OnLine Journal of Biological Sciences

Original Research Paper

The Harmfulness of Common Root Rot in Winter Wheat Varieties in Kazakhstan

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Article history
Received: 02-10-2022
Revised: 10-12-2022
Accepted: 10-01-2023

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Abstract: One of the main drawbacks of winter wheat varieties cultivated in Kazakhstan is their lack of resistance to common root rot. In 2020-2022, samples affected by root rot were taken in the earing phase in stationary experiments of the department of field crops and plant protection of the Kazakh research institute of agriculture and plant growing in the Almaty region. The research aimed to study the harmfulness of common root rot in commercial varieties of winter wheat. The weather did not significantly affect the harmfulness of common root rot. The harmfulness of the disease depended on the variety and degree of disease infestation. These indicators correlated with indicators of plant height, spike length, number of spikelets, and number and weight of grains ($p<0.05$). All varieties were affected by the disease to a low and moderate degree. In the varieties Almaly and Steklovidnaya 24, yield losses from the disease were 6.4-6.8%; in Farabi, Azharly, and Zhetysu 8.8-9.4%; and in Naz 13.0%. A total of 32-41% of plants were affected by the disease to a low degree and 10-21% to moderate and severe degrees. With a low degree of infestation, yield decreased by 2.4-7.1%, and with moderate and severe degrees by 4.5-12.1%. Factors of the degree of plant infestation and variety correlated ($p<0.05$) with dependent variables of productive business, stem length, spike length, number of spikelets, and weight of 1,000 grains. Using the method of linear regression, the authors concluded that the winter wheat spikelet number variable was significantly influenced by the variables of stem number (medium correlation) and spikelet length (strong correlation).

Keywords: Common Root Rot, Winter Wheat, Harmfulness, Variety, Harvest Decline

Introduction

In developed countries such as the US, EU, and Canada, winter wheat is cultivated with an average yield of 28 centner/ha (FAO, 2018). One of the main disadvantages of cultivated winter wheat varieties is their lack of resistance to common root rot (Agrios, 2005; Özer *et al*., 2020a; Wei *et al*., 2021), the main causative agent of which is the fungus *Bipolaris sorokiniana* Syn. *Helminthosporium sativum* teleomorph *Cochliobolus sativus* (Bozoğlu *et al*., 2022). The best measures to control common root rot in cereal crops (wheat, barley, rye, oats, perennial grasses, awnless bromegrass, meadow timothy, bristlegrass, sow thistle, common sow thistle) is the use of resistant varieties, organic and mineral fertilizers and phytosanitary precursors in crop rotations, as well as seed pretreatment with chemical and biological preparations (Yue *et al*., 2018; Allali *et al.*, 2019; Al-Sadi, 2021).

The low yield of wheat in Kazakhstan is largely due to the susceptibility of its cultivated varieties to common root rot; crop yields are sometimes reduced by 35-45% (Koishibayev, 2018).

The disease causes a reduction of productive business, thinning of herbage, reduction of the graininess of the ear, and grain weight, quality, and yield (Agrios, 2005). Recent research on common root rot in wheat has focused on the synergistic activity of fungicides used against common root rot in wheat (Wei *et al*., 2021), the ability of *B. sorokiniana* to cause root rot, black germination and leaf spotting (Al-Sadi, 2021), the use of fungi *Chaetomium spp*. as biological defense agents (Yue *et al*., 2018), actinobacteria (Allali *et al*., 2019) and finding donors of genetic resistance against *B. sorokiniana* (Özer *et al*., 2020b; Cui *et al*., 2021; Su *et al*., 2021).

In Kazakhstan, recent CIMMYT (International Maize and Wheat Improvement Center) studies established that the main soil pathogen in grain crops is *B. sorokiniana* (Özer *et al*., 2020a; Alkan *et al*., 2022). They considered the pathogenicity of common root rot in triticale caused by *B. sorokiniana* and found that it causes a reduction of productive business, crop thinning, reduction of earliness and grain weight, and a decrease in grain quality (Özer *et al*., 2020b). Studies evaluated the ability of *B. sorokiniana* isolated from spring barley leaves to survive in plant residuals of different crops (Dutbayev *et al*., 2022). However, there is not enough information about the severity of common root rot and the impact of the degree of disease damage on plant productivity in Kazakhstan.

The purpose of the study is to describe the severity of common root rot and evaluate its harmfulness in commercial varieties of winter wheat in the Almaty region.

Materials and Methods

In the structure of crops in southern and southeastern Kazakhstan, winter wheat is cultivated under irrigation and well-drained land on an area of 1, 000-1, 200 thousand ha with an average yield of 19 centner/ha. Therefore, it was important to conduct a study to reduce the level of harmfulness of common root rot in winter wheat (*Triticum aestivum*).

