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Reaction of spring barley cultivars grown in Finland to soil-borne infection by *Bipolaris sorokiniana* and to its toxic metabolites

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Abstract. Soil-borne infection of *Bipolaris sorokiniana* caused foot and root rot in all spring barley cultivars studied. Significant differences in susceptibility of the cultivars and pathogenicity of the fungus isolates were found. Primary symptoms caused by the fungus were seedling blight, later foot and root rot. Yield losses caused by the fungus varied from 3 % to 33 % the mean being c. 15 %. Yield losses could occur without severe disease symptoms. Toxic metabolites produced by the fungus induced visible foot and root symptoms in all cultivars tested and caused lesions in the leaves of some cultivars. Variability in toxin production of fungus isolates as well as the reaction of a cultivar to toxins was demonstrated. The cultivars most susceptible to soil-borne infection by the fungus also showed the most severe symptoms when exposed to toxic metabolites of the fungus.

Introduction

Bipolaris sorokiniana (Sacc. in Sorok.) Shoemaker, syn. *Helminthosporium sativum* (Pamm., King & Bakke), perfect state *Cochliobolus sativus* (Ito & Kurib.) Drechsl. ex Dastur, the cause of common root rot, spot blotch and black point, is a world-wide pathogen of wheat and barley (SPRAQUE 1950, BUTLER 1961, de TEMPE 1964, CHULKINA 1972, JØRGENSEN 1974). The fungus is carried by air, soil and seed but in dry temperate areas it is mainly soil-borne (DUCZEK & PIENING 1982). Soil-borne inoculum becomes important if cereals, particularly barley and wheat are increasingly grown in crop rotation (CHINN 1976). Inoculum density in the soil is related to the amount of fungal sporulation occurring on crop residues (REIS & WÜNSCHE 1984). Under favourable conditions the conidia of *B. sorokiniana* may survive several years in field soil (LEDINGHAM 1970). Oil crops and fallow in crop rotation significantly decrease the number of germinating conidia in the soil (CHINN 1976).

Yield losses of c. 10 % have been reported on barley (PIENING et al. 1976, STACK 1982). Soil-borne infection may also cause over-

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wintering damage on barley and wheat (FRANK & MARSHALL 1981).

Significant differences in reactions of barley cultivars to the fungus have been found (TINLINE & LEDINGHAM 1979). Similarly variable pathogenicity among the fungus isolates has been reported (EL-NASHAAR & STACK 1982).

In Finland the fungus is commonly found on the green barley crop (MÄKELÄ 1972, 1975) and seed crop (KURPPA 1975, 1984) and its importance as a soil-borne pathogen is obvious. However, little information is available about varietal reactions to soil-borne inoculum or pathogenicity of local fungus isolates. In addition to studying these problems the susceptibility of commercial barley cultivars to toxic metabolites produced by the fungus isolates was investigated. Finally, these results and data from the infectivity tests at different developmental stages of barley crop were compared to evaluate the reaction of a cultivar to common root rot.

Material and methods

A number of laboratory, greenhouse and field experiments were carried out to study obvious differences in susceptibility of spring barley cultivars to soil-borne infection of various isolates of *Bipolaris sorokiniana*. The effect of fungal metabolites on symptom appearance was also studied.

In greenhouse experiments barley was grown in 25 × 25 cm size plastic pots in loamy field soil pH c. 6.0. In the first two experiments (Table 1) the soil was sterilized but was not sterilized for subsequent experiments unless stated otherwise. In the experiments studying the effects of fungal metabolites (Table 7), barley seedlings were raised in sterilized sand. Levels of fertilizer as recommended for the field crop were used to fertilize the soil. The soil for pot experiments was inoculated with homogenized fungal cultures grown 3 weeks on PDA in petri dishes at 22°C. Approximately one fungal culture in a 9 cm diameter petri dish was used per pot and carefully mixed with the soil before potting. Where necessary, the number of the reproductive fungal units in the homogenates was determined with a haemocytometer and the inoculum densities adjusted.

Origin of fungal isolates were as follows:

A leaves six-row barley cv. unknown Keitele, Central Finland
B leaves two-row barley cv. Karri Lapinjärvi, Southern Finland
C leaves spring wheat cv. unknown Loimaa, Southern Finland
6136 seed six-row barley cv. Etu Kuopio, Central Finland
6262 seed six-row barley cv. Suvi Mommila, Southern Finland
6571 seed six-row barley cv. Pomo Kouvola, Southern Finland
7550 seed two-row barley cv. Birgitta Hämeenlinna, Southern Finland
8028 seed two-row barley cv. Karri Loimaa, Southern Finland

All experiments were replicated four times. For short term pot experiments 50 seeds were sown in each pot, otherwise 30 seeds were sown. The first short term experiments were designed to determine the effect of soil-borne infection on seedling emergence, early foot and root rot and foliar symptom development, and growth rate of young seedlings. After visual symptom observation, basal stems and roots of five seedlings showing symptoms were surface sterilized wich 1 % Na-hypochloride and placed on cornmeal agar containing 50 ppm streptomycin. Fungal growth was observed with a stereomicroscope after one and two weeks of incubation at 22°C.

