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Dependence of species composition and development of root rots pathogens of spring barley on abiotic factors in the Eastern Forest-Steppe of Ukraine

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Root rots of spring barley have become widespread and cause a significant damage to agriculture. The poorer the culture of agriculture is, the higher are the losses from the root rots. Non-observance of crop rotation, the presence of monoculture of one or another species of cereals and poor agricultural technique lead to deterioration of the structure and depletion of the soil, create the unfavourable conditions for the development of plants, and facilitate the accumulation of pathogenic fungi in the soil and plant remains. Abiotic factors significantly affect the species composition and pathogens of the root rots, which requires the specification of these indices parameters, especially under the conditions of the Eastern Forest-Steppe of Ukraine. We have found that Helminthosporium and Fusarium root rots of spring barley are the most widespread in the zone of the Eastern Forest-Steppe of Ukraine, the pathogenic organisms of which are fungi of the genus Drechslera spp. and Fusarium spp. The development and prevalence of root rots directly depend on the weather conditions during the vegetation period of spring barley and are intensified with a considerable amount of precipitation, high air humidity (60-80%), moderate temperature (19-20° C), and hydrothermal coefficient of 1,2-1,4. Under the conditions of the Eastern Forest-Steppe of Ukraine these diseases are taking their dynamic courses with a significant increase in the later stages of the plant-feeder development.
Keywords: Root rots of spring barley; *Bipolaris sorokiniana* Shoem.; Fusarium spp.; abiotic factors

Introduction

Recently the root rots of spring barley have become widespread and cause the significant damage to agriculture. The poorer the culture of agriculture is, the higher are the losses from the root rots. Non-observance of crop rotation, the presence of monoculture of one or another species of cereals and poor agricultural technique lead to the deterioration of the soil structure and its depletion, create the unfavourable conditions for the development of plants, and facilitate the accumulation of pathogenic fungi in the soil and plant remains.

The researches of the root rots were carried out by domestic and foreign scientists. (Korshunova, 1970) studied them in the northern Caucasus, (CHulkina, 1973, 1974) – in the Altai Territory, (Hanna, 1973) – in the Moscow region, (Voytova, 1977; SHevtsov & Lehtikov, 1976) – in Belarus, (Senekerimyan et al., 1977) – in Armenia, (Piening, 1973; Fernandez et al., 2009) – in Canada, (Meldrum et al., 2004) studied the root rots in Australia.

At present the root rots are investigated in detail on wheat crop. There is a very limited amount of data that concerns the study of the root rots of barley.

Quite often barley crops are affected by two pathogens of the disease. The Helminthosporium and Fusarium root rots, the pathogens of which are the fungi of the genus Drechslera spp. and Fusarium spp. (Peresyipkin et al., 1991; Engle et al., 2004; Prodaievych & Hentosh, 2015) are the most widespread in the zone of the Eastern Forest-Steppe of Ukraine.

On the shoots the root rot manifests itself in the form of brown or red-brown strokes or stripes on the primary roots, coleoptiles, and leaves. Sometimes one root is formed instead of three ones, and the sprouts become distorted and perish (Fernandez et al., 2011).

Dark brown oblong ulcers are formed on the primary and secondary roots, as well as on the underground internodes. These ulcers often merge, and as a result the affected tissue becomes black. The disease can be manifested itself in the form of browning, yellowing and moulding of the young leaves. In the case of the insignificant development the disease manifests itself in the form of elongated dark brown necrotic strips, the colour of which gradually passes on to the healthy tissue, and

there is no clear boundary between the healthy and affected tissue. In the case of the intensive development of the disease the base of the stalk becomes black and rotted as far as the lowest nodule (Markov et al., 2017).
Fungi of the genus Fusarium spp. develop on the weakened plants and affect the roots, bushing nodes and bases of the stalks. The affected parts of the plants become brown and destroy, and sometimes a dry rot is formed. The development of the disease is facilitated by relatively cool weather with high air humidity, reduced amount of solar radiation, quite high concentration of carbon dioxide and low concentration of oxygen. Among the genus Drechslera spp. the species *Bipolaris sorokiniana* Shoem is common with barley crop. The disease manifests itself on the shoots in the form of browning of the coleoptiles, yellowing and deformation of the leaves, and general oppression of the plants. On the adult plants there are the signs of decay, browning and blackening of the primary and secondary roots, bushing node and the lower part of the stalk, and as a result the plants lag behind the growth; then the white ears, empty ears, frail grains in the ear and the death of the productive stalks are observed (Stack, 1992; Kumar et al., 2002; Mathre et al., 2003). Sometimes the grain in the ear becomes brown and wrinkled and obtains a brown colour in the germ area (black germ). Fungi of the genus Drechslera develop under the conditions of warm and dry weather in the places with a high level of solar radiation and on the soils close to neutral.
The common features of the root rots pathogens are the relationship with the soil, the ability to change the saprophytic nourishment into parasitic one and the lack of strict specialization as for the affection of the host plants. But the pathogens differ under the environmental conditions. Thus, the temperature amplitude for the plants to be affected by Helminthosporium rot is in the range of 12-28 °C (Markov et al., 2017), at the same time to be affected by Fusarium species it ranges within the limits of 13-23 °C. The relative humidity for the genus Drechslera spp. should be not lower than 80-85%, and for the genus Fusarium it should be 40-80% (Boyko & Radyina, 2004).
It is believed that soil and air droughts often facilitate the intensive development of Fusarium; but dry weather conditions which change into wet ones facilitate the development of Helminthosporium (Voytova, 1975; Fedorenko, 1964).
Thus, a review of the literature shows that the hydrothermal indices have a significant influence on the pathogens, but there is no consensus among the scientists. The parameters of these indices should be clarified, especially under the conditions of the Eastern Forest-Steppe of Ukraine.

