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.) Drechs. ex Dastur, the cause of common root rot, spot blotch and black point, is a world-wide pathogen of wheat and barley (Sprague 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-
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 with 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 organomercural 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 presence 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 | Per cent injuries | Control | Ingrid |
|----------------|-------------------|---------|--------|
|                | Paavo             | Ingrid  |        |
|                | 10^0              | 10^-1   | 10^-2  | Mean  | 10^0              | 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 10^0 = c. 1,000,000 reproductive units/liter soil
F-values: Inoculum density = 134.0^*^, LSD_{0.05} = 8.1 %
Inoculum isolate = 7.4^*^, = 6.1 %

| Fungus isolate | Fresh weight of seedlings g/pot | Control | Ingrid |
|----------------|---------------------------------|---------|--------|
|                | Paavo                           | Ingrid  |        |
|                | 10^0                            | 10^-1   | 10^-2  | Mean  | 10^0              | 10^-1   | 10^-2  | Mean |
| A              | 34.8                            | 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^*^, LSD_{0.05} = 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 longitudinal 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 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, Porno 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 | Isolate | 1st year's experiment | 2nd year's experiment | Controls | A | B | A | B | A | B | A | B | A | B |
|----------|---------|-----------------------|-----------------------|----------|---|---|---|---|---|---|---|---|---|---|---|
| Eero     | 6571    | 99                    | 0.0                   | 96        | 11.4 | 94 | 12.8 | 93 | 15.0 | 94.3 | 13.1 | 98 | 0.0 | 96 | 10.4 | 96 |
| Etu      | 673     | 97                    | 13.4                   | 96        | 11.7 | 95 | 3.1  | 95 | 4.4  | 94.3 | 11.3 | 97 | 0.0 | 95 | 4.2  | 96 |
| Hin      | 673     | 97                    | 13.4                   | 96        | 11.7 | 95 | 3.1  | 95 | 4.4  | 94.3 | 11.3 | 97 | 0.0 | 95 | 4.2  | 96 |
| Ingrid   | 6571    | 96                    | 0.0                   | 95        | 4.2  | 94 | 6.2  | 92 | 4.8  | 93.7 | 3.5  | 96 | 0.0 | 95 | 4.2  | 96 |
| Karri    | 6571    | 95                    | 0.0                   | 96        | 18.5 | 92 | 23.9 | 90 | 24.4 | 91.3 | 22.7 | 97 | 0.0 | 95 | 21.5 | 94 |
| Ora      | 6571    | 95                    | 0.0                   | 96        | 16.8 | 94 | 22.6 | 80 | 25.0 | 92.7 | 21.5 | 94 | 0.0 | 95 | 21.5 | 94 |
| Paavo    | 6571    | 95                    | 0.0                   | 96        | 16.8 | 94 | 22.6 | 80 | 25.0 | 92.7 | 21.5 | 94 | 0.0 | 95 | 21.5 | 94 |
| Pirkka   | 6571    | 96                    | 0.0                   | 96        | 5.5  | 90 | 7.8  | 89 | 10.1 | 93.7 | 6.5  | 95 | 0.0 | 96 | 6.5  | 93 |
| Sivja    | 6571    | 96                    | 0.0                   | 96        | 5.5  | 90 | 7.8  | 89 | 10.1 | 93.7 | 6.5  | 95 | 0.0 | 96 | 6.5  | 93 |
| Tammi    | 6571    | 94                    | 0.0                   | 94        | 3.1  | 94 | 11.7 | 94 | 11.7 | 94.0 | 8.8  | 96 | 0.0 | 94 | 10.4 | 94 |
| Termu    | 6571    | 96                    | 0.0                   | 96        | 18.1 | 94 | 3.0  | 92 | 3.0  | 93.0 | 30.8 | 92 | 3.0  | 94 | 32.6 | 93 |

Means: 95.8 0.2 93.7 9.6 92.7 13.7 91.2 15.0 92.6 12.8 90.3 0.0 94.3 7.1 93.4 8.7 91.2 13.4 92.9 9.9

For 1st year's experiment, unsterilized loamy soil inoculated with the fungus two weeks before sowing the seeds. The pots were resown the following summer but no extra inoculum was added. 94% emergence was obtained.

For 2nd year's experiment, w/o controls = 1.44 %
Injuries (w/o cultivars) / treatments = 31.5 %
Injuries (w/o controls) / treatments = 28.9 %

F-values: 47.3 8.0 17.5 29.3 2.4 3.3 1.9 2.9 2.4
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 | 2nd year's experiment | Means w/o controls |
|----------|-----------------------|-----------------------|--------------------|
|          | Isolate | 6136 | 6571 | 7550 | C D | 6136 | 6571 | 7550 | 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 | 94.4 | 81.7 | 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 | 2nd year's experiment |
|-----------------------|-----------------------|
| Heads / treatments    | 6.46**, LSD0.05 = 7.09 % |
| - / - / cultivars     | 5.72**, = 9.09 % |
| Yield / treatments    | 28.82**, = 3.01 % |
| - / - / cultivars     | 6.30**, = 3.01 % |
| Heads / treatments    | 18.2**, LSD0.05 = 3.33 % |
| - / - / cultivars     | 9.6**, = 4.27 % |
| Yield / treatments    | 73.34**, = 4.14 % |
| - / - / cultivars     | 2.78*, = 5.46 % |
Varietal susceptibility to the fungus remained unchanged from the previous experiment. In these two experiments soil-borne infection by \textit{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, \(F = 17.8^{**}, \text{LSD}_{0.05} = 3.7\) %).