The long term experiments were designed to test the true pathogenicity of the fungus isolates to different barley cultivars as measured by the development of barley and grain yield. In the experiments detailed in tables 2 and 3 the soil was inoculated with

the fungus for the first year's study as described earlier. For the second year's experiments the pots were left after harvest in a covered store outdoors to overwinter. The following spring the soils in the pots were homogenized and mixed keeping each treatment separate. The soil lots were fertilized but no extra inoculum were added. These experiments were carried out in a partially covered greenhouse where the temperature and relative humidity were comparable to the conditions outdoors. Subsamples of grain from each cultivar and treatment were also examined for the incidence of *B. sorokiniana* in the seeds.

The inoculum potential of naturally infested field soil was studied in the field and in greenhouse experiments. In the field only symptom appearance and development and the fungus incidence in the seeds were studied but in greenhouse experiments disease development was followed at short intervals from seedling emergence to harvest.

Soil for the experiments was taken from a field plot where soil-borne and seed-borne infections by *B. sorokiniana* were studied during two previous growing seasons. Control soil was taken from the same field area, where non-infected barley crop was grown.

Control of soil-borne infection by organomercurial seed treatment was also studied. The seeds were treated with Ceresan seed dressing powder, 2 g powder/1 kg of seeds.

Up to five plants showing symptoms / pot, if available, were tested for the infection of *B. sorokiniana* as described earlier. In order to observe fungal invasion into the upper shoot a portion was surface sterilized in 1 % Na-hypochloride and cut into parts of 5 cm, which were then placed in order on the agar. Fungal growth was observed one week later with a stereomicroscope. The incidence of *B. sorokiniana* in grain yields was determined as described by KURPPA (1984).

Three experiments were carried out to determine the response of some barley cultivars to the metabolites of the fungus isolates. The medium containing fungal metabolites was produced by culturing fungus isolates 30 days in erlenmeyer bottles in liquid Zapek Dox medium. The medium was then filtered through filter paper followed by filtration through a 45 micron filter. Samples of these filtrates were autoclaved before dilution in fresh Zapek Dox medium.

Susceptibility of five barley cultivars to phytotoxins produced by nine fungus isolates was studied in the first experiment (Fig. 3). Eight day old barley seedlings raised in sterilized sand were cut at the coleoptile and the shoots were placed into 50 ml erlenmeyer bottles filled with 30 ml of differentially diluted media from fungal cultures (see GAYED 1962). The shoots in the bottles were exposed for 5000 lux fluorescent light 18 h/day and the symptoms in the seedlings were observed after 6, 24, 48 and 72 hours.

For the second experiment (Table 5) barley seedlings grown on sterilized sand were carefully and gently washed to remove the sand, dried for 5 minutes on filter paper and weighed. Before placing into the bottles filled with medium the seedlings were rinsed in sterile distilled water. After three days of incubation under 5000 lux illumination 18 h/day at 22°C the experiment was discontinued and the seedlings were reweighed.

Finally, barley was grown in sterilized sand, which was watered the first week with sterile Zapek Dox medium. During the remaining two weeks, filtered medium containing fungal metabolites was used for watering the seedlings. The seedlings were then gently washed out of sand, weighed and observed for the presense of symptoms.

All data were subjected to analysis of variance.

Results

Spring barley seedlings, growing in soil naturally infested or artificially inoculated with *B. sorokiniana,* became readily infected

Table 1. The effect of *Bipolaris sorokiniana* inoculum in sterilized loam soil on foot and root injuries (a) and fresh weight of seedling crop/pot (b) after 32 days growing period in laboratory experiments.

Fungus isolate[1]	a	Per cent injuries Cultivar and inoculum density								Mean of the isolate
		Paavo				Ingrid				
		10°*	10^{-1}	10^{-2}	Mean	10°	10^{-1}	10^{-2}	Mean	
A		81.5	60.5	24.5	55.0	74.5	39.0	24.5	46.0	50.5
B		83.0	54.6	17.0	51.5	85.6	62.0	30.5	60.0	55.7
C		77.0	34.6	22.0	44.5	60.5	40.0	23.5	41.3	42.9
Mean		80.5	49.9	21.2		73.5	47.0	26.1		

