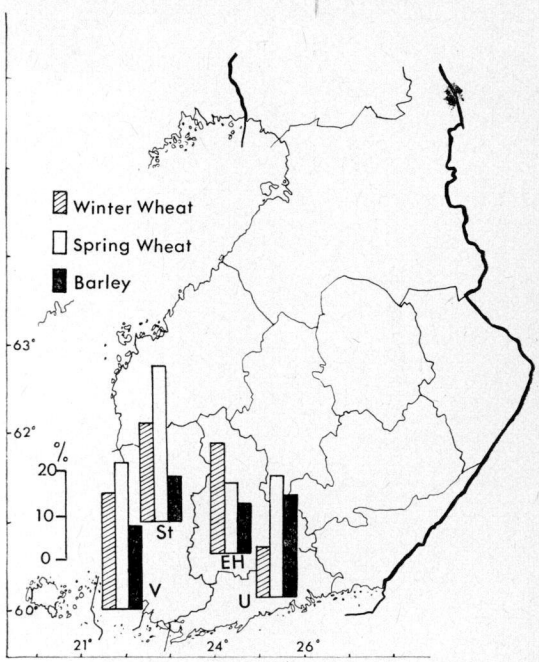


Fig. 10. Frequency (%) of *Gaeumannomyces graminis* on mature wheat and barley samples researched in 1967 at the different districts.

Gaeumannomyces graminis (Sacc.) v. Arx et Olivier. In the years 1975—1978 *Gaeumannomyces graminis* was found in cereals at 64 localities (Fig. 9). There were large variations in the frequency of the fungus depending on the cereal species, the trial year and the region. The fungus was most common in wheat, and quite common in rye, whereas it was rare in barley and virtually not found at all in oats (Table 1). In 1977 this fungus was considerably more prevalent than in the two previous years (Fig. 6). Geographically it was more common in Varsinais-Suomi and Satakunta than in Uusimaa and South Häme (Fig. 10).

The disease caused by *Gaeumannomyces graminis*, take-all, was manifested in different ways in the cereal stands. On some fields the disease appeared as weak areas in the stand consisting of low-growing, stunted, dark-coloured plants with many shrivelled heads. In most infected fields, however, take-all occurred scattered throughout the whole stand as individual diseased plants. Such plants grew poorly and usually had shrivelled heads. At first the heads were pale-coloured and could easily be distinguished from the still immature, green healthy plants. Later the heads became dark owing to masses of the sarpophytic fungus growing on the surface. Also these stands had a spotty, variegated appearance. Excessive moisture favoured the fungus, and consequently it was found in abundance in low, moist areas of the field.

The roots of take-all deseased plants had a uniformly dark or entirely black colour and

were poorly developed, sparse and fragile. When the plants were removed from the ground the roots often broke off. The mycelium of *Gaemannomyces graminis* growing on the root surface caused the roots to become thick, and soil particles were tightly attached to the surface (Fig. 7, Plates I and II). Ascocarps could also develop in the roots. In such plants where the roots had been damaged, the stems were short and slender and the development of the heads was hindered or completely prevented (Fig. 7). Destruction of the roots at a later stage caused the heads to become shrivelled or small-grained, but this did not affect the length of the stem.

In general the symptomatology of take-all was visible in the stem bases in both winter and spring wheat in 1976 and 1977. In these cases there was a positive correlation between the symptoms and the occurrence of *Gaeumannomyces graminis*. In 1977 a similar correlation was found in both rye and oats. In contrast, however in barley *G. graminis* seldom caused the typical darkening of the stem base.

The stem bases of the diseased plants were often dark, sometimes even shiny black. Between the lowest leaf sheath and the stem was a thick growth of mycelia and elongated ascocarps (Plates I and II). Their oblique openings protruded from the sheath, and the ascospores extruded as a reddish mass. The size of the ascocarps (80 ascocarps) varied 554—968 × 370—537 μm of which the openings measured 190—544 μm (Plates I and II). The asci (35 asci) had a size of 95—113 μm and the ascospores (200 spores) measured 75—95 × 3,3—3,4 μm.

Spores of *Phialophora* sp. occurred rarely and were found in only nine samples. Most of them were encountered in seedlings of winter wheat in the autumn; only three cases were of older plants. The samples studied were the following: Barley EH: Tammela 27. 7. 1975. Spring wheat St: Humppila 27. 7. 1975. Winter wheat EH: Jokioinen 4. 8. 1975, V: Halikko 28. 10. 1976 (2 samples), Kemiö 28. 10. 1976, U: Askola 2. 11. 1976, EH: Iitti 15. 11. 1976.

Rhizoctonia solani Kühn. *Rhizoctonia solani* was found in mature cereals at 58 localities. There were differences in the incidence of the fungus according to the year, the cereal species and the stage of plant development. In 1976 the fungus was unusually prevalent, whereas in 1975 it hardly occurred at all (Fig. 6). This fungus was more common in mature cereals and in seedlings of winter cereals in the autumn than in seedlings in the spring (Tables 1 and 2).

The symptomatology of *Rhizoctonia solani* was not distinct. The stem base could be black, variegated or spotted. Nevertheless the growth of the plant and the roots were generally normal. Under moist conditions, particularly in 1976, the roots became filled with pale-coloured or tan mycelia and also by pale sclerotia which later turned brown (Fig. 7). There were two types of mycelia. The more common type was pale and delicate, whereas the infrequent type was tan and hevier in structure (Plate IV). No correlation was found between the occurrence of *R. solani* and the appearance of spotted cereal stems. Neither were any regional differences observed.

Septoria nodorum Berkeley. *Septoria nodorum* was found in mature cereals at 41 localities. It appeared primarily in winter and spring wheat and only in small amounts in barley and rye. The fungus was common in the seedlings of winter wheat in the autumns 1975 and 1976 as well as in the springs 1977 and 1978. In mature plants it occurred in small quantities in 1976 (Fig. 6). Regional differences were observed to some degree. The fungus was somewhat more prevalent in Varsinais-Suomi and South Häme than in Uusimaa and Satakunta (Fig. 11).

Septoria nodorum caused darkening of the stems, especially at the nodes. In the leaf sheaths and glumes it caused spots which had shades of yellow and brown. Later the spots became pale grey from their centres. In the spots grew large quantities of pycnidia in different shades of brown. Under moist conditions large masses of orange-reddish spores exuded. In diseased