In 2020-2022, we used samples of winter wheat affected by root rot in the earing phase in the stationary experiments at the department of the gene pool of field crops and plant protection of the Kazakh research institute of agriculture and plant growing in the Almaty region (coordinates 43.237589, 76.692629). To determine the harmfulness of the disease in full ripeness, we analyzed grains from 50 plants with varying degrees of damage by root rot (healthy, slightly affected, moderately affected and severely affected). The degree of damage was determined visually according to the developed four-point scale (Fig. 1). We considered the number of stems, plant height, ear length, number of spikelets, grain weight from 50 plants, and the weight of 1,000 seeds (two samples of 500 seeds each) (Kuresbek *et al*., 2017; Sultanova *et al*., 2021).

Fig. 1: Winter wheat plants affected by common root rot (Kazakh research institute of agriculture and plant growing, Almalybak village, 2022); Note: Winter wheat plants affected by common root rot 0-healthy; 1 slightly affected, 2 moderately affected, 3 severely affected

The data were entered into the excel program and then uploaded to R-studio. Statistical data processing was performed using the R-Studio program according to the nonparametric Mann-Whitney test. The significance of the calculations was assessed using the P-value (Aphalo, 2017; Temreshev *et al*., 2022).

The prevalence of common root rot (P) is calculated using the formula:

$$P = n \times 100 \div N \quad (1)$$

where:
n = The total number of plants in the samples
N = The number of diseased plants

The development of root rot is calculated by the formula:

$$R = ab \times 100 \div AK \quad (2)$$

where:
a = The number of plants with the same lesion
b = The corresponding lesion score
A = The number of plants in the account
K = The highest lesion score (Morgounov *et al*., 2018; Sultanova *et al*., 2021)

The harmfulness of common root rot was calculated as the percentage of yield reduction in diseased plants compared to healthy ones using the formula:

$$B = (ab) \times 100 \div a \quad (3)$$

where:

B = The harmfulness of the disease or the decrease in yield (%)
a = The yield of healthy plants
b = The yield of diseased plants (Morgounov *et al*., 2018; Sultanova *et al*., 2021)

Results

In the field conditions, we evaluated the harmful effect of the intensity of winter wheat common root rot infestation in six commercial varieties. In crop rotations, spring barley is usually placed in the 3rd or 4th location after wheat or after fallow. Trials were conducted in 2020-2022. There was no significant effect of climatic conditions on the harmfulness of common root rot in this crop. It was statistically significantly related to the variety and the degree of disease damage; these indicators correlated with the indicators of plant height, ear length, the number of spikelets, and the number and weight of grains ($p<0.05$) (Figs. 2-3).

All varieties were affected by the disease in low and moderate degrees. In the varieties Almaly and Steklovidnaya 24, yield losses from the disease were 6.4-6.8%; in Farabi, Azharly, and Zhetysu 8.8-9.4%; in Naz 13.0%. The severity of common root rot in winter wheat was influenced by the degree of damage to plants and the percentage of diseased plants. 42-53% of plants were healthy, 32-41% were affected by root rot to a low degree, and 10-21%-to moderate and severe degrees.

The productive business was 1.3 in healthy plants, 1.2 in slightly affected plants, and 1.1 in moderately and severely affected plants. In terms of stem length (119-130; 119-127; 96-103 cm), ear length (14.6-15.6; 14.3-15.3; 7.7-8.6), and the number of spikelets (15.2-16.2; 14.4-15.2; 7.9-8.8, respectively). Ultimately, considering the number of plants affected by the disease, the weight of 1,000 grains decreased by 0.2-0.6% in slightly affected root rot, by 1.3-3.0% in moderately and severely affected plants; yield losses increased by 1.7-4.8 and 4.1-11.0%, respectively (Table 1).

The method of constructing a linear regression model revealed that the variable number of spikelets of spring wheat was statistically significantly influenced by the variables of the number of stems (medium correlation), spike length (strong correlation), and spike length (strong correlation) (Table 2).