[1] For origin of isolate see text
* Inoculum density 10° = c. 1 000 000 reproductive units/l liter soil
F-values: Inoculum density = 134.0^{xx}, $LSD_{t0.05}$ = 8.1 %
Inoculum isolate = 7.4^{xx}, = 6.1 %

	b	Fresh weight of seedlings g/pot								
		Paavo				Ingrid				
	Control	10°	10^{-1}	10^{-2}	Mean	Control	10°	10^{-1}	10^{-2}	Mean	Mean of the isolate
	34.8					45.2				
A		28.4	28.0	31.6	29.3		39.8	40.2	42.0	40.7	35.0
B		27.5	28.4	31.9	29.3		37.0	38.3	41.7	39.0	34.1
C		28.7	30.0	31.1	29.9		38.4	40.3	42.1	40.3	35.1
Mean		28.2	28.8	31.5			38.4	39.6	41.9		

F-values: Inoculum density = 8.1^{xx}, $LSD_{t0.05}$ = 11.0 % (Paavo 3.83 g, Ingrid 4.97 g)
Inoculum isolate < 1

by the fungus in pot or field experiments. The fungus was extremely pathogenic to barley in sterilized field soil. Most seedlings of the two barley cultivars (Table 1) in the experiments became infected when the inoculum density was c. 1 million reproductive units per liter of soil, but a 100-fold reduction in inoculum density also resulted in a high rate of infection and injury (Table 1 a.). The seedlings showed dark brown coleoptiles and root discoloration as well as longidual or oval dark brown lesions on the basal leaves. All crops in inoculated soils showed poor growth two to three weeks after emergence. When the seedlings were weighed five weeks after sowing, a significant growth reduction was found (Table 1 b.). The inoculum density was of major importance and fungus isolate or barley cultivar played a minor role. The mean weights of single seedlings remained significantly lower than those of controls but more biomass reduction was due to a lower number of seedlings per pot.

The fungus also significantly reduced the emergence of most of the 12 barley cultivars tested in non-sterilized loamy field soil. All barley cultivars showed foot discoloration and seedling blight with significant differences among them in the incidence and severity of disease (Table 2). Six-row cultivars Paavo, Pomo and Teemu were highly susceptible to foot discoloration and seedling blight but two-row cvs Ingrid and Karri as well as six-row cvs Otra, Suvi and Tammi appear to have some resistance.

The following summer, after natural overwintering of the soils, a similar reduction in the emergence and symptom appearance was found. All fungus isolates retained their infectivity in soil but some reduction in their pathogenicity was obvious (Table 2). The isolate 7550 was particularly pathogenic.

Table 2. The effect of soil-borne infection by *Bipolaris sorokiniana* on per cent emergence and injured seedlings of 12 spring barley cultivars in covered pot experiments

Cultivar	1st year's experiment[1] Isolate										2nd year's experiment Isolate									
	Controls		6136		6571		7550		Means w/o controls		Controls		6136		6571		7550		Means w/o controls	
	A[2]	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
Eero	99	0.0	96	11.4	94	12.8	93	15.0	94.3	13.1	98	0.0	96	10.4	96	10.4	92	15.2	94.7	12.0
Etu	99	0.0	97	13.4	96	14.9	94	13.8	95.7	14.0	98	0.0	93	10.8	88	14.8	89	10.1	90.0	11.9
Hja 673	97	0.0	95	7.4	95	11.7	93	15.0	94.3	11.3	97	0.0	96	4.2	96	8.3	92	14.1	94.7	8.9
Ingrid	96	0.0	95	3.1	95	3.1	91	4.4	93.7	3.5	96	0.0	95	1.0	96	5.2	95	2.1	95.3	2.8
Karri	96	0.0	94	4.2	94	6.2	92	9.8	93.3	6.7	96	0.0	96	2.1	97	4.1	93	7.5	95.3	4.6
Otra	95	0.0	96	7.3	94	8.5	92	12.0	94.0	9.3	96	0.0	93	6.4	93	5.4	90	7.3	92.0	6.4
Paavo	97	0.0	92	18.5	92	23.9	90	24.4	91.3	22.7	97	0.0	93	14.0	93	14.0	90	33.3	92.0	20.4
Pomo	87	2.3	84	16.8	84	22.6	80	25.0	82.7	21.5	94	0.0	91	13.2	89	13.5	87	21.8	89.0	16.2
Pirkka	95	0.0	91	6.6	91	10.0	89	10.1	90.3	8.9	95	0.0	93	4.3	93	6.5	89	9.0	91.7	6.6
Suvi	98	0.0	96	5.5	90	7.8	95	6.3	93.7	6.5	98	0.0	96	4.2	93	8.6	95	6.3	94.7	6.4
Tammi	94	0.0	94	3.1	94	11.7	94	11.7	94.0	8.8	96	0.0	96	1.0	94	6.4	93	9.7	94.7	5.7
Teemu	96	0.0	94	18.1	94	30.8	92	32.6	93.3	27.1	97	0.0	93	14.0	93	12.9	89	24.7	91.7	17.2
Means	95.8	0.2	93.7	9.6	92.7	13.7	91.2	15.0	92.6	12.8	96.3	0.0	94.3	7.1	93.4	8.7	91.2	13.4	92.9	9.9

[1] For 1st year's experiment unsterilized loamy soil was inoculated with the fungus two weeks before sowing the seeds. The pots were resown the following summer but no extra inoculum was added.