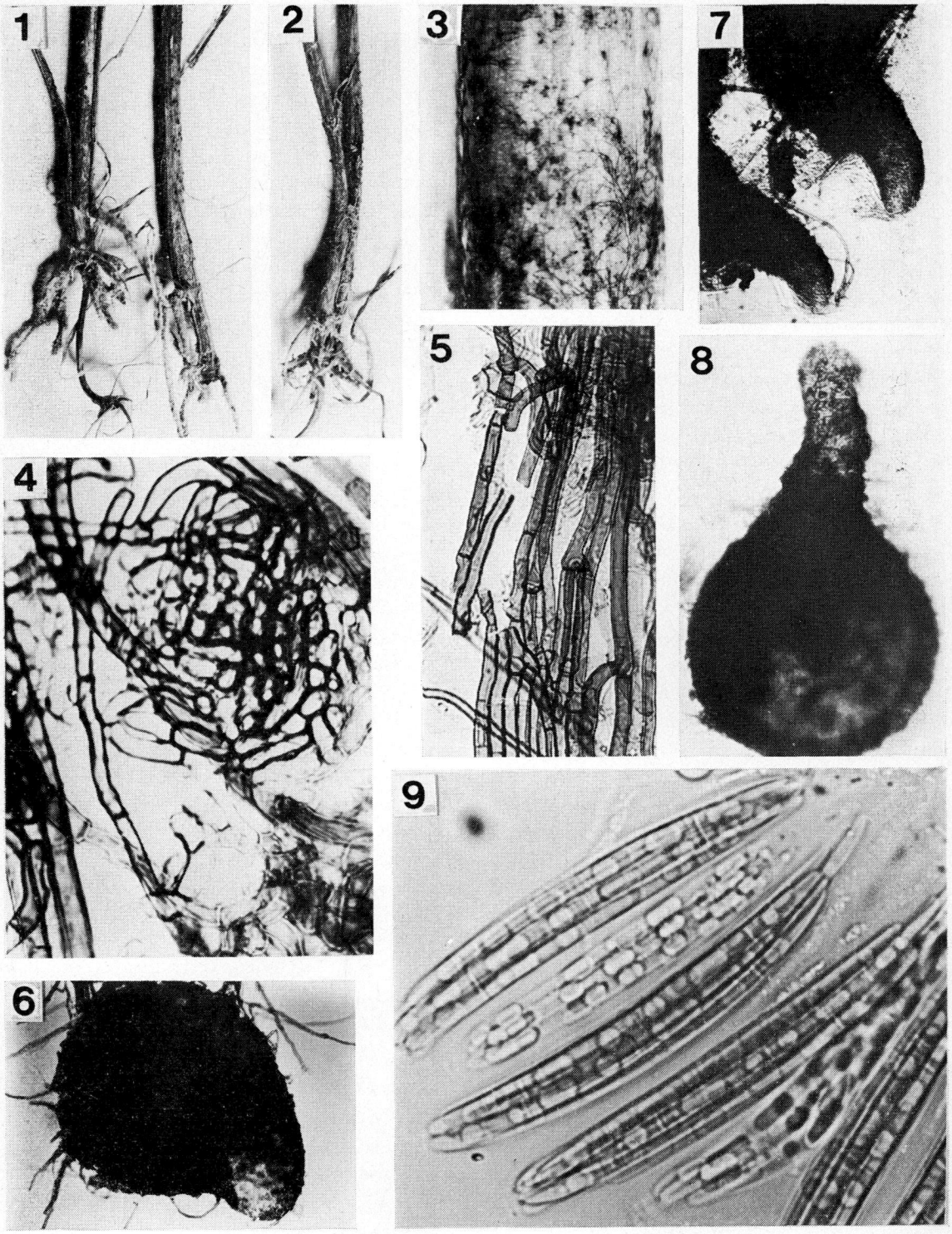


Plate I. 1—9: *Gaeumannomyces graminis*. 1, 4, 5, 8: on spring wheat. 2: on barley. 3, 6, 7: on winter wheat. 9: on rye. 1 and 2: old plants with infected roots and basal parts of stem, aside with necks of numerous small perithecia breaking through the surface of leaf sheath. 3 and 5: brown runner-hyphae or macrohyphae. 4: colourless infection hyphae or microhyphae. 6: the young perithecium. 7 and 8: the ripe perithecia. 9: ascus with ascospores of the fungus. Material: 1: V. Perniö 8. 9. 1977. 2: U. Tuusula 2. 9. 1977. 3: St. Kokemäki 13. 8. 1975. 4: V. Paimio 16. 8. 1977. 5: U. Tikkurila 31. 8. 1977. 6: V. Paattinen 8. 8. 1975. 7: U. Porvoo commune 17. 8. 1976. 8: V. Koski 17. 8. 1977. 9: EH. Pälkäne 18. 8. 1975. 1, 2: X 1, 3: X 10, 4, 9: X 1000, 5: X 600 6, 7, 8: X 160.

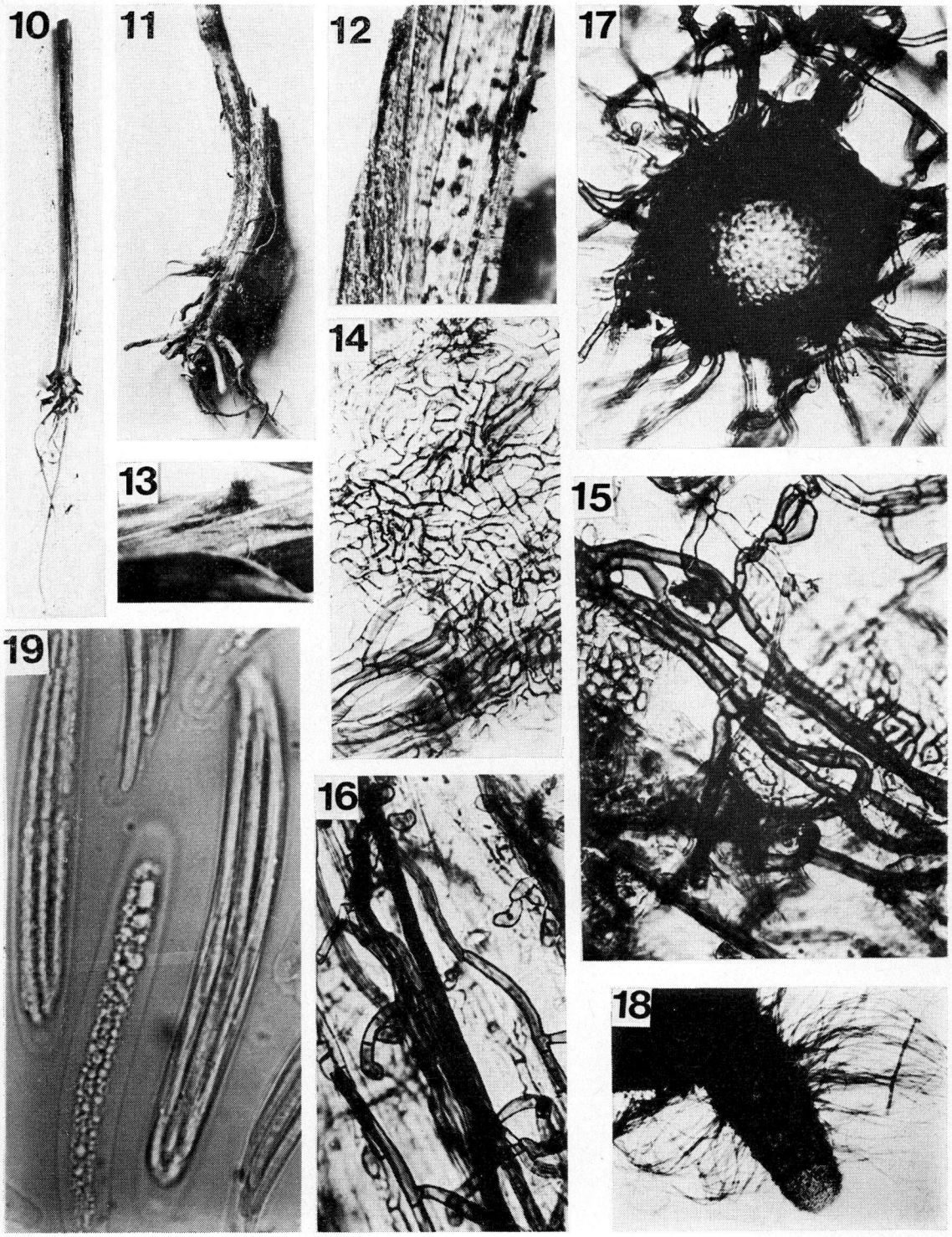


Plate II. 10—19: *Gaeumannomyces graminis*. 10—17, 19: on winter wheat. 16 and 18 on rye. 10 and 11: old plants with infected roots and basal parts of stem. 12 and 13: necks of small perithecia breaking through the surface of leaf sheath. 14—16: brown runner hyphae and colourless infection hyphae. 17: the young perithecium. 18: the ripe perithecium with long, dense hairs around the neck. 19: ascus and ascospores of the fungus.

Material: 10: St. Kokemäki 13. 8. 1975. 11: U. Lapinjärvi 24. 8. 1977. 12: St. Loimaa commune 4. 8. 1975. 13: Mellilä 17. 8. 1977. 14: EH. Iitti 22. 8. 1977. 15: V. Vahto 15. 8. 1976. 16: EH. Somero 17. 8. 1977. 17: St. Alastaro 4. 8. 1975. 18: EH. Hattula 20. 8. 1977. 19: U. Elimäki 24. 8. 1977. 10, 11: X 1, 12: X 8, 13: X 20. 14, 15, 16: X 600 17: X 500, 18: X 200, 19: X 1000.

