The Ability of *Bipolaris Sorokiniana* Isolated from Spring Barley Leaves to Survive in Plant Residuals of Different Crops

1Yerlan Dutbayev, 1Aidana Kharipzhanova, 2Nadira Sultanova, 3Abdelfattah A. Dababat, 2Madina Bekezhanova and 3Alibek Uspanov

1Kazakh National Agrarian Research University, Kazakhstan  
2Kazakh Research Institute of Plant Protection and Quarantine, Kazakhstan  
3International Maize and Wheat Improvement Center (CIMMYT), Turkey

**Abstract:** Spring barley is an important high-value crop globally. However, it is highly susceptible to soil-borne diseases in Kazakhstan and the world. *Bipolaris sorokiniana* (Sacc.) Shoemaker is the most important soil-borne pathogen that causes root rot and spot blotch diseases in cereal crops. This study aimed to evaluate the ability of *B. sorokiniana* isolated from spring barley leaves to survive in plant residuals of different crops. The fungus was isolated from spring barley leaves from the Zholbarys agro farm of Kerbylak district of Almaty, southeastern Kazakhstan, in 2021. Laboratory experiments were conducted at Kazakh National Agrarian Research University. The study was conducted on 10th days of seedlings of cereal, legume, and oilseed crops. The obtained results showed that seedlings of spring barley, spring wheat, and oats retained the *B. sorokiniana* infection. Interestingly, the infection of *B. sorokiniana* isolated from leaves of spring barley statistically significantly increased symptoms of spot blotch on spring wheat and spring barley seedlings, while symptoms decreased on oats (P-value <0.01). The introduction of rapeseed, chickpeas, peas, and oats into the crop rotation system in southeastern Kazakhstan could limit the volume of the *B. sorokiniana* infection in spring wheat and spring barley. On rapeseed, peas, and chickpeas seedlings no symptoms of spot blotch were observed (P-value <0.01).

**Keywords:** Spot Blotch, Wheat, Rapeseed, Chickpea, Peas

**Introduction**

Barley (*Hordeum vulgare* L.) in Kazakhstan is cultivated on an area of 1.5 million hectares with gross production of 1.9 million tons with a yield of 1.3 tons/ha, which is almost three times less than the global average (Rsaliev et al., 2017). The soil fungus *Cochliobolus sativus* Drechsler ex Dastur. of the anamorph *Bipolaris sorokiniana* (Sacc.) Shoemaker causes root rot and leaf spot on wheat, barley, rye, triticale, and other cereals. The fungus *B. sorokiniana* has a wide geographical distribution area (Guest, 2017; McDonald et al., 2018; Özer et al., 2020). The low yield of barley in Kazakhstan is largely due to the susceptibility of the cultivated varieties to leaf spotting, while the yield and productivity of plants are significantly reduced by 30-40% (Cegielko et al., 2018, 2019; Haas et al., 2018; Pathak et al., 2020). Barley strips are covered with dark spots with a brown or dark gray coating. Photosynthesis is disrupted, the growth and development of plants slow down and they form fewer primary and secondary roots. Under favorable conditions, similar spots appear on the internodes, which leads to lodging. When the plant roots rot, the mycelium of *B. sorokiniana* causes its underdevelopment and produces toxins that worsen the quality of malting barley varieties (Göksel et al., 2020a; Haas et al., 2018).

Recent global research is dedicated to studying *B. sorokiniana* on barley. Such research has been focused on the influence of fungal infection on indicators such as tyramine, serotonin, and other amines (Ishihara et al., 2017); the influence of the ToxA gene on the virulence of the spot blotch pathogen on barley and wheat (McDonald et al., 2018); the influence of the fungus on the quality of barley grain (Cegielko et al., 2018); change in the structure of RNA in the barley varieties susceptible and resistant to *Helminthosporium* blotch (Haas et al., 2018);
mapping of a dominant gene resistance to the new pathotype fungus in barley (Wang et al., 2019); assessment of the biological effectiveness of the types of Trichoderma spp. against B. sorokiniana (Singh et al., 2018); determination of the location of the loci of resistance to the pathogen of Helminthosporium leaf spots caused by B. sorokiniana in the genome of barley (Novakazi et al., 2020).