[2] A = % emergence; B = % visibly injured seedlings

F-values:

1st year's experiment			2nd year's experiment		
Emergence / treatments	= 47.3xx,	$LSD_{t0.05}$ = 1.47 %	Emergence / treatments	= 27.1xx,	$LSD_{t0.05}$ = 1.44 %
— » — / cultivars	= 8.0xx,	= 1.90 %	— » — / cultivars	= 5.7xx,	= 1.78 %
Injuries (w/o controls) / treatments	= 17.5xx,	= 2.33 %	Injuries (w/o controls) / treatments	= 31.5xx,	= 1.99 %
— » — — » — / cultivars	= 29.3xx,	= 2.97 %	— » — — » — / cultivars	= 28.9xx,	= 2.54 %

Table 3. The effect of soil-borne infection by *Bipolaris sorokiniana* on the relative number of grain producing heads and the relative grain yield of 12 barley cultivars in covered pot experiments.

Cultivar	1st year's experiment[1] Isolate								2nd year's experiment Isolate							
	6136		6571		7550		Means w/o controls		6136		6571		7550		Means w/o controls	
	C[2]	D	C	D	C	D	C	D	C	D	C	D	C	D	C	D
Eero	102.8	88.2	110.6	80.0	98.1	81.3	103.8	83.1	100.9	91.0	96.4	85.0	96.4	81.4	97.9	85.8
Etu	104.3	94.7	94.6	97.8	104.3	85.7	101.0	92.7	92.5	91.4	87.8	82.8	92.5	79.5	90.9	84.6
Hja 673	88.3	96.6	85.4	89.7	89.3	81.9	87.7	89.4	100.0	97.2	98.1	85.4	91.6	74.3	96.6	85.6
Ingrid	103.4	86.3	113.8	77.1	87.8	72.5	101.7	78.6	100.0	94.4	100.7	89.1	99.2	75.8	100.0	86.5
Karri	104.9	90.9	88.4	82.3	81.7	80.5	92.0	84.4	105.6	95.4	97.5	90.8	89.4	87.8	97.5	91.3
Otra	89.2	89.9	92.1	78.2	82.3	75.6	87.8	81.2	95.3	93.2	94.3	89.8	86.0	81.0	91.9	88.0
Paavo	88.4	80.3	88.5	65.6	68.4	62.3	81.8	69.4	91.2	92.4	81.3	81.7	75.5	67.9	82.7	80.7
Pomo	91.9	73.7	87.8	64.2	77.0	53.3	85.6	63.7	94.1	89.7	89.2	82.4	81.4	69.1	88.2	80.4
Pirkka	91.1	90.7	85.1	75.6	78.2	64.0	84.8	76.8	93.6	90.2	92.7	91.7	89.1	83.0	91.6	88.3
Suvi	103.0	97.8	83.5	88.4	94.8	94.6	93.7	93.6	100.0	95.7	87.0	85.3	88.9	81.0	92.0	87.3
Tammi	103.1	100.9	88.5	92.4	100.0	99.9	97.2	98.7	100.9	100.7	99.0	94.2	97.2	69.9	99.0	94.9
Teemu	83.1	67.4	74.1	64.4	67.4	45.9	74.9	59.2	87.0	82.8	84.2	76.1	75.9	66.9	82.3	75.3
Means	96.1	88.1	91.1	80.4	85.8	74.7			96.8	92.8	92.3	85.4	88.6	76.5		

[1] For details see table 2.

[2] C = Number of grain producing heads; D = grain yield as relative value of control as 100.0.

F-values:

1st year's experiment			
Heads / treatments	=	6.46^{xx}, $LSD_{t0.05}$	= 7.09 %
— » — / cultivars	=	5.72^{xx},	= 9.09 %
Yield / treatments	=	28.82^{xx},	= 2.31 %
— » — / cultivars	=	6.30^{xx},	= 3.01 %

2nd year's experiment			
Heads / treatments	=	18.2^{xx}, $LSD_{t0.05}$	= 3.33 %
— » — / cultivars	=	9.6^{xx},	= 4.27 %
Yield / treatments	=	73.34^{xx},	= 4.14 %
— » — / cultivars	=	2.78^{x},	= 5.46 %

Varietal susceptibility to the fungus remained unchanged from the previous experiment. In these two experiments soil-borne infection by *B. sorokiniana* significantly decreased the number of grain-carrying heads and simultaneously the grain yield of most cultivars (Table 3). The yields of cultivars with highest symptom incidence were the most severely affected by the fungus. However, significant losses were also associated with cultivars with mild disease symptoms. These cultivars include Eero, Ingrid and Pirkka.