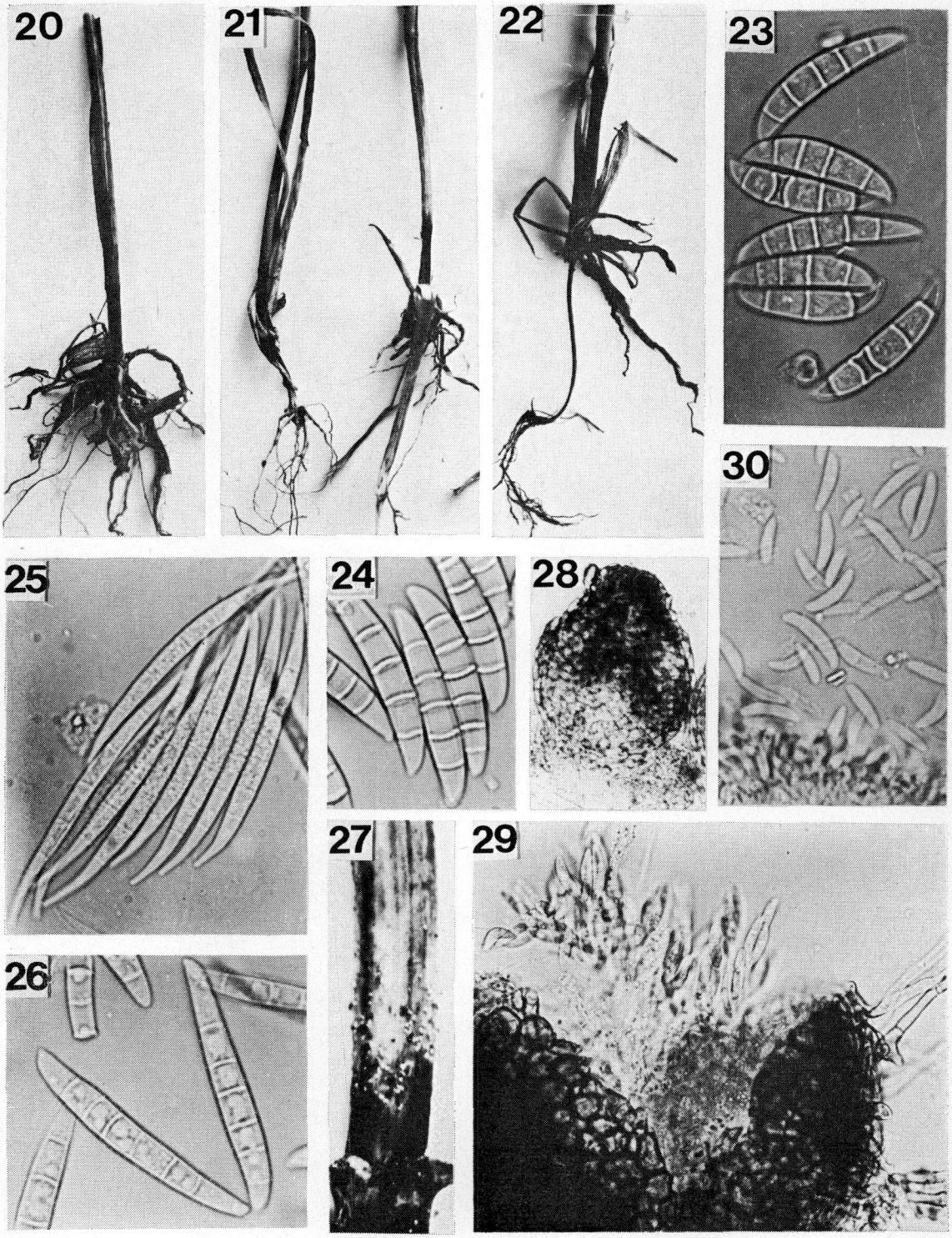
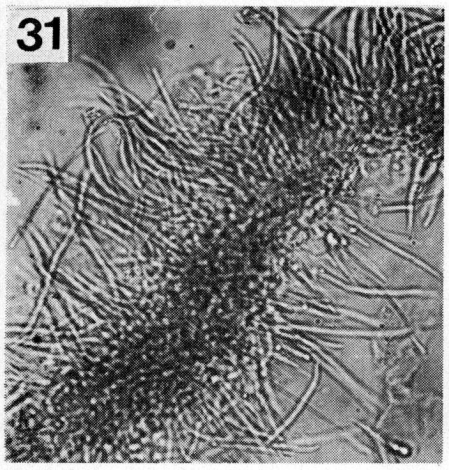
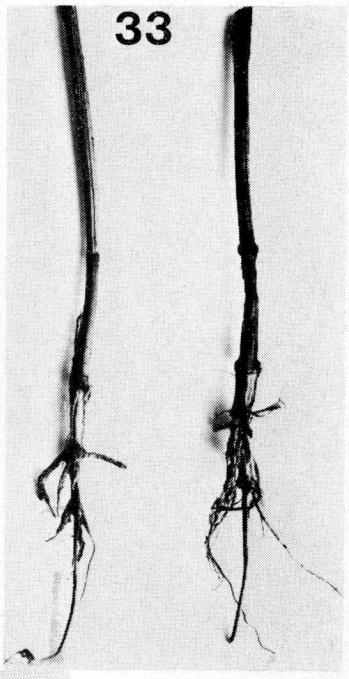
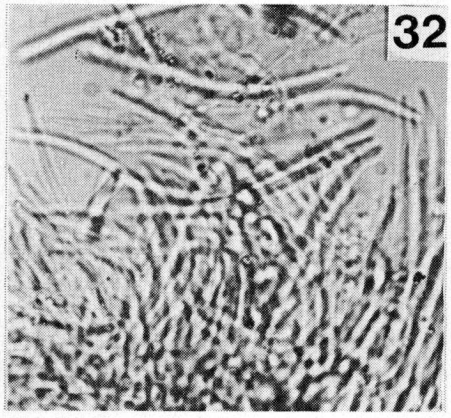


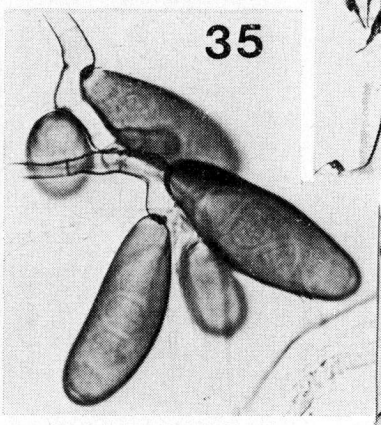
Plate III. 20—30. 20—24: *Fusarium culmorum*. 20—23: on spring wheat. 24: on barley. 25: *F. avenaceum* on spring wheat. 26: *F. graminearum* on winter wheat. 27—29: *Gibberella zeae*. 27 and 29: on oats. 28: on winter wheat. 30: *F. nivale* on rye. 20—22: old plants with brown infected basal parts of stem. 23—26, 30: conidia of *Fusarium* species. 27 and 28: old plant with perithecia, 29 perithecium with ascus and ascospores of *Gibberella zeae*.

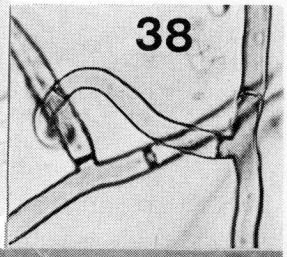
Material: 20: EH. Pälkäne 18. 8. 1975. 21: U. Anjala 17. 8. 1975. 22 and 23: V. Mietoinen 19. 8 .1975; 24: Pertteli 21. 6. 1978. 25: St. Kokemäki 13. 8. 1977. 26: EH. Tammela 27. 7. 1975. 27 and 29: EP. Ylistaro 13. 8. 1975. 28: EH: Somero 4. 8. 1975. 30: U. Tuusula 3. 8. 1977. 20—22: X 1/2, 23—26, 30: X 1000, 27: X 5, 28: X 30, 29: 200.

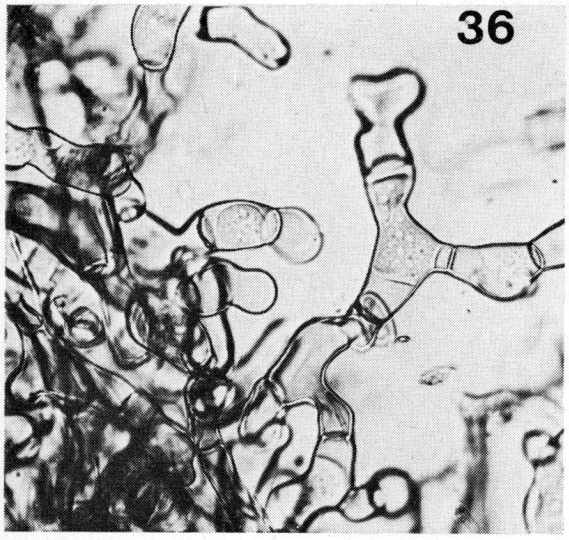












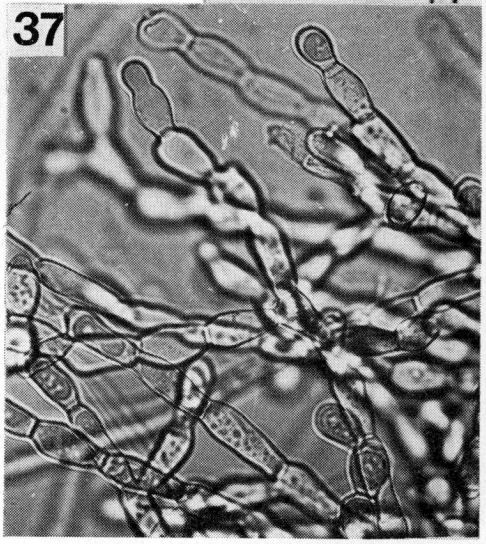


Plate IV. 31—38. 31 and 32: *Pseudocercosporella herpotrichoides* on winter wheat. 33—35: *Bipolaris sorokiniana* on barley. 36—38: *Rhizoctonia solani*, 36: on spring wheat, 37: on rye, 38: on oats.

