The influence of root rot (*Bipolaris sorokiniana*) on the productivity of durum wheat in the soil and climatic conditions of the Southern Urals

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Abstract. The detection of factors that affect the decrease in the productivity of durum wheat is the basis for the study of plant diseases in the soil and climatic conditions of the southern chernozems of the Cis-Ural region. On the basis of this premise, for the first time, studies on common root rot (*Bipolaris sorokiniana*) of durum wheat are conducted in field and laboratory conditions. There is the method of field experience, stationary accounting of agrometeorological conditions and disease determination is used. The results of six years research show that in the third variant of the experiment, the least spread and development of root rot is observed on a non-windy background of nutrition up to 28.6 and 10.2%. The dependence on the influence of air temperature is 94.4 and 70.0%. The highest crop yield of durum wheat was obtained in the average dry year of 2017 according to the green-manured fallow predecessor. It consists of 21.4 c on fertilized and 21.1 c per 1 ha on non-winded backgrounds of mineral nutrition. The maximum effect of root rot development on the decrease in durum wheat productivity is noted in the fourth version of the experiment and it consists of 80.04 and 89.66% on two nutrition backgrounds. The study results have a scientific and practical importance in the field of phytopathology, farming and intensive agriculture.

1. Introduction

*Bipolaris sorokiniana* is a destructive pathogen that causes diseases of both leaves and roots. Leaf diseases have the greatest impact on wheat crop yield [1]. These diseases are the main biotic obstacle to wheat production in the Eastern Gangetic Plains. It covers the main growing regions in India, Bangladesh, and Nepal [2-4]. Studies have been conducted on the geographical distribution of common wheat root rot in areas of Queensland, Australia. Soil populations of the causative agent of the *Bipolaris sorokiniana* disease were found in the studied territories, where the total rot was assessed. Common root rot has been identified in all areas and it is most severe in the Southwestern, Western, and Northern Darling Hills, and the least severe in the Central Highlands [5]. Losses of the wheat crop from these diseases can reach 50% in conditions that contribute to the infection of crops [6]. Significant losses of wheat crop yield were recorded in the warmer and wetter climate of South America [7].

Wheat root rot causes significant crop yield losses in South Asian countries and it is considered a serious prerequisite for deciduous diseases in warmer growing areas [8]. Leaf spotting caused by *Cochliobolus sativus* (anamorph: *Bipolaris sorokiniana*) is an economically important wheat disease.
worldwide. In a severe epidemic, the disease can lead to crop loss of up to 70% [9, 10].

Protection of crops from root rot is currently an urgent task of modern farming in the Russian Federation. In this regard, the purpose of the scientific work is to identify the influence of weather factors, precursors and nutrition backgrounds on the infestation of durum wheat crops with root rot and its relationship with crop yield. Based on this, research is being conducted to study the disease of durum wheat depending on soil and climatic conditions, the precursors of crop rotations, monocrop and mineral fertilizers in the steppe zone of the Southern Urals.

2. Materials and methods
The research was conducted from 2015 to 2020 at the stationary experimental site for crop rotations and monocrops of the Federal Scientific Center for Biological Systems and Agrotechnologies of the Russian Academy of Sciences, founded in 1988 on the territory of the Orenburg Cis-Ural region.

The soil of the experimental field is southern carbonate chernozem and in the 0-30 cm layer it contains: humus - 3.8%, hygroscopic moisture - 3.4%, total nitrogen - 0.26%, total phosphorus - 0.19%, nitrates - 12.3 mg, mobile phosphorus - 2.0 mg and exchangeable potassium - 35.0 mg per 100 g, pH of the soil solution - 8.2. The sum of the absorbed bases is 31.6 mg / eq. per 100 g of dry soil. The content of exchangeable sodium in the arable soil layer is 0.2 mg and hydrolytic acidity is 2.0 mg / eq. per 100 g. The bulk mass of the soil in the 0-30 cm layer is 1.22 g per 1 cm³.

In the experiment, the zoned variety of Orenburg 21 durum wheat was sown in the first decade of May with a norm of 4.0 million pieces of germinating seeds per 1 ha. The cultivation of durum wheat (*Triticum dūrum*) was carried out in grain – pair crop rotations: (weedfree fallow, soil – protective fallow, green-manure fallow) – durum wheat – soft wheat – millet-soft wheat-barley. The experiment scheme includes four variants of sowing durum wheat according to its predecessors in four-fold frequency: I. Sowing durum wheat after weedfree coulisse fallow (control); II. Sowing of hard wheat after soil – protective fallow; III. Sowing of durum wheat after the green-manured fallow; IV. Monocrop of durum wheat.