Materials and methods

During 2008-2018 the experimental researches were carried out under the laboratory conditions at the Department of Phytopathology of Kharkiv National Agrarian University named after V.V. Dokuchaiev and at the Scientific and Research Productive Centre “Experimental Field” of Kharkiv National Agrarian University named after V.V. Dokuchaiev, which is located in the Kharkiv district of the Kharkiv region, in the north-eastern part of the left-bank Forest-Steppe of Ukraine.
The soil cover is represented by strong, loose alkaline chernozem on a dust loamy loess with a thickness of a humus layer of 75 cm and more, with a content of humus in the arable layer of 5.4%. The hydrolytic acidity is 0.76-0.99 mm per 100 g of soil.
Spring barley was sown in the optimum terms with the sowing norm of 4.5 million of germinating seeds per 1 hectare. Earlier sugar beets were planted on this area and the soil had been ploughed before. This process was done three times. The growing technology is common for the Forest-Steppe zone.
Under the conditions of laboratory and field experiments the samples were taken during the phases of germinating, bushing out, forming ears and wax ripeness of spring barley grains. The calculation of spring barley affected by the root rots was carried out according to the methods of A.F. Korshunova (1970).
The removal of phytopathogenic fungi from the grains of barley was carried out by a laboratory method in accordance with the generally accepted methods (Naumova, 1970; Voytova, 1980; Tinline et al., 1994). The method of wet chambers was used in order to choose the pure fungal culture (Dudka et al., 1982). The pure cultures of the fungus were choosing from the affected parts of the seeds according to the generally accepted methods described by V.I. Bilaj (1989).
When studying the influence of hydrothermal factors on the diseases development, the following indices were used: air temperature, precipitation, air humidity and hydrothermal coefficient. The indices were compared with the average perennial indices and with one another. The hydrothermal coefficient was determined according to the formula (Bilyk & Kulieshov, 2006):

$$\mathrm{HTC} = \frac{\sum O * 10}{\sum T * 10}$$

Where, O - precipitation during the vegetation period, mm; T - the sum of temperatures during the same period, °C; The reliability of the obtained data was estimated by the method of dispersion, correlation and regression analyses with the help of the table processor MS Excel (Dospekhov, 1985).

Results and discussion

To find the pathogens of root rot we carried out the phytopathologic analysis of spring barley seeds. We have found out two phytopathogens. They are *Bipolaris sorokiniana* Shoem and *Fusarium sp*.
The mycological analysis showed that when the seeds of spring barley were infected by *Bipolaris sorokiniana* Shoem, the browning of the primary roots and coleoptiles was observed (Figure 1).
The microscopic analysis of mycelium *Bipolaris sorokiniana* Shoem (Figure 2) showed relatively large dark-brown elongated-ovate, fusiform or elliptical fragmentation spores, sometimes bent or uneven of 60-134 × 17-30 microns in size, with 3-10 transversal membranes (Figure 3).

a b

Figure 1. Symptoms of common root rot (Pathogen *Bipolaris sorokiniana* Shoem) on spring barley sprouts: a – healthy sprout, b – affected sprouts.

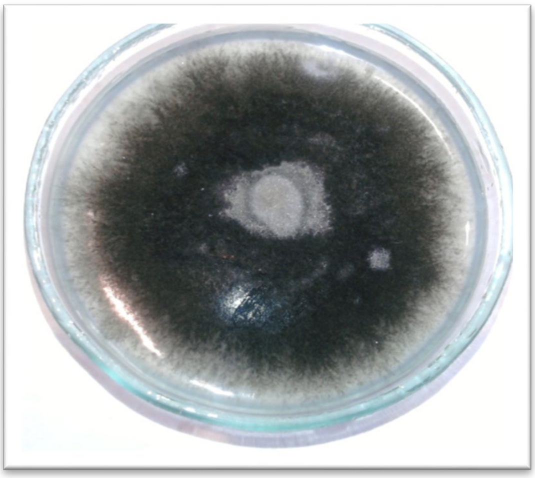
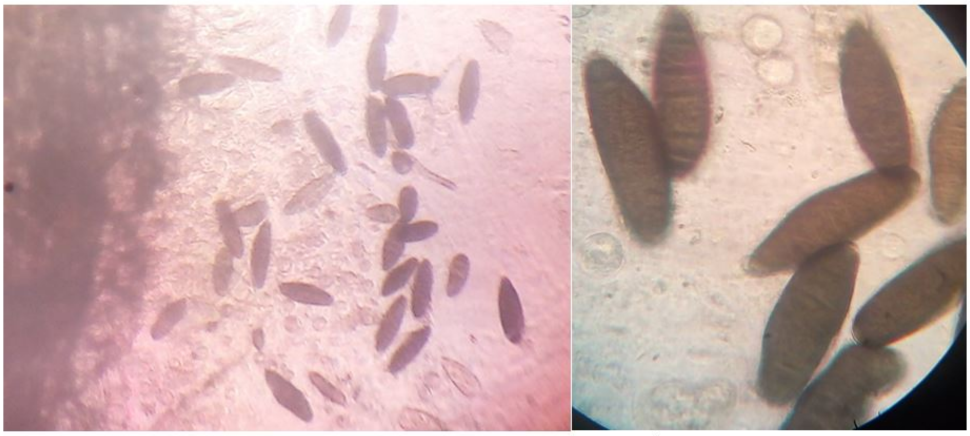


Figure 2. Colony of fungus *Bipolaris sorokiniana* Shoem on Chapek modified nutrient medium.