In Kazakhstan, studies on soil pathogens have recently been conducted to assess the collection of synthetic wheat for disease resistance (Suleimanova et al., 2016; Kuresbek et al., 2017; Morgounov et al., 2018) and the compatibility of barley varieties with leaf spot pathogens on an artificial infectious background (Pathak et al., 2020). The International Maize and Wheat Improvement Center (CIMMYT) researchers have conducted 2 intensive surveys for soil-borne diseases of grain crops and found that B. sorokiniana was the most common pathogen (Göksel et al., 2020). Özer et al. (2020) studied the biological features of common root rot on triticale caused by B. sorokiniana and found that the fungus caused growth retardation and necrosis of internodes on the roots. Sultanova et al. (2021) found that the most common diseases of barley in the southeastern region of Kazakhstan were the common root rot and dark brown spotting (caused by Bipolaris sorokiniana Shoem.).

The best measures to combat leaf spotting on barley are the removal of plant residues, crop rotation, cultivation of resistant varieties, and pre-sowing treated seeds with chemicals (Suleimanova et al., 2016; Guest, 2017; Kuresbek et al., 2017; Morgounov et al., 2018). In our study, we have established that the fungus B. sorokiniana isolated from the leaves of spring barley can persist in the seeds of spring wheat, spring barley, and oats. In addition, it was found that the fungal infection significantly increased the infection rate of seedlings of spring wheat and spring barley with B. sorokiniana, whereas it was decreased in oats. Seedlings of rape seed, chickpeas, and peas are not populated by the pathogen. We assume that the introduction of rapeseed, chickpeas, peas, and oats into the crop rotation of south-eastern Kazakhstan can reduce the infestation of spring wheat and spring barley with helminthosporous spots.

Our study aims to evaluate the ability of B. sorokiniana isolated from spring barley leaves to survive in plant residues of various crops.

Materials and Methods

Selection of Barley Leaves

The affected leaves with symptoms of leaf spotting were collected in the fields of the Zholbarys agro farm of the Kerbulak district of the Almaty region (GPS coordinates: 44.376726, 78.573329). The sowing of spring barley of the Arna variety was carried out in the third decade of April 2021. Pure cultures of the pathogen of dark brown spotting of the leaves of spring barley (the B. sorokiniana fungus) were isolated in the laboratory of the Kazakh Research Institute of Plant Protection and Quarantine named after Zh. Zhiembayev LLP in 2021 (Fig. 1).

Isolation and Identification of the Pathogen

To obtain B. sorokiniana isolate, pieces of barley leaves with symptoms of leaf spotting were sterilized in 90% alcohol for 1 min, then immersed in a 1% solution of sodium hypochlorite for 3 min and washed three times with sterile water (Fig. 1). Next, the affected parts of barley leaves with a size of 1 cm² were placed in Petri dishes on a Czapek nutrient medium.

Fig. 1: Symptom and signs of spot blotch on barley leaves (Zholbarys agro farm of Kerbylak district of Almaty region, July 2021)

Note: A: Symptoms of barley leaf spotting, B: Conidia of Bipolaris sorokiniana Shoem.
Laboratory Experiment

The impact of *B. sorokiniana* isolate was determined at the Kazakh-Japanese Innovation Center of the Kazakh National Agrarian Research University (KazNAIU) in Almaty. Conidia of *B. sorokiniana* were collected by adding distilled water to five-day Potato Dextrose Agar (PDA) dishes and scraping off the surface of the agar with a spatula. The suspension with conidia was purified from mycelium fragments by filtering through two layers of gauze. The concentration of the inoculate was adjusted to 8000 conidia per 1 mL of distilled water using a hemocytometer. Five-day-old seedlings of spring barley, spring wheat, rapeseed, chickpeas, peas, and oats were inoculated with approximately 0.2 mL of conidial suspension each. Seedlings were evaluated by the second leaves of plants 5 days after inoculation (Parikh et al., 2018; Singh et al., 2021).

The fungal mycelium was thoroughly washed with sterile distilled water to remove the remnants of the culture filtrate from the mycelial mat and placed on filter paper to remove excess moisture. The mat was weighed and distilled water was added to it (1 g of mycelial mat/4 mL of water). The mycelium was whipped in a blender at a speed of 5000 rpm for 5 min. The unsettled filtrate was filtered out (pore size: 0.45 Microns), 1 mL was added to 4 mL of sterile distilled water and the resulting suspension was used for seed inoculation.