The experiment uses the field method of research according to the method of B. A. Dospekhov. The studies were carried out on fertilized and non-fertilized food backgrounds. Mineral fertilizers at a dose of Na₂P₂O₅K₂O kg of active substance per 1 ha were applied across one part of the plots for steam and non-steam precursors. The second part of the plots was studied without fertilizers. The plot size of the fertilized food background of the first order is 14.4 x 30 m, the second non-fertilized is 7.2 x 30 m, therefore it is 14.4 x 60 and 7.2 x 60 m. The total area of the studied plots in crop rotations is 20736 m², in monocrop it consists 2592 m².

During the growing season of the crop, a rain gauge (gage) and a meteorological field thermometer were installed on the plots of the experiment, so the amount of precipitation and the average monthly daily temperatures were taken into account. The infection level costing of durum wheat by root rot was recorded before harvesting. In the crops of the plots on both feeding grounds, 10 samples were taken, 20 plants were uprooted from each meter site. In laboratory conditions, they were analyzed and affected level of the lower internode of wheat was determined in points on the scale of G. M. Razvyatkina. In the experimental plots, the crop yield of durum wheat was taken into account in the second half of August on two feed backgrounds with a Sampo-500 combine.

Processing and analysis of data on durum wheat grain crop yield, weather factors (precipitation, temperature, dry weather), and the extent of root rot spread and development in crops was performed using the multiple regression method in the statistical program "Statistica 12.0" ("Stat Soft Inc.", Tusla, Oklahoma, USA).

3. Results and discussions
As a result of the study for 2015-2020, a certain amount of precipitation is observed and amounts to 107 mm, which is 69% less than the average annual norm (155 mm). The average monthly air temperature is 1.2°C (20.3°C) higher than the standard indicator (19.1°C) and the number of dry days is 68 with a
norm of 56. During the study period, the hydro-thermal coefficient is 0.47 units, which characterizes the strongest dry conditions.

The prevailing unfavorable agrometeorological conditions in the growing season of durum wheat led to a positive influence of weather factors (precipitation, temperature, dry weather) on the spread and development of root rot in crop rotations and monocrop. The causative agent of common root rot is a fungus from Bipolaris sorokiniana.

In durum wheat crops, the greatest spread and development of root rot is observed according to the first and fourth variants of the experiment in the acutely arid years of 2016, 2018 and 2020. The maximum infestation of the plant is observed in the marked years and ranges from 45.3 to 48.5% for the precursor of the weedfree coulisse fallow and from 41.2 to 45.5% for durum wheat (without change) on a fertilized background of nutrition, respectively, 44.2 – 46.3% and 38.2 – 42.7% on a non-fertilized one (table). The development of durum wheat disease after these precursors ranges consists from 19.4 to 20.7% for both food backgrounds.