Similarly, naturally infested field soil infected all 16 spring barley cultivars tested in pot experiments. Symptom incidence and severity after four weeks growth in infested soil varied significantly between the cultivars. Among the cultivars not earlier tested, Aapo and Eva (two-row cvs) were resistant but Birgitta (two-row) and Vigdis (six-row) were susceptible (Fig. 1, F = 17.8**, $LSD_{t0.05}$ = 3.7 %).

The fungus also caused noticeable growth reduction in the experiments (Table 4); barley grown in infested soils remained 10—15 cm shorter than those in control soils. Yield loss averaged 24 %. An organomercurial seed dressing compound gave a slight yield increase, but did not protect the young seedlings from becoming infected. No infection of upper leaves or heads was found in any of the experiments when soil-borne infection was studied in relatively dry greenhouse conditions.

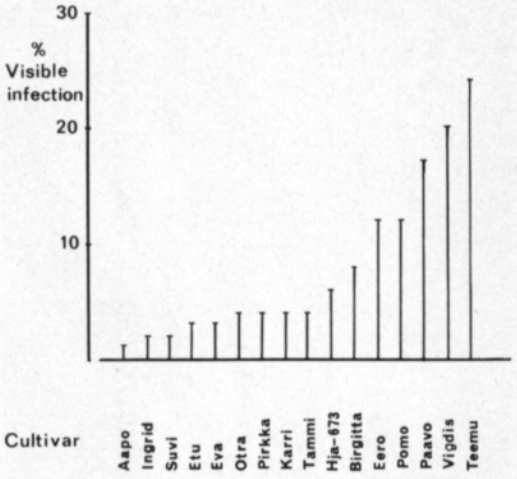

Fig. 1. Per cent seedlings of 16 barley cultivars showing symptoms induced by natural soil-borne infection by *Bipolaris sorokiniana* in greenhouse experiments after 4 weeks growth.

In the field the symptoms caused by the fungus were comparable to those in greenhouse experiments. The first seedling blight symptoms were found 2 to 3 weeks after sowing, depending on the temperature. Some increase in symptom incidence was found during the following weeks but no further foliar symptoms occurred during dry growing seasons when spore liberation from the secondary infection sources was minimal. In these conditions the fungus was localized in roots, basal stems and the lower senesceting leaves and was never found in upper leaves, upper shoot or heads. The foot and root rot symptoms, however, remained typical of the fungus even in these excep-

Table 4. The yield loss caused by natural soil-borne infection by *Bipolaris sorokiniana* on barley cvs. Birgitta and Otra in greenhouse experiments and the control of the fungus by mercurial seed treatment.

	Cultivar					
	Birgitta		Otra		Mean	
	Untreated	Treated	Untreated	Treated	Untreated	Treated
Control soil	100.0*	98.6	100.0	102.1	100.0	100.4
Infected soil	70.4	79.6	81.9	85.5	76.2	82.5

* Yields reported relative to control as 100.0

F-values: Soil = 145.5xx, $LSD_{t0.05}$ = 5.5 %
Seed treatment = 9.8xx, = 7.9 %

Fig. 2. Foot rot symptoms at the time of heading.

Fig. 3. Leaf dip senescence and root discoloration caused by toxic metabolites of *Bipolaris sorokiniana*.

tionally dry conditions (Fig. 2). Barley cultivars, which were found susceptible in pot experiments were also susceptible in the field but no data is presented because of the uneven distribution of the fungus in the field soil.

Metabolic products of *B. sorokiniana* containing phytotoxins were shown to be responsible for symptom appearance and decreased growth rate of barley seedlings (Fig. 3). The toxic effect was found whether barley seedlings were grown in toxin-containing liquid medium or in sand watered with this medium. In liquid medium the growth of barley seedlings was minimal during the three days period they were exposed to toxins (Table 5). Dilution of 5×10^{-3} from the filtered culture fluid was capable of inducing visible symptoms of leaf senescence and foot discoloration with a combination of growth decrease. Significant differences between barley cultivars and fungus isolates were found. The average per cent varietal growth inhibition originating from the toxic metabolites was as follows: Birgitta 17.6, Karri 25.2, Otra 26.7 and Paavo 31.2. Susceptibility to the toxins was comparable to that caused by soil-borne infection of the fungus. Autoclaved medium remained highly toxic.

Severe foot and root discoloration symptoms were found in young seedlings of all barley cultivars tested growing in sterilized sand after they were watered two weeks with medium containing filtered fungus culture fluid (Table 6). The culture metabolites from one fungus isolate induced significantly higher symptom incidence than any of the other isolates tested and similarly two barley cultivars were found to be more susceptible than the rest. Some interaction between the toxin source and the barley cultivar was also obvious. Toxic metabolites decreased growth rate of all cultivars (Table 7). However, differences were found: cv. Birgitta being the most susceptible and cv. Otra the most resistant.