a b

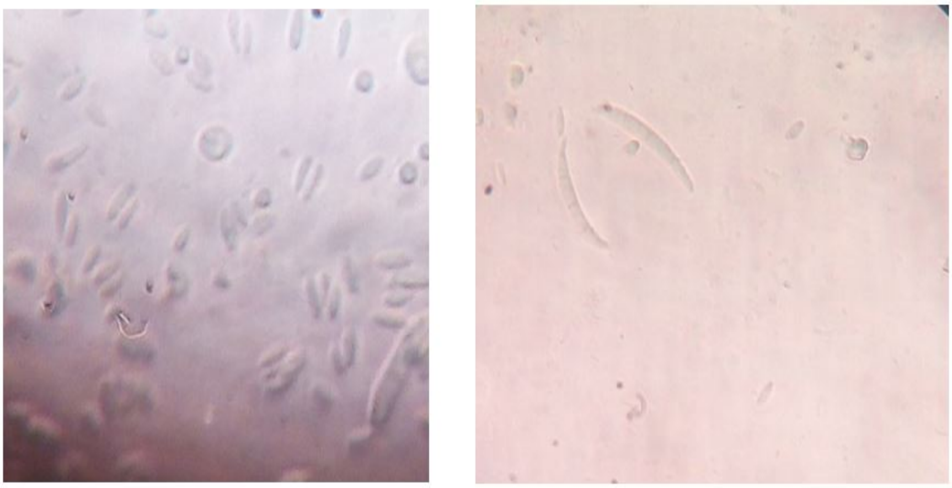
Figure 3. Fragmentation spores of fungus *Bipolaris sorokiniana* Shoem. (magnification × 135 (a); × 600 (b)).

In a wet chamber the fungi of the genus Fusarium formed a well-developed white or white-pink thin coating of air on the mycelium and fungus sporification (Figure 4).

The microscopic analysis of mycelium, taken from the affected seeds, allowed detecting the presence of two types of *Fusarium sp.* spores: micro fragmentation spores (unicellular and ovate) and macro fragmentation spores with 3-9 membranes. The latter were falcate, fusiform, of different curvature and elongation (Figure 5).

Figure 4. Sporification of *Fusarium sp*. on germinated barley grains

Figure 5. Colony of fungus *Fusarium sp*. on potato and glucose agar



a b

Figure 6. Spores of fusariosis pathogen: a – micro fragmentation spores; b – macro fragmentation spores (magnification ×600).

During the years of the research we have established that in the Eastern Forest-Steppe of Ukraine the species composition of barley root rots was presented by two pathogens – *Bipolaris sorokiniana* Shoem (69%) and *Fusarium sp*. (31%) (Figure 7).
The years of the research differed according to the weather conditions. The spring in 2008 came early, which made it possible to sow spring barley on April 15. During the vegetation period there was a warm weather with high air humidity (Figure 8). Such weather conditions positively influenced the prevalence and development of the root rots.

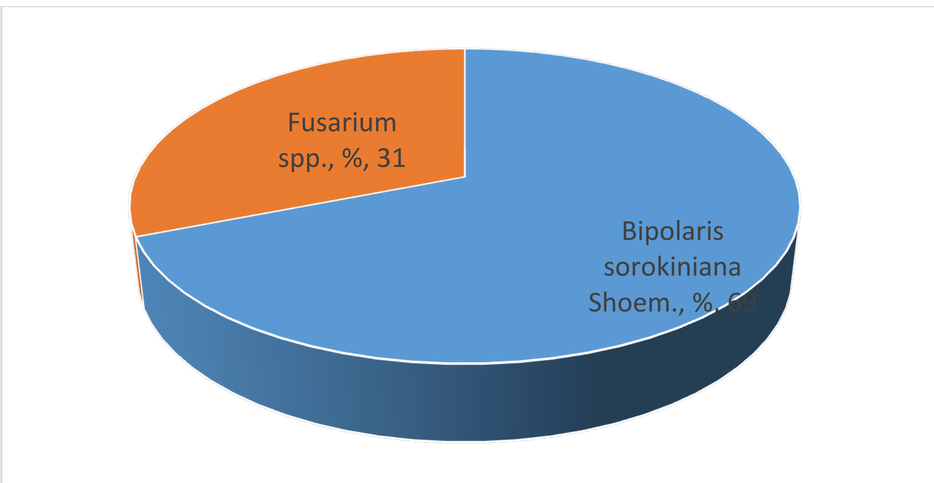


Figure 7. Species composition of spring barley root rots in the Eastern Forest-Steppe of Ukraine.

The average air temperature of 22.2 °C and a large amount of precipitation (67 mm) in the second decade of June facilitated the development of the diseases. The maximum development of the root rots (45.8%) was noted in early July, when the air temperature was 19.5°C, and the air humidity was 66%.

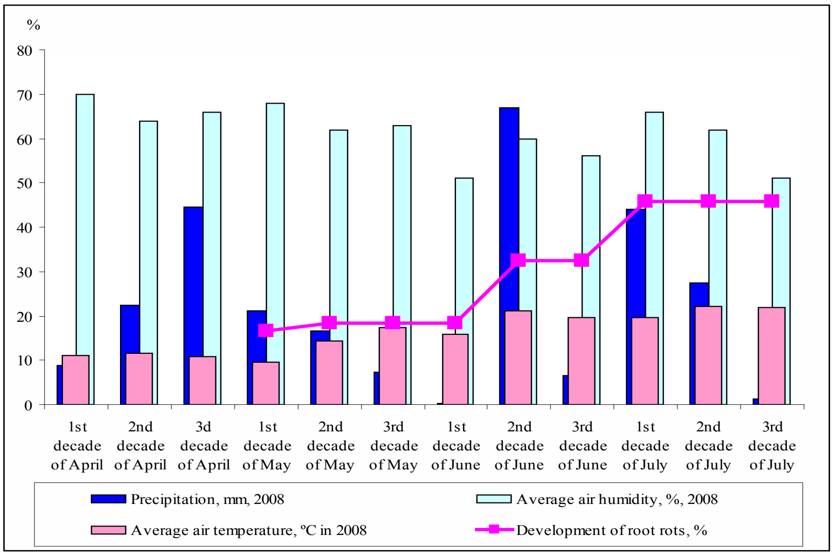


Figure 8. Dependence of spring barley root rots pathogens development upon weather conditions in 2008.