The seeds of spring barley, spring wheat, rapeseed, chickpeas, peas, and oats were sterilized with 92% alcohol for 1 min and washed twice with distilled water for 2 min. Then the seeds were dried on sterilized filter paper.

For inoculation, the seeds were immersed in a mushroom culture filtrate from the mycelial mat and placed on filter paper to remove excess moisture. The mat was weighed and distilled water was added to it (1 g of mycelial mat/4 mL of water). The mycelium was whipped in a blender at a speed of 5000 rpm for 5 min. The unsettled filtrate was filtered out (pore size: 0.45 Microns), 1 mL was added to 4 mL of sterile distilled water and the resulting suspension was used for seed inoculation.

<table>
<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>Spring barley</td>
<td>26.6</td>
<td>33.6</td>
<td>11.6</td>
<td>5.0</td>
<td>1.7</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Spring wheat</td>
<td>36.5</td>
<td>46.9</td>
<td>6.6</td>
<td>10.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Oats</td>
<td>53.5</td>
<td>18.3</td>
<td>6.6</td>
<td>0.0</td>
<td>0.0</td>
<td>21.6</td>
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</tr>
<tr>
<td>Rapeseed</td>
<td>43.2</td>
<td>0.0</td>
<td>3.3</td>
<td>0.0</td>
<td>22.0</td>
<td>0.0</td>
<td>29.9</td>
</tr>
<tr>
<td>Peas</td>
<td>64.7</td>
<td>0.0</td>
<td>13.3</td>
<td>22.0</td>
<td>0.0</td>
<td>0.0</td>
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</tr>
<tr>
<td>Chickpeas</td>
<td>10.4</td>
<td>0.0</td>
<td>10.0</td>
<td>0.0</td>
<td>0.0</td>
<td>79.6</td>
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</tr>
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</table>

The colonization of 5-day cereal, legume, and oilseed seedlings with fungal infection (Kazakh-Japanese innovation center, KazNAIU, 2021)

Results

The results of the analysis showed that 33.6-46.9% of 5th day seedlings of spring barley, spring wheat, and 18.6% of oat seedlings were infected with the fungus *B. sorokiniana*. The seedlings of rapeseed, peas, and chickpeas showed no signs of infection. On the 5th day, seedlings of crops were also populated with fungi from the genera *Fusarium*, *Aspergillus* spp., *Mucor*, as well as jointly affected by *Aspergillus*, and *Penicillium* spp. (Table 1, Fig. 2).
Table 2: Indicators of the ability of cereal, legume, and oilseed seeds to retain infection of *Bipolaris sorokiniana* (Kazakh-Japanese Innovation Center, KazNAIU. 2021)

<table>
<thead>
<tr>
<th>Seedlings</th>
<th>Inoculation with <em>B. sorokiniana</em></th>
<th>Healthy</th>
<th><em>B. sorokiniana</em></th>
<th>Another fungal infection</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Inoculated</td>
<td>34.00</td>
<td>40</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Non-inoculated</td>
<td>34.00</td>
<td>39</td>
<td></td>
</tr>
<tr>
<td>Spring barley</td>
<td>Inoculated</td>
<td>36.00</td>
<td>19</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Non-inoculated</td>
<td>44.00</td>
<td>18</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Inoculated</td>
<td>53.00</td>
<td>29</td>
<td></td>
</tr>
<tr>
<td>Oats</td>
<td>Non-inoculated</td>
<td>49.00</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Inoculated</td>
<td>47.00</td>
<td>51</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Non-inoculated</td>
<td>45.00</td>
<td>52</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Inoculated</td>
<td>64.00</td>
<td>36</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Non-inoculated</td>
<td>61.00</td>
<td>39</td>
<td></td>
</tr>
<tr>
<td>Rapeseed</td>
<td>Inoculated</td>
<td>11.00</td>
<td>89</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Non-inoculated</td>
<td>13.00</td>
<td>87</td>
<td></td>
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<tr>
<td></td>
<td>Inoculation factor</td>
<td>2.60</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Peas</td>
<td>Inoculated</td>
<td>100.00</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Non-inoculated</td>
<td>45.00</td>
<td>25</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Inoculated</td>
<td>100.00</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Non-inoculated</td>
<td>48.00</td>
<td>14</td>
<td></td>
</tr>
<tr>
<td>Spring wheat</td>
<td>Inoculated</td>
<td>18.00</td>
<td>55</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Non-inoculated</td>
<td>51.00</td>
<td>45</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Inoculated</td>
<td>16.00</td>
<td>64</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Non-inoculated</td>
<td>0.00</td>
<td>83</td>
<td></td>
</tr>
<tr>
<td>Oats</td>
<td>Inoculated</td>
<td>0.00</td>
<td>45</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Non-inoculated</td>
<td>0.00</td>
<td>40</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Inoculated</td>
<td>0.00</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Non-inoculated</td>
<td>0.00</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Inoculation factor</td>
<td>&lt;0.01</td>
<td></td>
<td></td>
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</tbody>
</table>