Material: 31 and 32: U. Artjärvi 21. 5. 1976. 33: ES. Mikkeli commune 22. 8. 1975. 34: EH. Jokioinen 27. 7. 1975. 35: ES. Juva 23. 8. 1975. 36: U. Snappertuna 19. 8. 1976. 37: V. Tenhola 19. 8. 1976. 38: St. Kokemäki 10. 6. 1976. 31: X 500, 32: X 1000, 33: X 1/2, 34: X 15, 35—38: X 500.

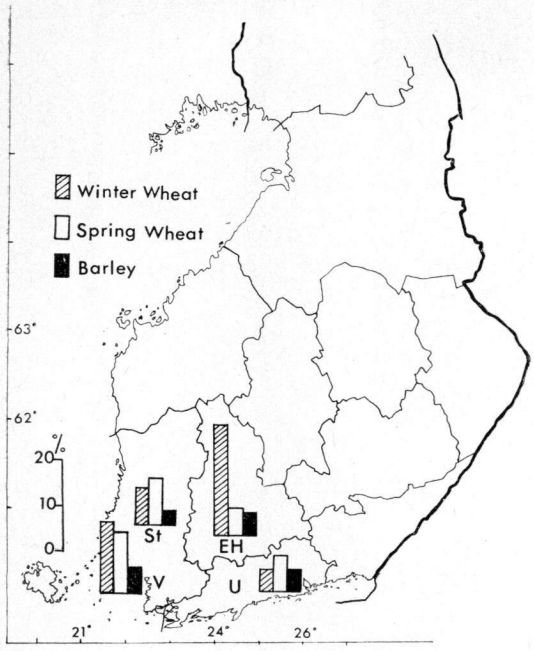


Fig. 11. Frequency (%) of *Septoria nodorum* on mature wheat and barley samples researched in 1976 and 1977 at the different districts.

seedlings the leaves had brown, yellow-rimmed spots; in addition, the tips of the leaves or even entire leaves were dead. In the stem base of the seedlings the tissue was brown in varying degrees, and parts of the roots were dead (Fig. 8).

Bipolaris sorokiniana (Sacc. on Sorok.) Shoemaker. *Bipolaris sorokiniana* was encountered in mature cereals at 18 localities (Fig. 9). It occurred almost exclusively in barley, and in a few scattered cases also in wheat and rye. The fungus was rare in seedlings, being found at only 7 localities. In 1975 it was more common than in the other trial years. In its occurrence the fungus was restricted to certain fields and was found year after year in these same fields.

Bipolaris sorokiniana caused darkening and indistinct spotting in the stem bases of cereals. Infected plants had a stunted growth and poor roots (Plate IV). In seedlings the damage appeared as brown spots in the stems and leaves coincidental with browning of the roots.

Pseudocercosporella herpotrichoides (Fron) Deighton (Plate IV). This fungus was observed at eight localities (V, U, EH). It was occasionally found in the seedlings of rye and winter wheat, principally in samples collected in the autumn.

Colletotrichum graminicola (Ces.) Wils. In 1977 *Collectotrichum graminicola* occurred commonly in mature oats and fairly commonly in barley. In other cereals it was found only sporadically. The fungus produced large numbers of small, sharply-defined black spots. In these spots developed conidiophores with their conidia.

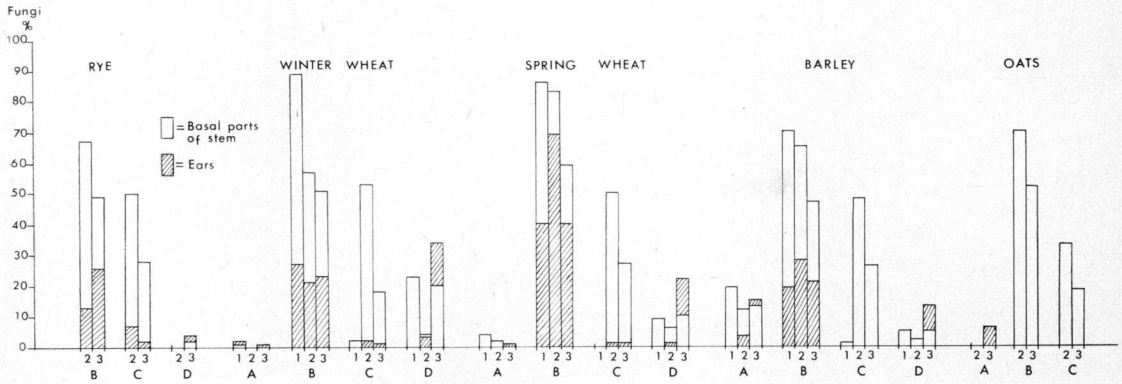


Fig. 12. Frequency (%) of some most important parasitic fungi on basal parts of stem and ears of mature cereal samples researched in 1975 (1), 1976 (2) and 1977 (3). A = *Bipolaris sorokiniana*, B = *Fusarium culmorum*, C = *Rhizoctonia solani*, D = *Septoria nodorum*.

DISCUSSION

In this investigation cereal plants affected with root and foot rot were examined visually on the basis of macroscopoc symptoms in the stem bases, roots and shrivelled heads. The fungi were determined microscopically from diseased plant parts cultured in moist chambers. This procedure proved to be advantageous even though it is not well suited for some phycomycetous fungi (cf. STETTER and LEROUL 1979). When the macroscopic symptoms and the microscopic results were compared, it was found that they were only partially correlated. The macroscopic symptoms varied widely or in some cases lacked completely. Consequently, determination of the fungal species was very uncertain, and often impossible (cf. NILSSON 1969, STETTER and LEROUL 1979).

Previous studies on root and foot rot diseases of cereals in Finland were based primarily on visual observations of the disease symptoms (HÅRDH 1953, IKÄHEIMO 1960, TALVIA 1970, TOIVIAINEN 1970, TEITTINEN 1974). The course of development of the disease with respect to the causal agent was consequently not established.

Many factors affect the occurrence of root and foot rot, such as weather conditions, cereal species and stage of plant development. The annual fluctuations, caused by weather conditions, were larger than the other variations (TALVIA 1970, TOIVIAINEN 1974, VIRTANEN 1979).

The warm and dry summer 1975 favoured *Fusarium* species, whereas they were at a minimum in the cool, wet summers 1977 and 1978 (cf. GLYNNE 1954, COLHOUN et al. 1968). In this study *Fusarium* species appeared in all the cereals and in the different developmental stages (cf. BOOTH 1971). The most common of the species was *F. culmorum*, while *F. avenaceum* was less numerous (cf. HÅRDH 1953, TOIVIAINEN 1974, UOTI 1975), especially in seedlings in the spring (cf. COLHOUN 1964). *F. graminearum* was somewhat rare (cf. HÅRDH 1953). *F. nivale* occurred in considerable amounts in the seedlings of rye only in the spring 1977 after an unusually long winter with a deep snow cover. This species is known in Finland only as a winter-damaging fungus causing injury to overwintering cereals, especially rye (JAMALAINEN 1970). *F. nivale* is considered also to be a causal agent of root and foot rot, together with three other *Fusarium* species: *F. culmorum*, *F. graminearum* and *F. avenaceum* (DUBEN and FEHRMANN 1978). *F. nivale* has been isolated from injured roots and from the soil (RAWLINSON and COLHOUN 1969). In Denmark the incidence of *Fusarium* species has not been found to increase during continuous barley cultivation, neither have these fungi been found to cause noteworthy decreases in yield when infecting the roots (STETTER and LEROUL 1979). However, opposite results have also been published (UOTI 1975, VOITOVA 1977).