The weather conditions in 2009 differed from the conditions of the previous year. The spring came for almost a decade later, which made it possible to sow barley on April 26. In April and May the air temperature was within the range of 8.6–13.7 °C (Figure 9), which inhibited the growth of spring barley plants and did not facilitate the development of the diseases. The year was characterised by dry weather conditions; the precipitation over the decades during the vegetation period of spring barley in 2009 amounted to 1.3-20.2 mm.

The maximum development of root rots was noted at the end of June and at the beginning of July. It amounted to 35%, which was by 10.8% less than in 2008.

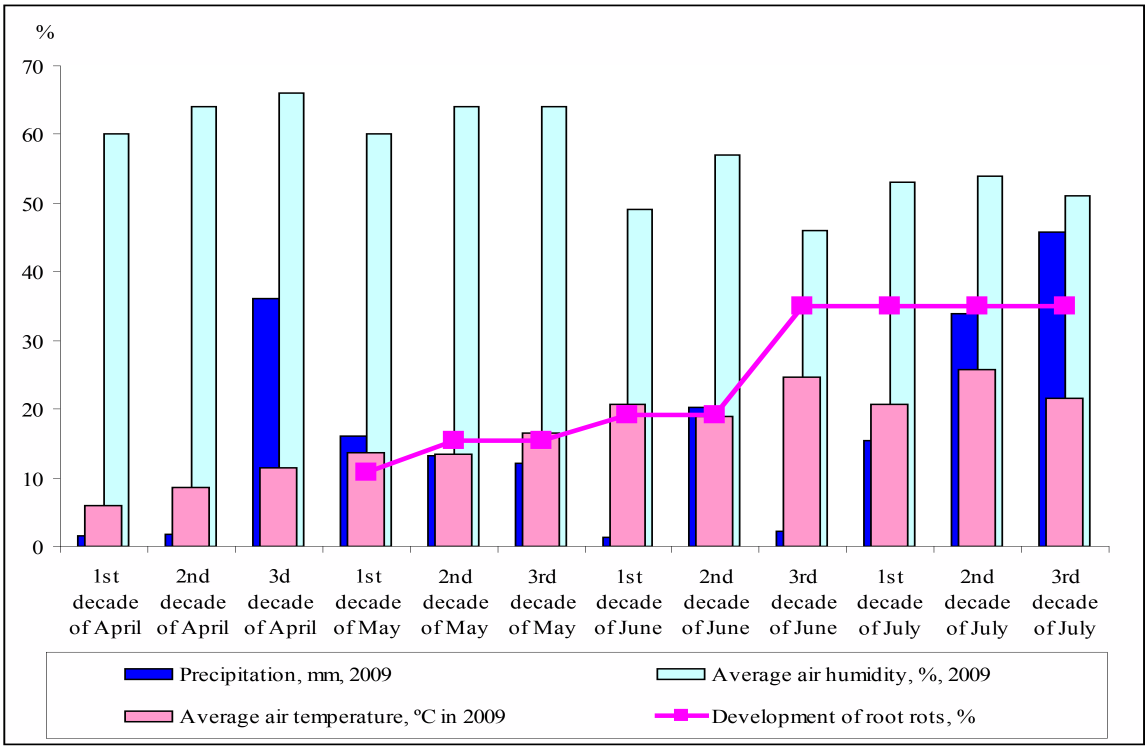


Figure 9. Dependence of spring barley root rots pathogens developmemt upon weather conditions in 2009.

The spring in 2010 came early, which made it possible to sow spring barley on April 18. During the vegetation period there was an optimal amount of precipitation. Such weather conditions facilitated the development of the diseases (Figure 10).

The maximum development of root rots (37.5%)was noted during the first decade of July when the air temperature was 23.4 °C, and the air humidity was 68%.

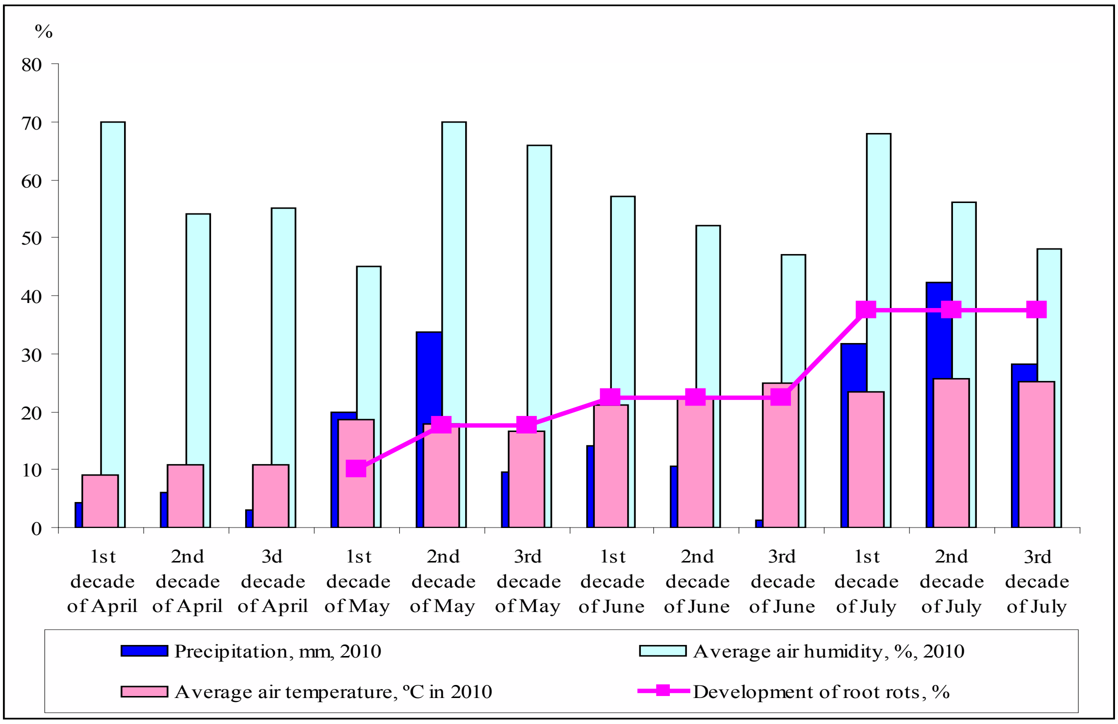


Figure 10. Dependence of spring barley root rots pathogens development upon weather conditions in 2010.