Table 5. The effect of toxic metabolites produced by *Bipolaris sorokiniana* on relative growth rate of barley seedlings during three days growing period in liquid Zapek Dox medium.

a. Non-autoclaved toxic medium

Cultivar	Isolate[1] 10^{-1} dilution						Isolate 5×10^{-3} dilution					Mean w/o control
	6136	6262	6571	7550	8028	Control	6136	6262	6571	7550	8028	
Birgitta	11.8*	14.7	2.6	8.9	1.8	33.3	15.7	19.1	11.8	16.1	14.6	11.7
Karri	10.3	12.8	10.7	3.7	1.3	36.3	15.5	20.5	13.4	16.1	13.5	11.8
Otra	16.2	23.4	9.1	3.7	5.0	41.7	27.9	25.3	9.8	22.7	9.4	15.2
Paavo	3.0	24.8	13.1	1.4	1.7	43.2	23.9	21.7	15.4	13.6	13.5	13.2
Mean	10.3	18.9	8.8	4.4	2.4	38.6	20.7	21.6	12.6	17.1	12.8	
b. Autoclaved toxic medium												
Birgitta	21.6*	25.1	14.6	9.1	7.2		28.9	29.1	17.8	19.8	24.3	19.7
Karri	13.2	9.6	4.1	4.1	6.1		20.9	15.3	6.1	10.6	13.9	10.4
Otra	14.1	21.0	6.4	8.0	3.7		17.4	19.6	19.9	12.2	24.7	14.7
Paavo	14.1	9.4	5.7	1.4	2.6		26.4	19.7	10.4	9.0	8.5	10.7
Mean	15.7	16.3	7.7	5.6	4.9		23.4	20.9	13.6	12.9	17.6	
Mean (a + b)	13.0	17.6	8.3	5.1	3.7	38.6	22.0	21.3	13.2	15.0	15.2	

[1] Toxin source

* Relative weight increase of seedlings (%)

F-values: Toxin source = 55.8^{xx}, $LSD_{t0.05}$ = 7.1 %
Barley cultivar = 19.3^{xx}, = 7.7 %

Table 6. Per cent seedlings showing root symptoms after three weeks growth in sterilized sand watered last two weeks with Zapek Dox medium containing metabolites produced by *Bipolaris sorokiniana* isolates.

Cultivar	Isolate						Mean w/o control
	Control	6136	6262	6571	7550	8028	
Birgitta	0.0*	5.0	22.5	0.0	7.5	90.0	25.0
Karri	0.0	17.5	12.5	2.5	32.5	17.5	16.5
Otra	0.0	2.5	2.5	12.5	5.0	27.5	10.0
Paavo	0.0	22.5	35.0	57.5	32.5	57.5	41.0
Mean	0.0	11.9	18.1	18.1	19.4	48.1	

* Seedlings showing root symptoms (%)

F-values: Toxin producing isolate = 4.6^{x}, $LSD_{t0.05}$ = 13.3 %
Barley cultivar = 5.0^{x}, = 14.8 %

Table 7. The relative fresh weight of barley seedlings after three weeks growth in sterilized sand watered last two weeks with Zapek Dox medium containing metabolites produced by *Bipolaris sorokiniana* isolates.

Cultivar	Isolate					Mean w/o control
	6136	6262	6571	7550	8028	
Birgitta	81.4*	69.6	74.7	79.1	66.2	74.2
Karri	77.4	79.0	88.1	79.7	79.7	80.8
Otra	85.2	98.1	89.0	93.2	89.3	91.0
Paavo	76.6	80.7	79.3	85.2	78.0	80.0
Mean	80.2	81.9	82.8	84.3	78.3	

* Relative fresh weight. Controls for each cultivar = 100.0

F-values: Barley cultivar = 10.3^{xx}, $LSD_{t0.05}$ = 8.3 %
Toxin producing isolate < 1

Discussion

Differences in resistance of barley cultivars to common root rot have been widely reported but the incidence and severity of visible symptoms has not always been comparable to yield losses as reported by PIENING (1973), TINLINE and LEDINGHAM (1979) and STACK (1982). In this study severe disease reaction was usually followed by severe yield reduction but high yield losses were also found without visible symptoms. Genetically inherited susceptibility to common root rot in certain Finnish six-row barley cultivars, such as Paavo and its relatives, appears to be dominant, but some resistance to the disease is obvious in some cultivars. The cultivars now shown to be highly susceptible to soil-borne infection have previously been shown by KURPPA (1984) to carry the highest rate of seed infection. High incidences in seedling symptoms and injuries were always followed by high root rot incidence differing in this respect to the results reported by STACK (1981). The number of grain producing heads/pot has been used to estimate or forecast yield. According to VERMA et al. (1973), the number of heads/plant is greatly affected by root rot, which agrees with this study. LUTZ et al. (1983) have, however, reported number of kernels per head and particularly dry weight of kernels are the primary effects of the disease.

Variation in pathogenicity of different fungus isolates has also been reported by EL-NASHAAR and STACK (1982). However, the average pathogenicity of the isolates in various localities was similar. It follows that for a cultivar to be field resistant it must have wide-scale resistance to the fungus.