Fig. 2: Seedlings of crops on the 5th day after sowing on PDA (KazNAIU. 2021)
5th day seedlings of spring barley, spring wheat, rapeseed, chickpeas, peas and oats inoculated with a suspension of the *B. sorokiniana* conidia. A rank scale was used for the analysis. The results of the analysis showed that the average values in the groups for the inoculation factor were equal (Table 2, P-value = 2.6). However, the process of inoculation of seedlings was carried out in a random order.

After 10th days according to the inoculation factor, the P-value at a 99% confidence interval was small, <0.01. This means that the average values in the groups were unequal and we can correctly speak about the significant impact of *B. sorokiniana* infection on the seedlings (Table 2). The results showed that the seedlings of spring wheat and spring barley infected with the pathogen had an increased level of *B. sorokiniana* infection (100%) compared to the non-infectious background (45-48%). In oat seedlings, there were no significant differences in the fungal population of seedlings between inoculation backgrounds (49-53%). In rapeseed, 16% of the surface of inoculated seedlings was infected with the fungus *B. sorokiniana*, while non-inoculated seedlings showed no symptoms of the disease. Peas and chickpeas were not affected by infection (Table 2). Another fungal infection affected oats (45-55%), rapeseed (64-83%), chickpeas (100%), and peas (40-45%).

Thus, we assume that the introduction of rapeseed, chickpea, pea, and oat seeds into crop rotation limits the infectious load of the fungus *B. sorokiniana* in spring wheat and spring barley crops in the conditions of the Almaty region (Table 2, Fig. 3).

![Fig. 3: Seedlings of grain crops on the 10th day after inoculation with a suspension of *Bipolaris sorokiniana*](image-url)
Discussion

*Bipolaris sorokiniana* is the pathogen responsible for spot blotch disease in cereals. The disease could be carried out by seeds, roots, or air (Matorin et al., 2018; Pathak et al., 2020; Al-Sadi, 2021). Plowing, removing weeds and cereals, and introducing plants that are not affected by root rot into crop rotation reduces the amount of *Bipolaris sorokiniana* inoculum in the soil (Duveiller and Dubin, 2002).

Recent studies on *B. sorokiniana* in cereals have been focused on developing control of common root rot as a phytosanitary previous crop (Campanella et al., 2020), pesticide research (Wei et al., 2021), actinobacterial activity (Campanella et al., 2020), antagonistic activity of *Bacillus* sp. (Harba et al., 2020) and source of non-fungi toxic wheat-protecting metabolites that induces resistance to tomato wilt (Shcherbakova et al., 2018). The use of *Brassica carinata* as a previous crop of durum wheat as green manure can reduce the number of *B. sorokiniana*, *Fusarium* spp. conidia and common root rot incidence by 49%, and the weight of grain by 48% compared to wheat monoculture (Campanella et al., 2020).