The weather conditions in 2011 differed from the previous three years of the research. The spring came almost two decades later, which made it possible to sow spring barley only on May 2. Beginning from the second decade of May the weather conditions were characterised by high temperature of 18.3-22.1 °C and the air humidity of 47-70% (Figure 11). During the second decade of June and the first decade of July there was a maximum fall of rain (242.5 mm), which caused a significant development of root rots (63.3%).

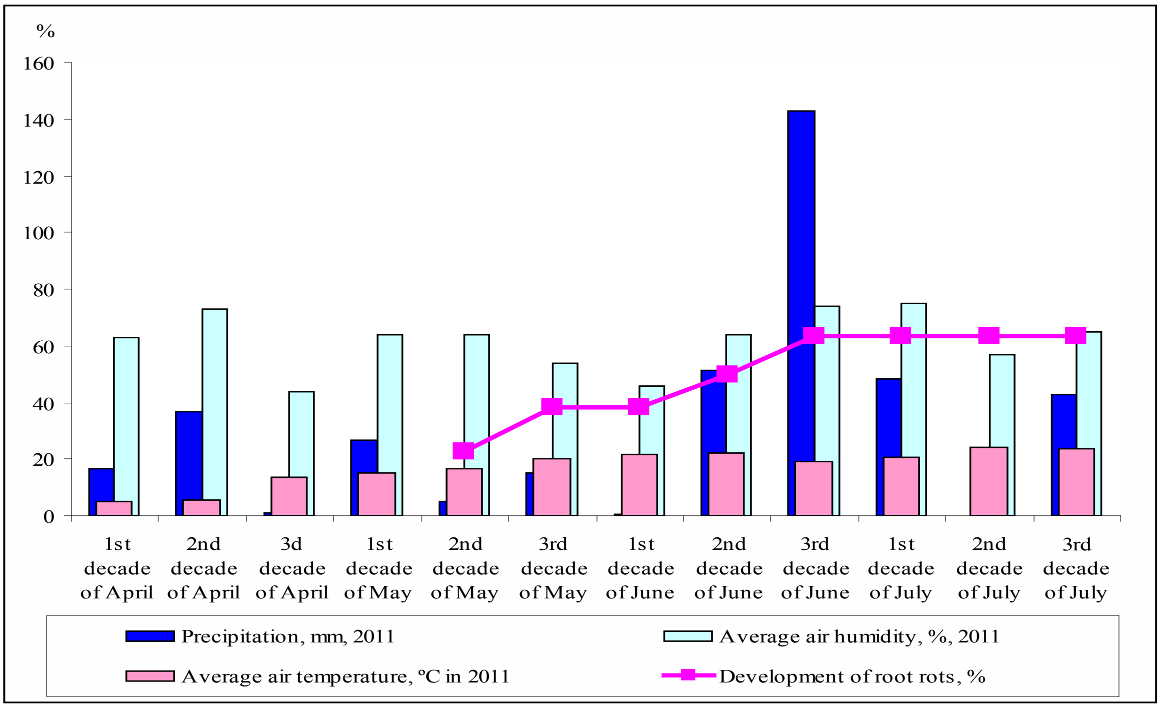


Figure 11. Dependence of spring barley root rots pathogens development upon weather conditions in 2011.

The spring in 2017 came late and it was dry, which made it possible to sow spring barley only in the second decade of May. Beginning from the third decade of May the weather conditions were characterised by high temperature of 18.3–24.3°C and the air humidity of 51-73% (Figure 12). The year was characterised by dry weather conditions; the amount of precipitation over the decades during the vegetation period of spring barley in spring 2017 amounted to 1.1-15.4 mm, which did not facilitate the development of the diseases. The maximum development of root rots was noted at the beginning of July (24.2%).