Bipolaris sorokiniana occurred likewise more commonly in the warm, dry summer 1975 than in the other years (cf. SKOU 1966, JØRGENSEN 1974). The fungus was predominantly a pathogen of barley and was somewhat rare. In the nordic countries the fungus is found primarily in barley seedlings (KOLK and OLSSON 1975, KURPPA 1976, OLOFSSON 1976, HJORSTHOLM 1979). In Danish trials with continuous barley cultivation the fungus was much more prevalent after the 8th and 9th years than after the first, third and fourth years. The effect of *B. sorokiniana* in causing lower cereal yields was at least as great as that of *Gaeumannomyces graminis* (STETTER and LEROUL 1979).

The cool and dry summer 1976 favoured especially *Rhizoctonia solani* (PITT 1964, REINECKE 1977). The fungus was more prevalent in mature plants than in seedlings. Its most serious damage, however, is considered to be inflicted to seedlings (PITT 1964). The fungus is found widespread in all the nordic countries, although its

significance as a pathogen is believed to be minor (HANSEN 1963, PETERSEN 1963, TALVIA 1970, TOIVIAINEN 1974, NILSSON 1974 a).

The wet and cool summer 1977 was favourable especially to *Gaeumannomyces graminis*. This situation has been observed previously in Finland (IKÄHEIMO 1959, TOIVIAINEN 1974) and is typical for this fungus (NILSSON 1969, WALKER 1972). In the present study the fungus occurred in mature plants, predominantly in winter and spring wheat (cf. MIELKE 1974) and commonly also in barley and rye, but only very rarely as a vegetative mycelium in oats. Thus the culture of *G. graminis* var. *avenae* isolated by TOIVIAINEN (1966) from oats remains as a rare single case in Finland. On the other hand, the fungus is known to cause damage to oats e.g. in Norway (HANSEN 1964).

In Danish trials with continuous barley cultivation *Gaeumannomyces graminis* occurred in the greatest numbers in the third and fourth years, and rarely in the first or ninth years (STETTER and LEROUL 1979). Take-all decline is known, also in some Norwegian soils (MAGNUS 1979), as in many other countries (cf. HORNBY 1979). The declines in yield caused by this fungus were quite large (HJORSTHOLM 1979). Yield declines during monoculture have generally been known to be greatest in the third to fifth years (GUNNINGHAM 1975, JENSEN 1975, TEITTINEN 1977).

Wet growing seasons were also favourable to *Septoria nodorum* (cf. JØRSTAD 1967, BRÖNNIMANN 1968). The fungus was most common in winter wheat, especially in seedlings in autumn. Such is the situation elsewhere, too (BRÖNNIMANN 1968, KOLK and OLSSON 1975, JENKYN and KING 1977).

Also the species *Pseudocercosporella herpotrichoides* thrives in cool, wet weather conditions (JØRGENSEN 1964). In the present study the fungus was found sporadically in the seedlings of winter wheat particularly in the autumn. Also in Sweden, autumn infection is considered to be more serious in winter wheat than spring infection (OLVÅNG 1978). The fungus is common in the nordic countries (JØRSTAD 1956, PETERSEN 1963, NILSSON 1974 b), in the Baltic countries (KORSHUNOVA 1968) and is widespread throughout Europe (CMI Map 74, 1969). In Finland the fungus has been previously observed in large amounts especially in spring wheat (HÅRDH 1953) and in barley (TALVIA 1970). On the other hand, there is uncertainty about the significance of the disease (TOIVIAINEN 1974). The divergence in results may be due partly to possible changed conditions but primarily to inaccuracy in the research methods.

The effect of root and foot rot diseases on the yield levels is difficult to ascertain in this sort of study, despite its great importance. In the area of this study the average cereal yields fluctuated widely in the different years (OFF. STATIST. FINL., AGRIC. 1975, 1976, 1977). In 1975 the yields were somewhat higher than normal, with only rye giving lower than normal yields in Varsinais-Suomi as a result of severe spring frost damage. In 1976 the cereal yields were exceptionally large, amounting to as much as 20—30 % higher than average for rye, barley and oats, while wheat yielded about the same as in 1975. In contrast the 1977 yields were unusually low. Compared to the 1975 yields, the 1977 levels were lower by the following amounts: winter cereals 20—30 %, spring wheat slightly less, barley about 10 % and oats only slightly lower than in 1975.

The number of shoots in the mature cereals was somewhat greater in 1976 than in 1977. This confirms, although not convincingly, the view (cf. TEITTINEN 1977, OLSSON 1978) that such yield reductions are due to root and foot rot diseases which decrease the number of shoots per plant.

In 1976 there were considerably more shrivelled heads in winter cereals, especially winter wheat than in 1977. On the other hand, in 1976 the yields were much higher than in 1977. Consequently the numbers of shrivelled heads are not a reliable indication of the yield-reducing

effect of root and foot rot diseases (cf. HÅRDH 1953, IKÄHEIMO 1960). The occurrence of shrivelled heads can be due to many factors, e.g. frost damage.

The total numbers of fungi as well as the numbers of parasites in the mature cereals and seedling samples were greater in 1976 than in 1977. Exceptions were barley and oats, in which there were more fungal species in 1977 than in 1976 (MÄKELÄ and MÄKI 1980). It has been observed (PETERSEN et al. 1976) that as the soil moisture decreases the frequency of micro-organisms in the root level increases. In the present study *Rhizoctonia solani* was very common in 1976, particularly in mature cereals. Similarly *Fusarium* species, especially *F. culmorum*, occurred somewhat commonly. The large total numbers of fungi as well as the prevalence of root and foot rot are not reflected in the 1976 yield levels, which were exceptionally high. The advantageous weather conditions in this year masked the effect of other factors (cf. OLSSON 1978).

The weather conditions in 1977 were extremely unfavourable for cereal development. In that year *Gaeumannomyces graminis* occurred about three times more abundantly in wheat and rye, and about five times more abundantly in barley than in 1976. This fungus is known to be prevalent in wet years (SKIPSNA 1961, NILSSON 1969, COOK 1972, GRIGER 1972, VOITOVA 1977). In the present study the cereal yields were exceptionally low. It is known that this fungus causes considerable yield losses (SHIPTON 1972, OLSSON 1978, WESTE 1978, STETTER and LEROUL 1979).

In 1977 also *Septoria nodorum* occurred much more abundantly in wheat, especially winter wheat, than in 1976, The fungus is an important pathogen under moist conditions (BLOCK 1957, OBST 1969, JENKYN and KING 1977). It may also cause considerable declines in yield (SMEDEGÅRD-PETERSEN 1974, JONES 1975, KING 1977).

It is obvious that in years with unfavourable weather conditions the deterimental effect of certain kinds of fungal damage is intensified, although it is difficult to establish the separate effects of the individual factors (cf. OLSSON 1978).

Part of the yield losses caused by root and foot rot diseases is due to the fact that the seedlings die and the number of plants in the stand decreases (cf. SLOPE 1968, WESTE 1975). Especially seedlings of winter cereals suffer losses during the winter (NILSSON 1969, MAGNUS and HANSEN 1973, HAEGEMARK and OLVÅNG 1976). In the present study many species of fungi causing root and foot rot occurred in the seedlings. The bulk of them were the same species as those found in the mature plants (cf. MÄKELÄ and MÄKI 1980). There were many injuries and at the same time more pathogenic fungi in the seedlings of winter cereals than in those of spring cereals. In addition to the present study, the authors found in a preliminary cereal monoculture trial on silt soil at the Pälkäne experimental station in South Häme that 50 % of the seedlings of winter wheat and 10 % of the rye seedlings died during the winter 1977—1978. *Fusarium nivale* was encountered only in small amounts in the rye seedlings in the spring. On the other hand, other *Fusarium* species, especially *F. culmorum* and *F. avenaceum*, occurred in winter wheat and rye, both in the seedlings and in the mature stands. The same situation was observed for *Rhizoctonia solani*. In mature stands *Gaeumannomyces graminis* was found, and in seedlings of winter wheat additionally *Septoria nodorum* occurred.

In the opinion of the authors, root and foot rot diseases as a cause of destruction to seedlings of winter cereals, especially winter wheat, in southern and southwest Finland, are very important and can be compared with the so-called winter damage caused by low temperature fungi. Such winter damage has generally been considered to be caused exclusively by *Fusarium nivale*, the classical winter damage fungus. This fungus rarely occurred in large numbers in the area of investigation and then only in rye

to any noteworthy extent (cf. BLOMQVIST and JAMALAINEN 1968). On the other hand, every spring, seedlings of winter wheat can be found which were damaged during the winter to a greater or lesser extent depending on the circumstances.