Metabolites on *B. sorokiniana* toxic to barley seedlings have been reported as early as the 1950's by LUDWIG (1957) but according to DUTRECQ et al. (1980) no definite answer has yet been given whether toxin-resistant plants will also be resistant to infection by the fungus. In this study most barley cultivars showing high susceptibility to toxic metabolites were also more susceptible to infection by the fungus. However, it is possible that the variability in the toxins reported by DAVIS et al. (1982) was not present in this study.

B. sorokiniana is a world-wide pathogen of cereals of such importance that all available resistance against it, as developed by plant breeding as reported by WILCOXSON et al. (1980) should be used. It would appear that the reaction to toxic metabolites of *B. sorokiniana* could be used to screen barley breeding lines for susceptibility to common root rot before submitting promising lines to infection tests.

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References

BUTLER, F.C. 1961. Root and foot rot disease of wheat. Sci Bull. No 77, New South Wales Dept Agric.

CHINN, S.H.F. 1976. *Cochliobolus sativus* conidia populations in soils following various cereal crops. Phytopath. 66: 1082—1084.

CHULKINA, V.A. 1972. Soil infestation and some methods for its suppression in the control of common root rot of barley. A translation of Mikologiya i fitopatologiya 6: 435—439.

DAVIS, C.M., CHRIST, J.E., PUEPPKE, S.G. & STACK, R.W. 1982. A bioassay for toxic metabolites of *Helminthosporium sativum*. Phytopath. 72: 1134.

DUCZEK, L.J. & PIENING, L.E. 1982. Effect of seeding dept, seeding date and seed size on common root rot of spring barley. Can. J. Pl. Sci. 62: 885—891.

DUTRECQ, A., SOMMEREYNS, G. & SEMAL, J. 1978. Using resistance to the toxin of *Helminthosporium sativum* as a means of selecting cereals: toxicity tests and toxin preparation. Ann. Appl. Biol. 89: 370—373.

EL-NASHAAR, H.M. & STACK, R.W. 1982. Pathogenic

variation in populations of *Helminthosporium sativum*. Phytopath. 72: 1135.

Frank, J.A. & Marshall, H.G. 1982. The influence of root rot on the winter survival of wheat and barley plants. Phytopath. 72: 260.

Gayed, S.K. 1961. Production of symptoms of barley leafspot disease by culture filtrate of *Helminthosporium sativum*. Nature, Lond. 191: 725—726.

— 1962. The pathogenicity of six strains of *Helminthosporium sativum* to three cereals with special reference to barley. Mycopath. 18: 271—279.

Jørgensen, J. 1974. Occurence and importance of seed borne inoculum of *Cochliobolus sativus* in Denmark. Acta Agric. Scand. 24: 49—54.

Kurppa, A. 1975. Ohran tyvi- ja lehtilaikku — yleistyvä piilevä kasvitauti. Käytännön Maamies 1975, 7: 20—21.

— 1984. *Bipolaris sorokiniana* on barley seed in Finland. J. Agric. Sci. Finl. 56: 175—181.

Ledingham, R.J. 1970. Survival of *Cochliobolus sativus* conidia in pure culture and in natural soil at different relative humidities. Can. J. Bot. 48: 1893—1896.

Ludwig, R.A. 1957. Toxin production by *Helminthosporium sativum* P., K. & B. and its significance in disease development. Can. J. Bot. 35: 291—303.

Lutz, A., Van Alfen, N.K. & Kidambi R. 1983. The role of *Helminthosporium sativum* in barley crown rot and yield loss. Phytopath. 73: 960.

Mäkelä, K. 1972. Leaf spot fungi on barley in Finland. Acta Agric. Fenn. 124: 1—33.

— 1975. Occurence of *Helminthosporium* species on cereals in Finland in 1971—1973. J. Sci. Agric. Soc. Finl. 47: 181—217.

Piening, L.J. 1973. Differential yield response of ten barley cultivars to common root rot. Can. J. Pl. Sci. 53: 763—764.

—, Atkinson, T.G., Horricks, J.S., Ledingham, R.J., Mills, J.T. & Tinline, R.D. 1976. Barley losses due to common root rot in the Prairie Provinces of Canada, 1970—1972. Can. Pl. Dis. Surv. 56: 41—45.

Reis, E.R. Wünsche, W.A. 1984. Sporulation of *Cochliobolus sativus* on residues of winter crops and its relationship to the increase of inoculum density in soil. Pl. Dis. 68: 411—412.

Spraque, R. 1950. Diseases of cereals and grasses in North America. 538 p. New York.

Stack, R.W. 1981. Seedling disease responce not a good indication of adult plant susceptibility to *Helminthosporium* root rot. Phytopath. 71: 257.

— 1982. Yield losses in spring barley due to common root rot in Eastern North Dakota. Phytopath. 72: 1139—1140.