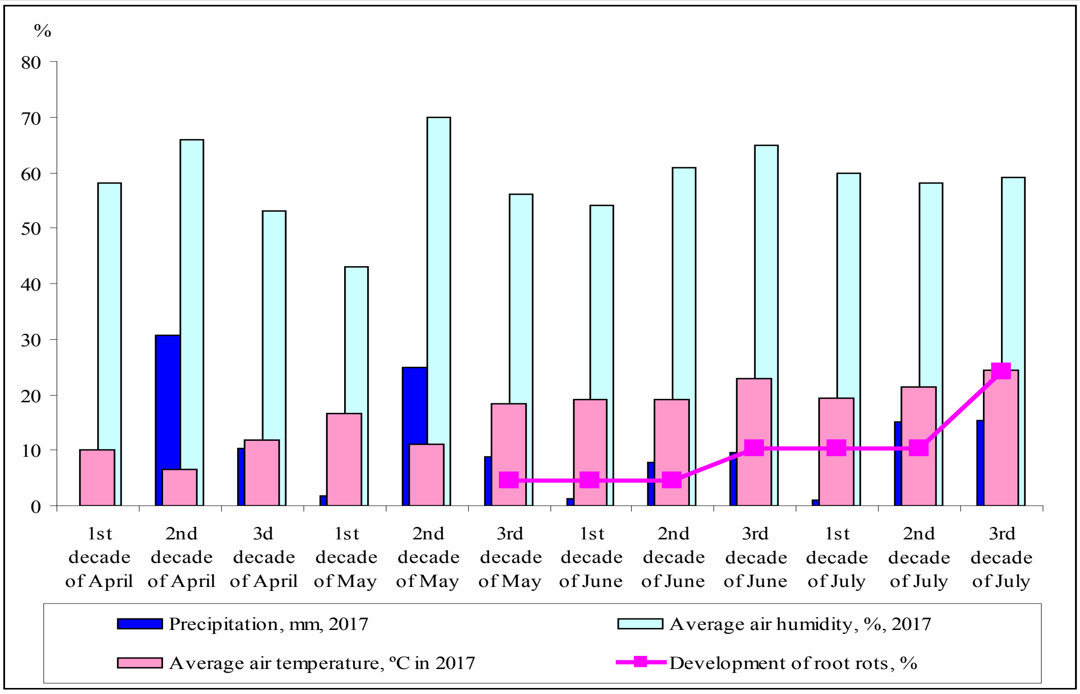


Figure 12. Dependence of spring barley root rots pathogens development upon weather conditions in 2017.

The spring in 2018 came early, which made it possible to sow spring barley in the second decade of April. During the vegetation period there were hot and dry weather conditions that inhibited the growth of spring barley plants and did not facilitate the development of root rots (Figure 13). The average temperature of 24.1 °C and a large amount of precipitation (34.6 mm) in the third decade of June facilitated the development of the diseases. The maximum development of root rots (38.4%) was noted in the second decade of July, when the air temperature reached 22.1 °C, and the air humidity was 73%.

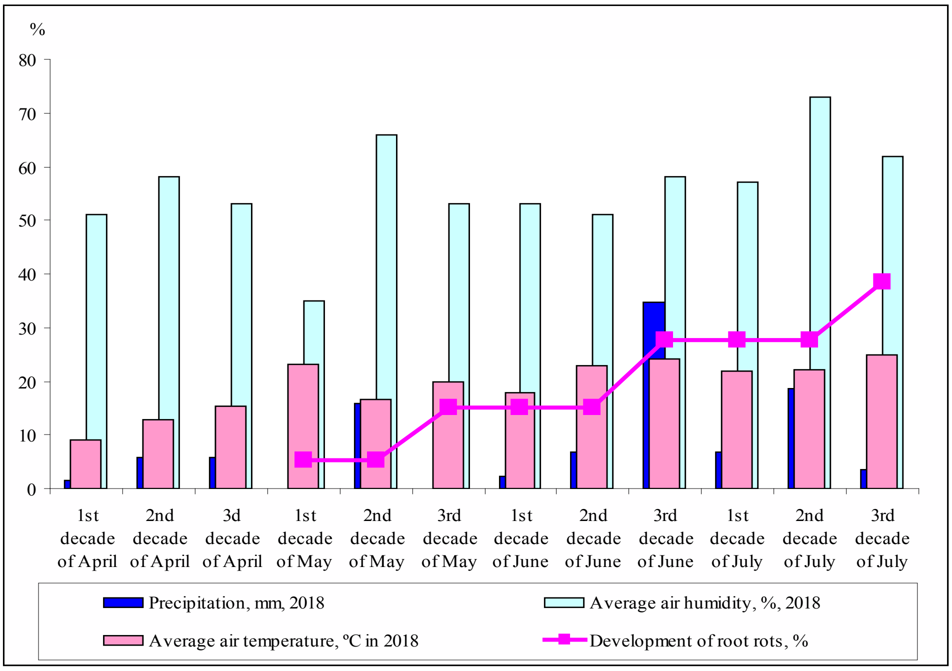


Figure 13. Dependence of spring barley root rots development upon weather conditions in 2018.

Such weather conditions significantly influenced the development of root rots (Table 1).

Table 1. Development of spring barley root rots depending on weather conditions, 2008-2018.

Month	Year	Average air temperature, °C	Precipitation, mm	Average air humidity,%	HTC	Root rots development%
May	2008	13.7	45.3	64.3	1.3	18.3

	2009	14.6	41.1	62.7	0.9	15.5
	2010	17.7	63.0	60.3	1.2	17.5
	2011	17.3	46.6	60.7	0.2	22.5
	2017	15.4	35.6	56.3	0.4	4.6
	2018	19.9	15.9	51.3	0.3	5.4
June	2008	18.9	73.9	55.7	1.2	32.5
	2009	21.5	23.6	50.7	0.4	19.2
	2010	22.8	26.0	52.0	0.4	22.5
	2011	20.8	194.6	61.3	3.3	38.3
	2017	20.4	18.6	60.0	0.3	10.4
	2018	21.6	43.5	54.0	0.6	15.0
July	2008	21.2	72.8	59.7	1.2	45.8
	2009	22.7	95.0	52.7	1.5	35.0
	2010	24.7	102.2	57.3	1.4	37.5
	2011	23.0	91.0	65.7	1.4	46.4
	2017	21.7	31.6	59.0	0.5	24.2
	2018	23.0	28.7	64.0	0.4	38.4
HIP_{05}	–	1.9	71.7	8.3	1.4	6.7

As a result of the analysis of the meteorological data of the vegetation periods of spring barley in 2008-2018 we have established a correlation relationship and with the help of the regression analysis method we have obtained the equation of the dependence of the root rots development upon the amount of precipitation, and on this basis we have built the diagram (Figure 14).