This view is supported also by studies of the fungi in cereal heads (Table 4). *Fusarium nivale* was found only in one sample of rye in autumn 1977. In contrast, many other *Fusarium* species were encountered in the heads of all the different cereals, with *F. culmorum* being most prevalent and *F. avenaceum* also in considerable amounts. Among the other fungi causing root and foot rot were *Septoria nodorum* commonly in the heads of winter wheat and less frequently in those of barley, and *Bipolaris sorokiniana* in barley heads.

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Kaiho Mäkelä and Päivi Parikka
Agricultural Research Centre
Institute of Plant Pathology
SF-01300 Vantaa 30, Finland

SELOSTUS

Viljan tyvitautien esiintyminen Etelä-Suomessa vuosina 1975—1978

KAIHO MÄKELÄ ja PÄIVI PARIKKA

Maatalouden tutkimuskeskus

Aineisto kerättiin vuosina 1975—1978 maan tärkeimmiltä leipäviljan tuotantoalueilta Lounais- ja Etelä-Suomesta pääasiassa viljelijäin pelloilta ja Maatalouden tutkimuskeskuksen koeasemilta. Tällä alueella on yksipuolista viljanviljelyä harjoitettu tehokkaasti 1950—1960-luvuilta lähtien. Aineisto käsitti 1035 tuleentunutta viljanäytettä 119 paikkakunnalta ja 1029 orasnäytettä 91 paikkakunnalta ja edusti kaikkia viljalajeja, runsaimmin vehnää ja ohraa. Vioittumat arvioitiin (20 yksilöä/näyte) kasvin tyvistä ja juuristosta silmävaraisesti. Sienet määritettiin kosteuskammiomenetelmää käyttäen mikroskooppisesti.

Korjuuaikaan syksyllä oli valtaosa viljan tyvistä ja juuristosta jollakin tavoin vioittuneita. Terveitä yksilöitä oli vähiten (vuosina 1976 ja 1977 keskim. 7—23 %)

ohralla ja syysvehnällä, eniten (keskim. 30—80 %) kauralla. Lievästi vioittuneita kirjavia tyviä ja kohtalaisen hyviä juuristoja oli noin puolella tutkituista tuleentuneista yksilöistä kaikilla viljoilla. Ankarasti vioittuneita, tummuneita tyviä ja huonoja juuristoja oli eniten (keskim. 35—45 %) vehnällä ja ohralla, vähiten (alle 10 %) kauralla. Oraat olivat terveempiä kuin tuleentuneet viljat. Kevätviljan oraat olivat terveempiä kuin syysviljan oraat. Syysviljan oraat olivat syksyllä terveempiä kuin keväällä. nimenomaan lehdistöltään. Kaura oli kaiken ikänsä muita viljoja terveempää. Vuosien välillä oli eroavuutta vioitusten määrissä.

Myös kahujen tähkien määrä vaihteli viljalajeittain ja vuosittain. Eniten niitä oli syysvehnällä, vähiten kauralla ja ohralla.

Tyvitautisymptomit ja niitä aiheuttavien sienten esiintyminen vastasivat toisiaan vain osittain. Sienilajit ja niiden yleisyys vaihtelivat suuresti viljalajista, kehitysasteesta, vuodesta ja kasvupaikasta riippuen. Eniten sieniä esiintyi vehnällä ja ohralla, vähiten kauralla. Tuleentuneissa viljoissa ja syysviljan oraissa oli sieniä enemmän kuin kevätviljan oraissa. Eri tyvitautien aiheuttajat olivat vallitsevia erilaisina kasvukausina. Niinpä *Gaeumannomyces graminis* ja *Septoria nodorum* esiintyivät yleisimmin sateisina ja viileinä kesinä, *Fusarium* lajit taas suosivat lämpimiä säitä. Meillä tärkein syy tyvitautien vaihteluihin on löydettävissä juuri ilmastollisista tekijöistä.

Yleisimmät sienet olivat *Fusarium culmorum* (W. G. Smith) Sacc., *Gaeumannomyces graminis* (Sacc.) v. Arx et Olivier, *Rhizoctonia solani* Kühn ja *Septoria nodorum* Berkeley.

Fusarium culmorum esiintyi yleisenä kaikilla viljalajeilla, eri ikäisissä kasvustoissa ja eri alueilla. Se suosi lämmintä kasvukautta 1975. Muita *Fusarium* lajeja määritettiin toistakymmentä. Näistä oli melko yleinen *F. avenaceum* (Corda ex Fr.) Sacc. harvinainen puolestaan *F. graminearum* Schwabe ja sen kestoaste *Gibberella zeae* (Schw.) Petch., *F. nivale* (Fr.) Ces. esiintyi yleisenä vain rukiin oraissa keväällä 1977.

Merkittävä oli *Gaeumannomyces graminis*, mustatyven aiheuttaja. Sieni oli yleisin vehnällä, yleinen myös rukiilla, harvinaisempi ohralla. Kauralla sientä esiintyi tuskin lainkaan. Sateisena ja viileänä kasvukautena 1977 oli sientä huomattavasti enemmän kuin kahtena edellisenä vuonna. Myös alueellista eroavuutta esiintyi.

Rhizoctonia solani, tyvi- ja juurilahon aiheuttaja, oli yleisempi syksyllä kuin keväällä. Sieni suosi viileää ja vähäsateista kasvukautta 1976. *Septoria nodorum* esiintyi ennenmuuta syysvehnällä yleisempänä oraissa ja tähkissä kuin tuleentuneissa kasvustoissa. Kosteina kasvukausina ja niitä seuraavina vuosina sientä oli runsaasti. Myös alueellisesti eroavuutta esiintyi. *Bipolaris sorokiniana* (Sacc. on Sorok.) Shoemaker, ohran tyvi- ja lehtilaikun aiheuttaja, oli pääasiassa ohrassa, tuleentuneissa kasvustoissa ja tähkissä peltokohtaisena. *Pseudocercosporella herpotrichoides* (Fron) Deighton, tyvilaikun aiheuttaja, todettiin vain satunnaisesti syysviljan oraissa syksyisin. *Collectotrichum graminicola* (Ces.) Wils. oli yleinen tuleentuneessa kaurassa 1977 ja melko yleinen ohrassa.

Sienten suuri kokonaismäärä, sen paremmin kuin tyvitauteja aiheuttavien sienten, kuten *Rhizoctonia solanin* ja *Fusarium* lajien yleisyys ei ole näkyvissä vuoden 1976 satotasossa, joka oli poikkeuksellisen korkea. Edulliset sääolot vuonna 1976 peittivät muitten tekijöitten vaikutukset.

Sen sijaan vuonna 1977, jolloin viljojen satotaso oli erittäin alhainen, esiintyi *Gaeumannomyces graminista* vehnillä, ohralla ja rukiilla. Samoin *Septoria nodorum*ia syysvehnällä paljon yleisemmin kuin vuonna 1976. On ilmeistä, että sääsuhteiltaan epäedullisina vuosina myös määrättyjen sienituhojen merkitys korostuu, vaikkakin eri tekijäin osuutta on vaikea eritellä.

Tyvitautien aiheuttamista satotappioista osa johtuu siitä, että oraita kuolee ja kasvuston yksilöluku vähenee. Tämä koskee varsinkin syysviljoja, ennen muuta syysvehnää. Näillä tyvitautien merkitys orastuhojen aiheuttajina Etelä- ja Lounais-Suomessa on rinnastettavissa ns. talvituhoihin. Näitä on vanhastaan pidetty yksinomaan ns. talvituhosienten, nimenomaan *Fusarium nivale*n aiheuttamina. Tätä sientä esiintyy tutkimusalueilla runsaasti harvoina talvina ja silloinkin merkittävänä vain rukiilla. Sen sijaan huonosti talvehtinutta syysviljan orasta ja lukuisia *Fusarium*-lajeja, *Septoria nodorum*ia ja muita tyvitautien aiheuttajia tapaa pelloilla joka kevät, enemmän tai vähemmän olosuhteista riippuen. Tätä käsitystä tukevat myös viljojen tähkistön sienitutkimukset. *Fusarium nivalea* esiintyi vain rukiin tähkissä yhdessä näytteessä syksyllä 1977. Sen sijaan esiintyi kaikilla viljoilla yleisenä monia edellä mainittuja tyvitautien aiheuttajia.

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Seria PHYTOPATHOLOGIA N. 74 — Sarja KASVITAUDIT n:o 74

TOBACCO MOSAIC VIRUS (TMV) TYPES FROM TOMATO IN FINLAND[1)]

ANNIKKI LINNASALMI

LINNASALMI, A. 1980. **Tobacco mosaic virus (TMV) types from tomato in Finland.** Ann. Agric. Fenn. 19: 254—259. (Agric. Res. Centre, Inst. Plant Path., SF-01300 Vantaa 30, Finland.)