Tempe, J. de. 1964. *Helminthosporium* spp. in seeds of wheat, barley, oats and rye. Proc. Int. Seed Test. Assoc. 29: 117—140.

Tinline, R.D. & Ledingham, R.J. 1979. Yield losses in wheat and barley cultivars from common root rot in field tests. Can. J. Pl. Sci. 59: 313—320.

Verma, P.R., Morrall, R.A.A. & Tinline, R.D. 1973. Root rot disease of wheat in a cultivated ecosystem. Tech. Report, Matador Project, Univ. of Sascatchewan No 30, 221 p.

Wilcoxson, R.D., Rasmusson, D.C., Banttari, E.E. & Johnson, D.A. 1980. Feasibility of selecting for resistance to kernel discoloration in barley. Pl. Dis. 64: 928—930.

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SELOSTUS

Suomessa viljeltyjen ohralajikkeiden alttius *Bipolaris sorokiniana*-sienen maalevintäiselle tartunnalle ja sienen toksisille aineenvaihduntatuotteille

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Ohran tyvi- ja lehtilaikkua aiheuttavan *Bipolaris sorokiniana*-sienen (syn. *Helminthosporium sativum*, koteloaste *Cochliobolus sativus*) vahingollisuutta maalevintäisenä taudinaiheuttajana tutkittiin Helsingin yliopiston kasvipatologian laitoksella vuosina 1973—1979. Erityishuomio tutkimuksissa kohdistettiin ohralajikkeiden reagointiin sieneen ja sen toksisiin aineenvaihduntatuotteisiin. Pyrkimyksenä oli myös etsiä luotettavia, infektointikokeita yksinkertaisempia menetelmiä ohralajikkeiden taudinkestävyyden toteamiseksi.

Astiakokeet tehtiin kasvihuoneessa tai kasvukausien aikana sateelta suojatussa ulkotilassa. Kasvualustana oli peltomulta, mikä oli sienen luontaisesti infektoimaa tai mihin sienikasvusto oli lisätty. Aineenvaihduntatuotteiden toksisuutta selvittävissä kokeissa sieni kasvatettiin Zapek-dox ravintoliuoksessa, mitä suodatettuna samaan ravintoliuokseen laimennettuna käytettiin ohran oraiden kasvatukseen erlenmeyerpulloissa tai oraiden kasteluun hiekkakasvatuksissa.

B. sorokiniana aiheutti tyvi- ja juurilaikkuja sekä myös koko maanalaisen versonosan ruskettumista ja kuivettumista kaikissa tutkituissa lajikkeissa. Ensimmäisinä oireina astia- ja kenttäkokeissa havaittiin tummanruskeita pitkulaisia lehtilaikkuja heti orastumisen jälkeen. Kasvun edistyttyä sieni ei enää levinnyt ylemmäksi versoon eikä infektoinut muodostuvaa jyväsatoa korrensisäisesti kasvamalla, mutta tyvitautioireet vahvistuivat ja niihin liittyen verson kasvu sekä sadonmuodostus jäivät heikoksi.

Lajike-erot olivat suuria ja ne säilyivät samansuuntaisina eri tavoin järjestetyissä kokeissa. Sieni aiheutti voimakkaimmat tyvitautioireet lajikkeissa Teemu, Paavo ja Pomo sekä lievimmät lajikkeissa Aapo, Ingrid ja Tammi. Sienen aiheuttama satotappio vaihteli 3 %:sta (Tammi) 33 %:iin (Teemu) ollen keskimäärin noin 15 %. Sieni aiheutti monitahoisissa lajikkeissa keskimäärin pahempaa vioitusta kuin kaksitahoisissa. Kylvösiemenen peittaaminen ei suojannut nuorta orasta sienitartunnalta, mutta saattoi viivästyttää sitä jossain määrin.

Sienen aineenvaihduntatuotteina syntyvät toksiinit aiheuttivat juuri- ja tyvioireita kaikissa tutkituissa lajikkeissa, joissakin lisäksi myös lehtioireita. Ohralajikkeiden reagointierot toksiineihin samoin kuin toksiini-isolaattien erot olivat samansuuntaisia, mitä infektiokokein todettiin. Oraan voimakas reagoiminen toksiineihin paljasti useimmiten lajikkeen tai linjan alttiuden myös sieni-infektiolle.

Ohran tyvi- ja lehtilaikkusientä on pidettävä maassamme vakavana taudinaiheuttajana. Sieni on oloissamme pääasiallisesti siemen- ja ilmalevintäinen, mutta sitä kertyy maahan tyvitaudinaiheuttajaksi lisääntyvästi erityisesti ohran satojätteissä. Tätä kertymistä voidaan estää helpoimmin käyttämällä viljelykiertoa, peittaamalla kylvösiemen elohopeapitoisella tai sopivalla systeemisellä valmisteella ja kulottamalla puidun ohrakasvuston sänki ennen kyntöä.

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