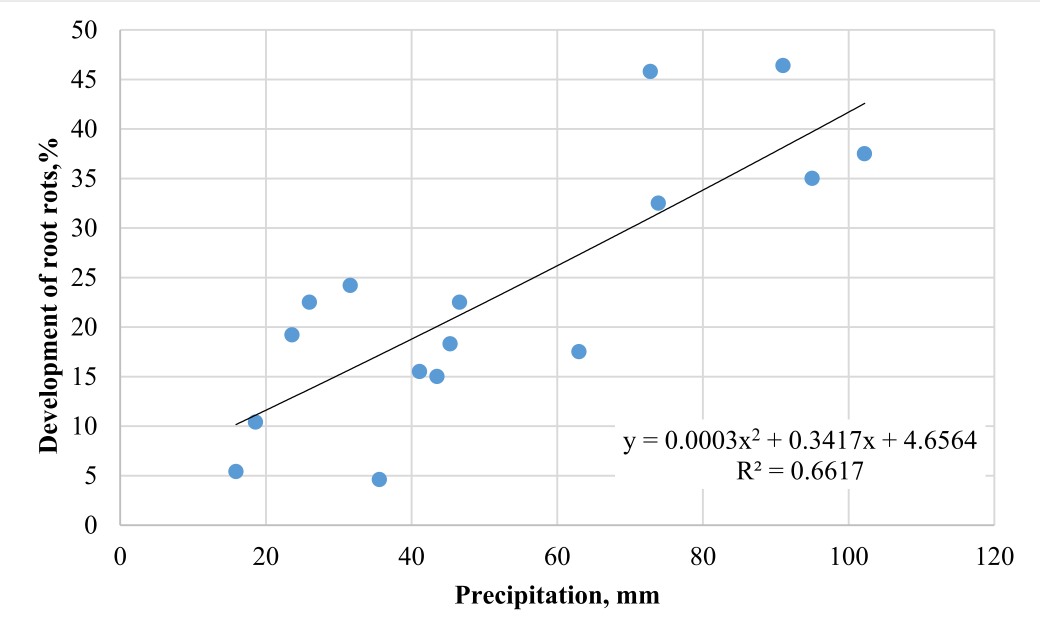


Figure 14. Dependence of root rots pathogens development upon the amount of precipitation, mm, 2008–2018.

The Pearson correlation coefficient (rP) showed a high correlation between the indices of root rots development and the amount of precipitation. The correlation coefficient was at the level of 0.81. The Spearman correlation coefficient (rS) showed a high and direct correlation between the indices; it was at the level of 0.72. However, the Kendall correlation coefficient (rK) showed an average correlation of 0.57.

Using the method of regression analysis we have obtained the equation showing the dependence of root rots development upon the amount of precipitation. The determination coefficient (R^2) amounted to 0.66. Based on the data obtained, it can be concluded that the development of root rots depends on the amount of precipitation during the vegetation period of barley by 66.2%.

Statistically processing the data (Pearson correlation coefficient), we have established an average correlation between the indices of root rots development and the average air temperature. The coefficient was rP=0.53. With the help of the correlation coefficients of Spearmen and Kendall an average correlation of rS=0.59 and a weak correlation of rK=0.43 between the indices have been established.

Based on the regression analysis method we have built the diagram showing the dependence of root rots pathogens development upon the average air temperature (Figure 15). The determination coefficient (R^2) was 0.336. As a result it was found that the development of root rots pathogens depends on the average air temperature only by 33.6%.

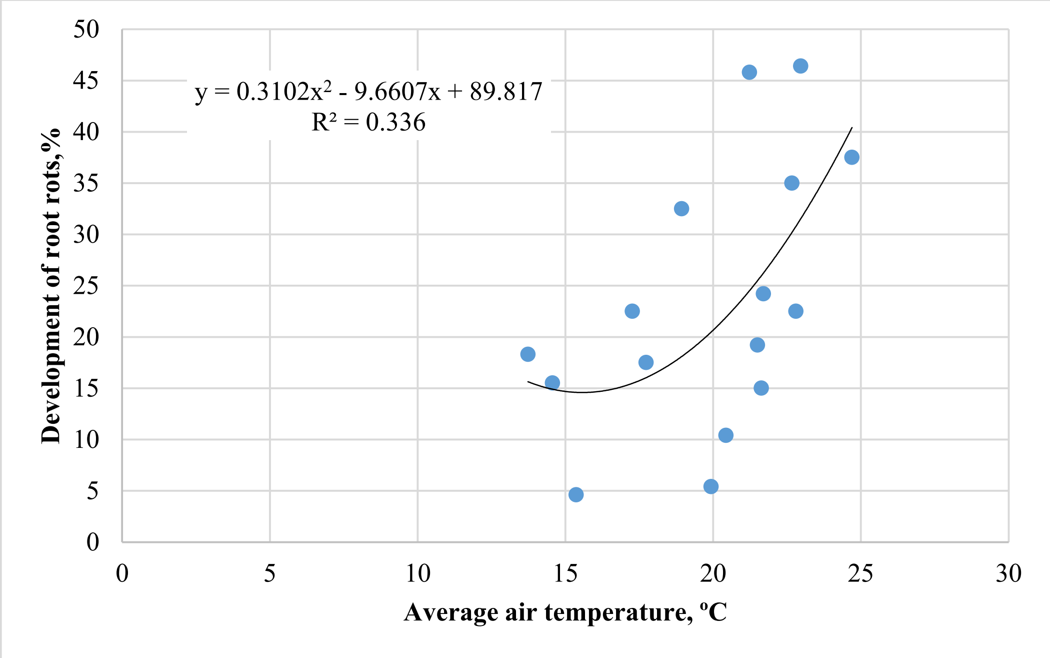


Figure 15. Dependence of root rots pathogens development upon average air temperature, °C, 2008-2018.

Summing up the above-stated information it has been established that during the vegetation period the development of pathogens of root rots is more dependent on the amount of precipitation than on the average air temperature. As a result the dependence between the development of root rots pathogens and the index of the territory humidity (hydrothermal coefficient of Selianinov, HTC) was established (Figure 16). So, using the Pearson correlation coefficient a high correlation between the indices at the level of rP=0.70 was established. The correlation coefficients of Spearmen and Kendall showed an average dependence at the level of rS=0.62 and rK=0.53.