In the tobacco mosaic virus (TMV) material from tomato (*Lycopersicon esculentum* Mill.) in Finland (1962—65) three main groups were characterized: the mild green mosaic, by far the most prevalent (93 %), the yellow mosaic (4 %) and the severe green mosaic (3 %) types, which occurred only sproradically. The types are characterized by their symptomatology in tomato and in five *Nicotiana*-test plants (*N. tabacum* L. cv. Samsun and cv. Xanthi, *N. glutinosa* L., *N. rustica* L. and *N. sylvestris* L.) as well as on the basis of their thermal inactivation point (TIP), RNA base composition and amino acid composition. The analyses were performed on a total of 55 isolates.

Index words: TMV types in tomato, symptomatology, TIP, RNA bases, amino acids, Finland.

In connection with the study made in the years 1962—65 (LINNASALMI and MURTOMAA 1966) on the distribution of tomato viruses in Finland, 55 isolates were selected on the basis of preliminary tests from TMV material (445 samples) for classification studies. Three main groups could be characterized in the material, and they are referred to in this paper as mild green mosaic (47 isolates), yellow mosaic (4 isolates) and severe green mosaic (4 isolates) TMV types. The mild green mosaic type is by far the most prevalent (93 %); both yellow mosaic (4 %) and severe green mosaic (3 %) types occur only sporadically in our tomato cultivations.

The classification of these types is based on the symptomatology of isolates in the tomato *Lycopersicon esculentum* Mill. cv. Bonner Beste and in the testplants *Nicotiana tabacum* L. cv. Samsun and cv. Xanthi, *N. glutinosa* L., *N. rustica* L. and *N. sylvestris* L., as well as on determinations of TIP, RNA base composition, total amino acid composition and carboxyl terminal amino acid. The biological and chemical analysis methods used are described in earlier publications (LINNASALMI 1966, LINNASALMI and MURTOMAA 1966, LINNASALMI and RASHID 1969).

Symptom characteristics of the types in different hosts are shown in Table 1.

[1)] The main part of these results were presented in a lecture held 16. 9. 1975 at the II International conference on progress and problems in vegetable virus research in Avignon, France.

Table 1. Symptoms of TMV types in different host plants and their thermal inactivation points.

Host plant	Mild green mosaic	Yellow mosaic	Severe green mosaic
L. esculentum ..... cv. Bonner Beste	green mosaic	yellow mosaic	green mosaic, leaf curling, mild stunting
N. tabacum ..... cv. Samsun	green mosaic, mild leaf curling, necrotic local lesions	yellow mosaic, ± distinct ringspots, no necrotic local lesions	severe green mosaic, leaf curling and blister-like malformation, stunting, no necrotic local lesions
cv. Xanthi	necrotic local lesions	necrotic local lesions	necrotic local lesions
N. glutinosa	necrotic local lesions	necrotic local lesions	necrotic local lesions
N. rustica	± necrotic local lesions	± necrotic local lesions	severe green mosaic, leaf curling and blister-like malformation, stunting, ± necrotic local lesions
N. sylvestris	necrotic local lesions	necrotic local lesions	severe green mosaic, leaf curling and blister-like malformation, stunting, no necrotic local lesions
TIP °C	82—84, 88—90	82—84	92—94

It should be mentioned that no symptoms whatever appeared on the fruit in the experiments. Apparently TMV damage on tomato fruits is generally rare under Finnish conditions.

The systemic symptoms of the mild green mosaic type are mild both in tomato (Fig. 1 a) and Samsun tobacco (Fig. 2 a). According to the thermal inactivation point (TIP), the type can be divided into two groups, one with a TIP of 82—84 °C and the other with 88—90 °C. No essential symptomatological differences were found, except that the systemic mosaic symptoms in the 88—90 °C group were usually a little stronger, especially in Samsun tobacco.

The systemic symptoms of the yellow mosaic type in tomato (Fig. 1 b) and Samsun tobacco (Fig. 2 a) are expressed chiefly as a yellow mosaic. The TIP is low, only 82—84 °C.

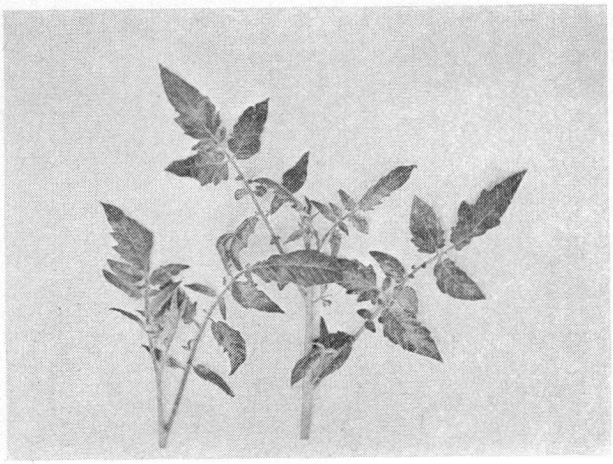
The systemic symptoms of the severe green mosaic type are very strong in the tobacco species (Fig. 2 a—c), while the symptoms in tomato (Fig. 1 c) differ less from symptoms caused by the mild green mosaic in tomato. A feature in common with the yellow mosaic type is the lack of necrotic local lesions in Samsun. The TIP is very high, 92—94 °C.

The mean results of the chemical analyses are shown in Table 2.

Table 2. Chemical composition of TMV types.

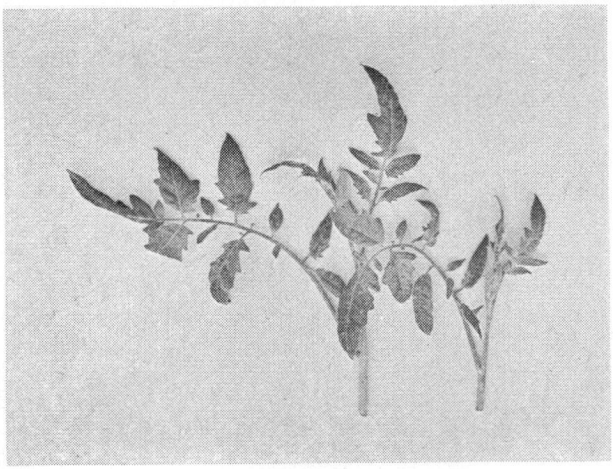
Types	Mild green mosaic	Yellow mosaic	Severe green mosaic
RNA bases [1]	moles %		
guanine	24,9	24,0	26,0
adenine	29,4	30,7	28,6
cytosine	17,5	17,3	18,0
uracil	28,3	28,0	27,5
Amino acids	residues per subunit		
Asp	18	18	19
Thr	16	16	15
Ser	14	15	15
Glu	20	20	17
Pro	9	9	8
Gly	6	6	6
Ala	11	11	15
Val	15	15	14
Cys	1	1	1
Met	1	1	0
Ile	6	6	8
Leu	14	13	12
Tyr	5	5	4
Phe	8	8	8
Lys	2	2	2
Arg	9	9	11
Try	3	3	3
Total	158	158	158
C-terminal acid ..	serine	serine	threonine

[1]) Data from LINNASALMI and RASHID 1969.