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.

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 senescing 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-

| 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: \(F = 145.5^{**}, \text{LSD}_{0.05} = 5.5\) %
\(F = 9.8^{**}, \text{LSD}_{0.05} = 7.9\) %
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 $5 \times 10^{-3}$ 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.

| Cultivar | Isolate 1 | 10⁻¹ dilution | Isolate 5 × 10⁻³ dilution | Mean w/o control |
|----------|-----------|---------------|---------------------------|------------------|
|          | 6136 | 6262 | 6571 | 7550 | 8028 | 6136 | 6262 | 6571 | 7550 | 8028 | 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 |       |

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 | Control | 6136 | 6262 | 6571 | 7550 | 8028 | Mean w/o control |
|----------|---------|---------|------|------|------|------|------|------------------|
| Birgitta | 0.0*    | 0.0     | 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 | 19.0 |                 |
| 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 |       |                 |

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 | 6136 | 6262 | 6571 | 7550 | 8028 | Mean w/o control |
|----------|---------|------|------|------|------|------|------------------|
| 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*, LSD₀.₀₅ = 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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Suomessa viljeltyn 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 maa-levintäisenä taudinaihheettajana tutkittiin Helsingin yliopiston kasvipatologian laitoksella vuosina 1973—1979. Erityishuomio tutkimuksissa kohdistettiin ohralajikeiden reagointiin sieneen ja sen toksiisiin aineenvaihduntatuotteisiin. Pyrkimyksenä oli myös etsiä luotettavia, infektointikokeita yksinkertaisempia menetelmiä ohralajikkeiden taudinkestävyyden toteamiseksi.

Astiakokeet tehtiin kasvihuoneessa tai kasvukausien aikana sateelta suojattua ulkotilassa. Kasvualustana oli peltoraulta, mikä oli sienen luontaisesti infektoimaa tai mihin sienikasvusto oli lisätty. Aineenvaihduntatuotteiden toksisuutta selvittävissä kokeissa sieni kasvatettiin Zapek-dox ravintoliuoksessa, mitä suodatettuna saaman ravintoliuoksen haimennettuna käytettiin ohran oraiden kasvatukseen erlemeyerpullossa tai oraiden kastelun hiekkakasvatuksissa.

*B. sorokiniana* aiheutti tyvi- ja juurilaikkuja sekä myös koko maananlaisen versonon ruskettumista ja kuivettumista kaikissa tutkituissa lajikkeissa. Ensimmäisinä oireina astia- ja kenttäkokeissa havaittiin tummanruskeat pitkulaisia lehtilaikkuja heti orastumisen jälkeen. Kasvun edistytyy sieni ei enää levinnyt ylemmäksi verssoon eikä infektoinut muodostuvaa jyvästää korreensäisesti kasvamalla, mutta tyvitauioireet vahvistuivat ja niihin liittyen verson kasvu sekä sadomuo-dostus jäävät heikoksi.

Lajike-erot olivat suuria ja ne säilyivät samansuuntaisina eri tavoin järjestetystä kokeissa. Sieni aiheutti makkaimmat tyvitauioireet lajikkeissa Teemu, Paavo ja Pomo sekä lievimmät lajikkeissa Aapo, Ingrid ja Tammi. Sienen aiheuttama satotappio vaihteli 3 %:sta (Tammi) 33 %:iiin (Teemu) ollen keskimäärin noin 15 %. Sieni aiheutti monitahoisissa lajikkeissa keskimäärin pahempaa viioitusta kuin kaksitahoisissa. Kyvösienenen peittaaminen ei suojannut nuorta orasta sienitartunnalta, mutta saattoi viivästytää sitä jossain määrin.

Sieniä molemmista toksiineista syntyvät toksiinit aiheuttivat suuret tyvi- ja lehtioireita, joissa eri lajikkeissa, joissakin lisäksi myös lehtioireita. Ohralajikkeiden reagointierot toksiineihin samoin kuin toksiini-isolaattien erot olivat samansuuntaisia, mitä infektiokokkein todettiin. Oravan toimivan reagoiminennon toksiineihin paljasti useimmiten lajikkeen tai linjan alttiuden myös sieni-infektioille.

Ohran tyvi- ja lehtilaikkusientä on pitettävä maasamme vakavana taudinaihheettajana. Sieni on oloissamme pääasiallisesti siemen- ja ilmalevintäinen, mutta sitä kertyy maahan tyvitauioheuttajaksi lisääntyvästi erityisesti ohran satojärjestelmissä Tätä kertymistä voidaan esittää helpoimmin käyttämällä viljelykierrota, peittaamalla kyvösienenen elohopeapitoisella tai sopivalla systemiselällä valmistella ja kulottamalla puidun ohrakasvuston sänkön ennen kyntöä.

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