Table 1: Influence of the variety and the degree of damage to winter wheat by common root rot on biometric indicators of plant productivity (Kazakh research institute of agriculture and plant growing, Almalybak village, 2020-2022)

							Weight of grain, grams		Decline, %	
Variety	Degree of Infestation root rot	Bushiness, pieces	Percentage of affected plant	Stem length, cm	Spike length, cm	Number of spikelets, pcs	1,000 grains	Weight of grains from 50 plants	Weight of 1,000 grains	Weight of grain from 50 plants
Almaly	Healthy	1.3	53.0	119.0	15.0	15.5	38.3	65.4	-	-
	Slightly affected	1.2	35.0	119.3	15.1	15.1	36.6	60.5	0.6	1.7
	Moderately and severely affected	1.1	12.0	96.5	8.4	8.8	25.4	25.9	1.6	4.7
Steklovidnaya 24	Healthy	1.3	55.0	127.8	15.6	16.1	37.4	77.8	-	-
	Slightly affected	1.2	35.0	123.4	15.3	14.4	36.3	71.2	0.6	2.3
	Moderately and severely affected	1.1	8.0	99.4	8.0	9.5	21.5	21.5	1.3	4.5
Farabi	Healthy	1.3	49.0	122.1	14.6	16.1	37.4	67.8	-	-
	Slightly affected	1.2	41.0	123.4	14.3	14.0	36.3	56.2	0.4	4.8
	Moderately and severely affected	1.1	10.0	97.7	7.9	9.5	22.5	26.5	1.5	4.1
Azharly	Healthy	1.3	51.0	130.9	15.7	16.2	38.4	76.5	-	-
	Slightly affected	1.2	35.0	127.3	15.1	16.0	37.9	68.6	0.2	2.8
	Moderately and severely affected	1.1	14.0	103.7	8.2	7.9	28.5	29.6	2.1	6.6
Naz	Healthy	1.3	47.0	121.0	15.3	15.5	37.8	76.5	-	-
	Slightly affected	1.2	32.0	120.4	14.8	15.8	36.4	69.4	0.4	2.3
	Moderately and Severely affected	1.1	21.0	101.5	8.6	8.1	23.6	24.2	3.0	11.0
Zhetisu	Healthy	1.3	42.0	118.9	15.4	15.2	39.4	79.5	-	-
	Slightly affected	1.2	42.0	119.5	15.1	14.8	38.5	75.7	0.4	1.6
	Moderately and severely affected	1.1	16.0	98.6	7.7	9.1	26.5	34.3	2.1	7.2
P-value	Variety		<0.05	<0.05	<0.05	<0.05	<0.05	<0.05		
	Degree of infestation with root rot	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05			

DOI: 10.3844/ojbsci.2023.187.192

Table 2: Linear regression model of the influence of significant variables on the number of spikelets in winter wheat plants (Almaty region, 2020-2022)

Response	Significant variables, P-value		
Number of spikelets	Number of stems	Stem length	Spike length
	0.001**	<0.001***	<0.001***

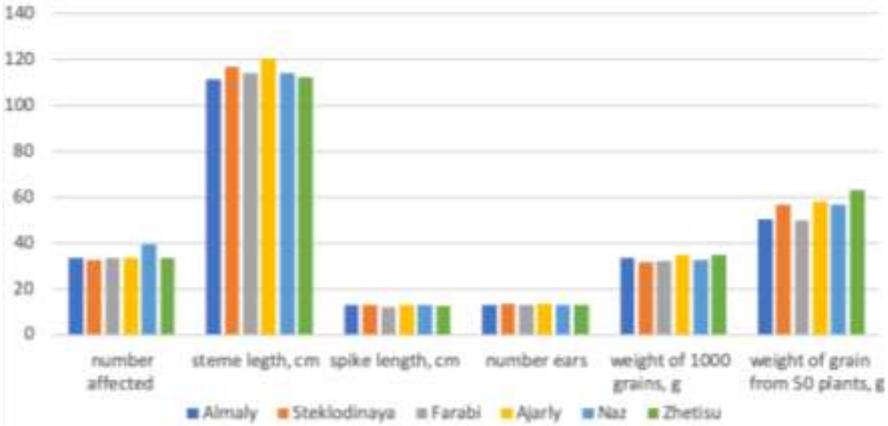

Fig. 2: Influence of the variety of winter wheat affected by common root rot on biometric indicators of plant productivity (Kazakh research institute of agriculture and plant growing, Almalybak village, 2020-2022)