**Table.** Influence of the degree of root rot spread and development on the crop yield of durum wheat.

| Variant | Predecessor | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | Average coefficient | Significance level | Influence of the factor, % |
|---------|-------------|------|------|------|------|------|------|---------------------|-------------------|--------------------------|
| I       | Weedfree coulisse fallow (control) | 38.6a | 47.4a | 27.8a | 48.5a | 36.4a | 45.3a | 40.6b | 12.00 | 0.02 | 77.06* |
|         |             | 35.3  | 46.3  | 25.5  | 45.3  | 28.7  | 44.2  | 37.5  | 13.65 | 0.02 | 77.33 |
|         |             | 18.2  | 21.2  | 12.7  | 22.3  | 18.3  | 20.2  | 18.8a | 4.76  | 0.04 | 66.62f |
|         |             | 17.1  | 20.8  | 10.4  | 20.4  | 16.5  | 19.4  | 17.4  | 5.75  | 0.02 | 75.57 |
|         |             | 6.4   | 4.8   | 20.1  | 4.6   | 10.3  | 8.6   | 9.1a  | -1.61 | 0.00 | 88.43f |
|         |             | 5.6   | 1.9   | 19.2  | 3.3   | 9.5   | 7.5   | 7.8   | -1.54 | 0.00 | 91.85 |
| II      | Soil – protective fallow | 26.2  | 38.3  | 22.5  | 38.2  | 30.4  | 37.3  | 32.1b | 11.02 | 0.01 | 83.20f |
|         |             | 25.3  | 37.4  | 20.6  | 37.6  | 28.6  | 35.2  | 30.8  | 10.85 | 0.00 | 86.11 |
|         |             | 11.0  | 19.3  | 9.8   | 19.6  | 13.7  | 16.1  | 14.9c | 5.97  | 0.03 | 70.84f |
|         |             | 9.5   | 17.6  | 8.7   | 17.3  | 11.8  | 15.0  | 13.3  | 5.84  | 0.02 | 77.10 |
|         |             | 2.5   | 6.5   | 20.1  | 4.8   | 2.8   | 9.0   | 7.6d  | -1.43 | 0.06 | 61.30f |
|         |             | 2.0   | 2.8   | 17.4  | 4.7   | 2.6   | 8.4   | 6.3   | -1.38 | 0.03 | 70.26 |
| III     | Greenmanured fallow | 27.2  | 37.2  | 18.6  | 33.2  | 26.0  | 36.0  | 29.7b | 11.76 | 0.00 | 93.61f |
|         |             | 24.4  | 35.3  | 16.4  | 30.4  | 25.4  | 39.5  | 28.6  | 13.81 | 0.00 | 94.45 |
|         |             | 12.5  | 14.0  | 5.3   | 15.7  | 9.8   | 13.8  | 11.8c | 4.97  | 0.07 | 59.35f |
|         |             | 10.6  | 13.2  | 2.1   | 13.7  | 8.6   | 13.0  | 10.2  | 6.33  | 0.03 | 70.04 |
|         |             | 2.6   | 5.1   | 21.4  | 5.0   | 4.8   | 8.6   | 7.9d  | -0.63 | 0.43 | 16.01f |
|         |             | 2.4   | 2.1   | 21.1  | 3.9   | 4.1   | 8.0   | 6.9   | -0.62 | 0.41 | 16.85 |
| IV      | Durum wheat | 37.7  | 41.2  | 28.7  | 43.7  | 32.2  | 45.5  | 38.2a | 9.42  | 0.04 | 69.01c |
|         |             | 36.2  | 39.5  | 17.5  | 38.2  | 30.4  | 42.7  | 34.1  | 13.25 | 0.03 | 72.19 |
|         |             | 16.4  | 22.8  | 8.8   | 23.8  | 13.6  | 28.6  | 19.0c | 11.28 | 0.01 | 80.26f |
|         |             | 14.7  | 21.5  | 7.4   | 20.5  | 10.7  | 27.0  | 17.0  | 11.39 | 0.01 | 81.77 |
|         |             | 9.4   | 5.6   | 11.8  | 3.7   | 7.3   | 1.4   | 6.5d  | -0.50 | 0.01 | 80.04f |
|         |             | 9.0   | 2.0   | 11.5  | 2.9   | 5.8   | 1.0   | 5.4   | -0.48 | 0.00 | 89.66 |

* in the numerator-fertilized food background, in the denominator-non-fertilized.
* disease spread in %.
* root rot development in %.
* effect of air temperature on root rot spread, %.
* the effect of temperature on the development of root rot, %.
* the impact of the development of root rot on productivity, %.

The least spread of root rot occurs in the cultivation of hard wheat for all predecessors and food backgrounds in 2015, 2017, 2019. The range is from 18.6 to 38.2% on fertilized and 16.4-36.2% on non-fertilized power backgrounds. In all variants of the experiment, its development is noted according to the established years and contains a level from 2.1 to 18.3% on two food backgrounds. This observation
is explained by the medium-dry growing season of durum wheat, which leads to a decrease in the vital activity of fungi due to repeated rains in the form of showers that moistened the arable soil layer. The development of root rot in durum wheat crops for both food backgrounds is significantly lower compared to the infection effect.

On average, the highest percentage of root rot infection and development is observed in the first and fourth variants of the experiment. The lowest percentage of distribution and development is observed on durum wheat after green-manured fallow and it is 29.7; 11.8% on fertilized and 28.6; 10.2% on non-fertilized food backgrounds. Reducing the infection of durum wheat crops is provided by the previous leguminous crops (oats+peas) in the green-manured fallow, which are embedded in the soil and disinfect the soil from fungal diseases by their decomposition (releasing alkaloids and phytoncides).

Over the years of the study, the intensity of the disease of durum wheat root rot after soil protection steam (occupied by Sudan grass) is slightly higher than for siderates and is 32.1% in distribution, with the development of 14.9% on fertilized and, respectively, 30.8; 13.3% on non-fertilized food backgrounds. Sudan grass in soil–protective fallow significantly reduces root rot infestation due to its biological characteristics (medium resistance to diseases) compared to weedfree fallow and monocrop.