*Bacillus* spp. has antagonistic activity against the virulent *B. sorokiniana* (isolate CRR16) by 59-92% (Harba et al., 2020). According to Allali et al. (2019), the actinobacteria strain LB12 strain has biological activity in vivo against the *Bipolaris sorokiniana* in durum wheat seedlings cv. Vitron. This strain can produce indole-3-acetic acid, siderophores, and hydrogen cyanide by seedlings, which showed chitinolytic activity and solubilized inorganic phosphates, which are useful for stimulating growth and biocontrol of plant activity. In addition, the treatment of wheat seeds with spores of the MB22 strain led to an increase in the dry weight, length of roots, and shoots of seedlings and reduced the damage index of common root rot.

According to Wei et al. (2021), the combined application of two fungicides significantly can inhibit the growth of fungal mycelium *B. sorokiniana*-the half of the maximum effective concentration of the mixture contains the active ingredients fluoxadiazol and difenoconazole in a ratio of 1:4. Shcherbakova et al. (2018) showed that *F. sambucinum* strain FS-94 induces resistance to tomato wilt and has been shown as a source of non-fungi toxic wheat-protecting metabolites, which were contained in a mycelium extract. Pre-inoculation treatments of seeds with PME significantly decreased the incidence (from 30 to 40%) and severity (from 37 to 50%) of root rot on seedlings without any inhibition of the seed germination and Potentiation of Deoxynivalenol (DON), DON monoacetylated derivatives and zearalenon production in FCR agents.

According to Duveiller and Dubin (2002), long-term use of rapeseed has some fungitoxic effects on *helminthosporium* leaf spot in wheat, which is the causative agent. At the same time, wheat and barley must not be rotated in the same fields infected with common root rot. In this current study, it was found that seedlings of spring barley, spring wheat, and oats can retain infection with the fungus *B. sorokiniana*. Infection with *B. sorokiniana* statistically significantly increased the manifestations of spotting on seedlings of spring wheat and spring barley and decreased on oats.

Sultanova et al. (2021) found that the most common diseases of barley in the southeastern region of Kazakhstan were common root rot and leaf spot caused by *B. sorokiniana* and *Drechslera graminea*. In this region, *B. sorokiniana* develops mainly in the conidial stage, whereas the fungus forms the ascigorous stage of *Cochliobolus sativus* (Ito et Kurib.) Drechsler ex Dastur., which is almost lost in the pathogen development cycle. On the primary and secondary roots, as well as on the underground internodes, dark brown elongated ulcers are formed, which often merge and at the end the affected tissue becomes black. The disease can manifest itself as browning, yellowing, and mildew in young leaves (Rysbekova and Sultanova, 2022).

Saad et al. (2021) evaluated the ability of *F. pseudograminearum*, *F. culmorum*, *F. graminearum*, and *B. sorokiniana* to cause root rot in winter cereals. It was found that barley and soft wheat plants had the highest rates of disease development on leaf sheaths and root internodes (64.7-99.6%), while these indexes were low on oats (5%).

The fungus *B. sorokiniana* causes symptoms of common root rot and leaf spotting on cereals (Guest, 2017; McDonald et al., 2018; Özer et al., 2020). Infection with *B. sorokiniana* statistically significantly increased the manifestations of spotting on seedlings of spring wheat and spring barley, while it decreased them on oats. We assumed that the introduction of rapeseed, chickpeas, peas, and oats into the crop rotation of southeastern Kazakhstan may limit the volume of *B. sorokiniana* infection in spring wheat and spring barley. There were no signs of spotting on the seedlings of rapeseed, peas, and chickpeas.

Conclusion

In this study, we have evaluated the ability of *B. sorokiniana* isolated from spring barley leaves to survive in plant residues of various crops. It has been concluded that the seeds of spring barley, spring wheat, and oats can retain the infection caused by *B. sorokiniana*. The introduction of rapeseed, chickpeas, peas, and oats into the crop rotation system in southeastern Kazakhstan could limit the volume of the *Bipolaris sorokiniana* infection in spring wheat and spring barley. On rapeseed, peas, and chickpeas seedlings no symptoms of spot blotch were observed.

We plan to devote our future studies to the molecular genetic identification of pathogens of root rot in cereal crops and determine their pathogenicity in other soil and climatic zones of Kazakhstan.
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Author’s Contributions
All authors equally contributed to this study.

Ethics
This article is original and contains unpublished material. The corresponding author confirms that all of the other authors have read and approved the manuscript and that no ethical issues are involved.

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286