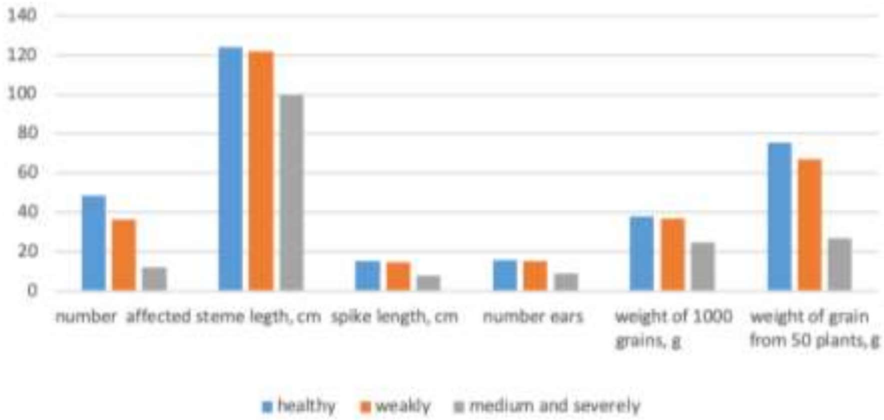

Fig. 3: Influence of the degree of damage of winter wheat affected by common root rot on biometric indicators of plant productivity (Kazakh research institute of agriculture and plant growing, Almalybak village, 2020-2022)

Discussion

In the southeastern region of Kazakhstan, the main causative agent of common root rot and leaf spotting is *Cochliobolus sativus Drechsler ex Dastur*. of the anamorph *B. sorokiniana (Sacc.)* (Sultanova *et al*., 2021). It develops predominantly in the conidial stage. Sometimes the fungus forms the marsupial stage of *Cochliobolus sativus (Ito et Kurib.) Drechsler ex Dastur*. Dark brown oblong ulcers are formed on primary and secondary roots, as well as on underground internodes, which often merge and the affected tissue turns black at the end. The disease may manifest itself in young leaves turning brown and yellowing and powdery mildew (Rysbekova and Sultanova, 2022).

The fungus *B. sorokiniana* is capable of encoding a large number of uncharacterized putative effective proteins, such as CsSp1, which is an effector of fungal virulence and is involved in triggering host immunity to the disease (Zhang *et al*., 2022). Physiological (relative water content, membrane stability index, and chlorophyll content) and non-enzymatic metabolites (soluble sugar, protein, soluble phenol, and flavonoid content) parameters of cereal plants inoculated with *B. sorokiniana* are changed (Satti *et al*., 2021; Holz *et al*., 2022). Leaf sheaths and subroot internodes of barley and winter wheat seedlings can be affected by root rot by 64.7-99.6% (Saad *et al*., 2021). According to our data, 42-53% of winter wheat plants were healthy, 32-41% were slightly affected by common root rot disease and 10-21% were moderate to severely affected.

Wu *et al*. (2021), who conducted studies from 1992-2017 in Australia, the US, and Mexico, 10.2% of *B. sorokiniana* isolates contain the ToxA gene, which interacts with the Tsn1 gene in wheat to result in a susceptible plant response to the disease. We recommend using these results in breeding for resistance to leaf spots and common root rot. According to our data, in the varieties almaly and steklovidnaya 24, yield losses from the disease were 6.4-6.8%; in Farabi, azharly, and zhetysu -8.8-9.4%; in Naz -13.0%.

To assess yield loss and avoidable yield loss caused by *B. sorokiniana*, we developed a linear regression model in case of avoidable yield loss and 1,000 grain weight, 40.99-44.12 and 17.06-20.50% 1,000 grain weight could be avoided due to every 1% decrease in area under disease progress curve (Devi *et al*., 2018). According to our data, the variable number of spikelets in winter wheat is influenced by the variables of stem number (medium correlation) and spike length (strong correlation).

Conclusion

The purpose of the study was to determine the harmfulness of common root rot in commercial varieties of winter wheat in the Almaty region. There was no significant effect of climatic conditions on the harmfulness of common root rot in the crop. The harmfulness of the disease depended on the variety and the degree of the disease, which correlated with indicators of plant height, ear length, the number of spikelets, and the number and weight of grains (p-value <0.05).

All varieties were exposed to the disease to low and moderate degrees. In the varieties Almaly and Steklovidnaya 24, yield losses from the disease were 6.4-6.8%; in Farabi, Azharly, and Zhetysu 8.8-9.4%; in Naz 13.0%. 32-41% were slightly affected by common root rot disease and 10-21% were moderate to severely affected. With a low degree of the infestation, the harvest of the variety decreased by 2.4-7.1% and with moderate and severe degrees, it decreased by 4.5-12.1%. Factors of the degree of plant infestation and crop varieties correlated (p<0.05 value) with the dependent variables of productive business, stem length, ear length, number of spikelets, and weight of 1,000 grains.

Using the technique of linear regression, we found that the variable number of spikelets in winter wheat is significantly influenced by the variables of stem number (medium correlation) and spike length (strong correlation).

Acknowledgment

The authors thank the reviewers for their contribution to the peer evaluation of this study.

Funding Information

The authors have not received any financial support or funding to report.

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 no ethical issues are involved.

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