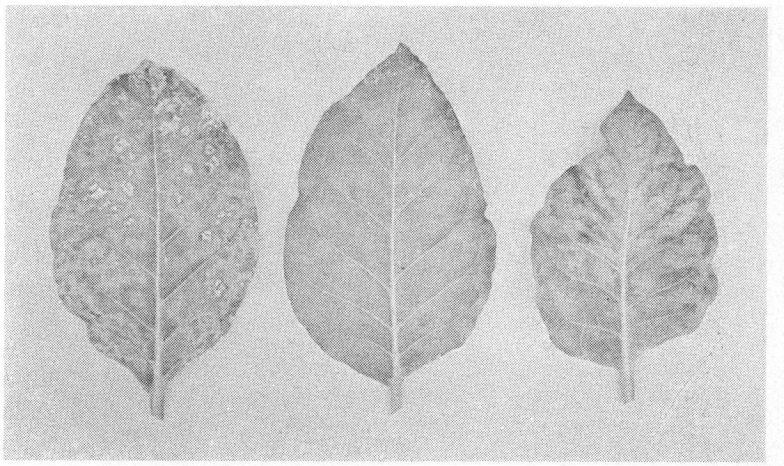
a. mild green mosaic

b. yellow mosaic

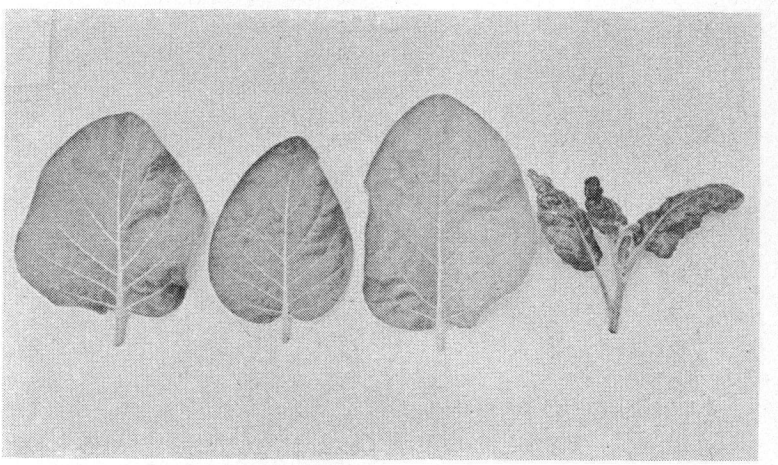


c. severe green mosaic

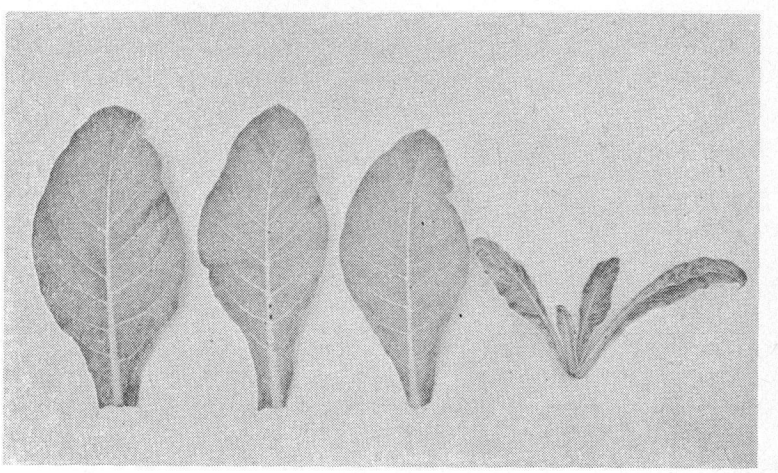
Fig. 1 a—c. Systemic symptoms of TMV types in tomato cv. Bonner Beste. Orig.



a. *N. tabacum* cv. Samsun
from left: yellow mosaic, mild green mosaic, severe green mosaic (systemic symptoms)



b. *N. rustica*
from left: control, mild green mosaic (local lesions), yellow mosaic (local lesions), severe green mosaic (systemic symptoms)



c. *N. sylvestris*
from left: control, mild green mosaic (local lesions) yellow mosaic (local lesions), severe green mosaic (systemic symptoms)

Fig. 2 a—c. Symptoms of TMV types in *Nicotiana* test plants. Orig.

The RNA base ratios of all types are similar, except for a small difference in the proportions of guanine and adenine for the severe green mosaic compared with the values for the other types.

There is a similarity in amino acid composition between the mild green and yellow mosaic types, as is evidenced in the amounts of amino acid residues; likewise the carboxyl terminal acid is the same for both, namely serine. The severe green mosaic type differs essentially from the previous two; it is lacking in methionine, and its carboxyl teminal acid is threonine.

With regard to their symptomatology and amino acid composition, parallels can be drawn between the Finnish TMV types presented in this paper and certain strains of TMV described by other workers:

— between the mild green mosaic type and the dahlemense strain (WITTMANN-LIEBOLD and WITTMANN 1963, KNIGHT 1963),
— between the yellow mosaic type and the yellow tomato atypical mosaic virus (Y-TAMV) strain (KNIGHT et al. 1962, KNIGHT 1963) and
— between the severe green mosaic type and the common tobacco mosaic virus (vulgare) strain (TSUGITA 1962, KNIGHT 1963).

The exact classification and nomenclature of TMV isolates/isolate groups as strains is possible and justified only after both their biological properties and their detailed chemical composition, including the nucleotide and amino acid sequences are known.

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Annikki Linnasalmi
Agricultural Research Centre
Institute of Plant Pathology
SF-01300 Vantaa 30, Finland

SELOSTUS

Tupakan mosaiikkivirus (TMV) -tyypit tomaatissa Suomessa

ANNIKKI LINNASALMI

Maatalouden tutkimuskeskus

Tupakan mosaiikkivirusaineistossa (TMV) tomaattiviljelmiltä Suomessa (v. 1962—65) erotettiin kolme pääryhmää, lievä viherkirjo-tyyppi, joka oli ylivoimaisesti yleisin (93 %) sekä keltakirjo (4 %) ja vahva viherkirjo (3 %) -tyypit, jotka esiintyivät vain sporaadisesti. Tyypit on karakterisoitu niiden symptomatologian nojalla tomaatissa (*Lycopersicon esculentum* Mill.) ja viidessä *Nicotiana* -testikasvissa (*N. tabacum* L. cv. Samsun ja cv. Xanthi, *N. glutinosa* L., *N. rustica* L. ja *N. sylvestris* L.) sekä niiden lämmönsietorajan, ribonukleiinihappoemäskoostumuksen ja aminohappokoostumuksen perusteella. Analyysit tehtiin yhteensä 55:stä isolaatista.

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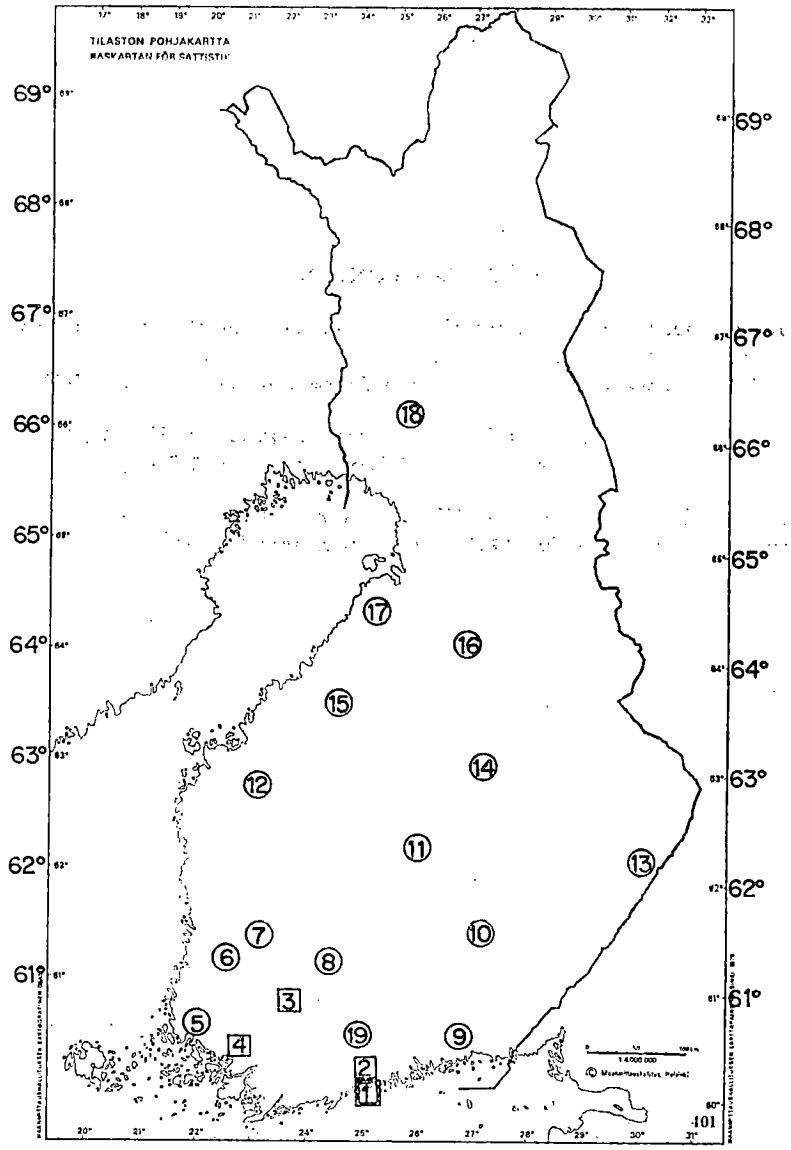

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