The infection is most strongly developed during the permanent cultivation of durum wheat, as all favorable conditions are created for the development of cereal weeds (chicken millet, quinoa, thistle, couch grass), the causative agent of the disease, which lead to the accumulation of parasitic fungi in the soil. In 2020, there is a decrease in the crop yield in monocrop to 1.0 c from 1 ha on a non-fertilized background of nutrition. The infection of durum wheat root rot from the application of mineral fertilizers is significantly increased due to frequent droughts. In the soil, there is an excess accumulation of nitrates (especially in weedfree fallow), which are not used by the plant and lead to the loss of the ability of bacteria to produce biologically active substances (antibiotics and others) on a fertilized food background. Under these conditions, the number of fungi in the soil increases, which leads to the disease of the plant.

Over the six years of the study, the highest crop yield of durum wheat was obtained in the average dry year of 2017 according to the predecessor of green-manured fallow and it is 21.4 c on fertilized and 21.1 c per 1 ha on non-fertilized mineral nutrition backgrounds. In 2020, the lowest productivity of the plant in monocrop is observed and amounts to 1.4 and 1.0 c per 1 ha for two food backgrounds.

On average, over the years of the study, the highest crop yield was obtained for durum wheat after weedfree coulisse fallow and it is 9.1 and 7.8 c per 1 ha for both food backgrounds. This fact is explained by the action of other processes in the soil, such as the accumulation of productive moisture and nutrients in the weedfree fallow before sowing durum wheat. As a result, a puny grain is formed due to the manifestation of root rot.

Due to the fact that it is difficult to determine the influence of each individual factor on the disease and the crop yield of durum wheat, statistical processing of the results is used using the apparatus of multiple relationships. Data for six years of research on all variants of the experiment were mathematically processed using multiple regression analysis, in which the dependence of root rot on air temperature was found.

The greatest influence of the air temperature during the growing season of durum wheat on the spread of root rot is noted in the third version of the experiment. On a fertilized background, the food content is 93.61% with a regression coefficient (b) of 11.76, the significance level (p)-0.002, on a non – fertilized background – 94.45%, 13.81, 0.001, respectively, with an optimal value of p≤0.05. The optimal air temperatures in the growing season led to a great influence on the development of the disease in the monocrop of the crop and it consists 80.26 and 81.77% on two food backgrounds. Statistical processing of the results for all variants of the root rot spread and development experience, depending on the air temperature, shows positive regression data from 4.76 to 13.81 units and a significance level from 0.00 to 0.07 units. These results indicate the best dependence of root rot on the air temperature in the plant's crops on the background without fertilizers, which indicates their connection with the nutrient status of the soil.
The maximum effect of root rot development on the crop yield of durum wheat is observed in the first and fourth versions of the experiment and it consists 88.43; 80.04 on the fertilized and 91.85; 89.66% on non-fertilized food backgrounds with a significance criterion of 0.005; 0.016 and 0.003; 0.004, which is explained by a good relationship between the signs. The regression coefficient for this observation has negative values compared to other indicators. The least influence of the disease on crop productivity is observed after the green-manured fallow in the grain-steam crop rotation and is 16.01 and 16.85% for both food backgrounds at the level of 0.43 and 0.41 units, which represents an insignificant relationship between the signs.

As a result of mathematical data processing, a strong relationship is established between the development of root rot and the yield of durum wheat after black steam in the grain-steam crop rotation and monocrop, which is interpreted as follows: the higher the damage to crops, the lower the productivity of the plant. In this regard, to reduce the infection of durum wheat crops with root rot in agricultural production, we recommend sowing seeds after the precursor of green-manured fallow in the grain-steam crop rotation without the use of mineral fertilizers.

4. Conclusions
The infection of durum wheat crops with root rot, which leads to a decrease in productivity, depends on soil and climatic conditions, crop rotation precursors, monocrops and mineral fertilizers. As a result of the statistical data processing carried out using the method of multiple regression analysis, the best relationship between air temperature and root rot is revealed, which is observed in the distribution of the disease in the third and development in the fourth variants of the experiment. With positive data from the results of multiple regression, a significant dependence of root rot on the air temperature is established on an non-fertilized background of nutrition. The greatest influence of root rot development on durum wheat productivity is observed after green-manured fallow in crop rotation and monocrop, which is determined by statistical data processing, which provides a good relationship between the factors. Crop yield depends to a small extent on the development of the disease after the green-manured fallow in the crop rotation and leads to an insignificant relationship, as shown by the negative regression.

The durum wheat crop placed in the first, second, and fourth variants of the experiment is more affected by root rot than after the green-manured fallow in the crop rotation. In the monocrop the crop yield decreases due to the strong activity of the disease, which leads to the formation of a puny grain and darkening in the embryo area. The application of mineral fertilizers contributes to an increase in the spread, development of root rot and productivity of durum wheat, depending on agrometeorological conditions and precursors. In the third variant of the experiment, an insignificant influence of the factor (the development of root rot) on the crop yield of hard wheat is observed.

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