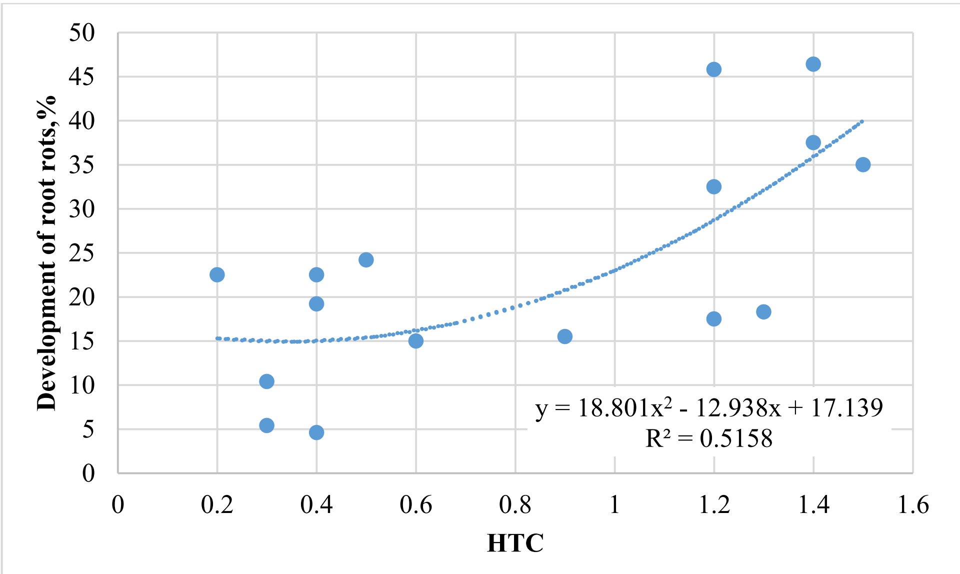


Figure 16. Dependence of root rots pathogens development upon HTC, 2008–2018.

With the help of the regression analysis method the equation of dependence of root rots development on the level of HTC was obtained. The determination coefficient (R^2) was 0.5158. That is, the development of root rots pathogens depends on the level of HTC during the vegetation period by 51.6%, and it depends on the other factors by 48,4%. In the course of the research it was established that the maximum development of root rots pathogens takes place when the hydrothermal coefficient reaches the indices of 1.2-1.4 (Figure 16).

Conclusion

The species composition of root rots of spring barley in the Eastern Forest-Steppe of Ukraine is represented by two pathogens. They are *Bipolaris sorokiniana* Shoem and *Fusarium sp*. The development and prevalence of root rots pathogens directly depend on the weather conditions during the vegetation period of spring barley and are intensified with the considerable amount of precipitation, high air humidity (60-80%), moderate temperature (15-23°C), and hydrothermal coefficient of 1.2-1.4. The development of these diseases under the conditions of the Eastern Forest-Steppe of Ukraine takes place dynamically with a significant degree of an increase in the later stages of the plant-feeder development.

References

Bilyk, M. O., & Kulieshov, A. V. (2006). Praktykum z fitosanitarnoho monitorynhu i prohnozu. Kharkiv. (in Ukrainian).

Boyko, A. K., & Radyina, A. A. (2004). Vliyanie temperaturyi i otnositelnoy vlajnosti vozduha na porajennost kolosa yarovogo yachmenya vozbuditelyami fuzarioza. Integrovaniy zahist roslin na pochatku XXI stolittya. Proceed. Int Conf. Kiev: IZR. (in Russian).

Engle, J. S., Lipps, P. E., & Mills, D. (2004). Spot blotch and common root rot. Frankfort: Ohio University press.

Fernandez, M. R., Holzgang, G., & Turkington, T. K. (2009). Common root rot of barley in Saskatchewan and north-central Alberta. Canadian Journal of Plant Pathology, 31(1), 96-102. doi:10.1080/07060660909507577

Fernandez, M. R., & Conner, R. L. (2011). Root and crown rot of wheat. Prairie Soils Crops J, 4, 151-157.

Kumar, J., Schafer, P., Huckelhoven, R., Langen, G., Baltruschat, H., Stein, E., Nagarajan, S., Kogel, H. K. (2002). Bipolaris sorokiniana, a cereal pathogen of global concern: cytological and molecular approaches towards better control. Mol Plant Pathol, 3, 185-195

Markov, I. L., Bashta, O. V., Hentosh, D. T., Dermenko, O. P., & Pikovskyi, M. I. (2017). Silskohospodarska fitopatolohiia. Kyiv: Interservis. (in Ukrainian).

Mathre, D. E., Johnston, R. H., & Grey, W. E. (2003). Diagnosis of common root rot of wheat and barley. Plant Health Progress, 4(1). doi:10.1094/PHP-2003-0819-01-DG.

Meldrum, S. I., Platz, G. J., & Ogle, H. J. (2004). Pathotypes of Cochliobolus sativus on barley in Australia. Aust Plant Pathol, 33, 109–114.

Naumova, N. A. (1970). Analiz semyan na gribnuyu bakterialnuyu infektsiyu. Leningrad. (in Russian).

Peresyipkin, V. F., Tyuterev, S. L., & Batalova, T. S. (1991). Bolezni zernovyih kultur pri intensivnyih tehnologiyah ih vozdelyivaniya. Moscow: Agropromizdat. (in Russian).

Prodaievych, T., & Hentosh, D. T. (2015). Osoblyvosti rozvytku korenevykh hnylei yachmeniu v umovakh SFH “Tsabii L.V.” Kirovohradskoi oblasti. Dosiahnennia i perspektyvy v zakhysti roslyn vid khvorob. Materialy I Vseukrainskoi studentskoi naukovoi konferentsii (26-27 bereznia 2015 roku, m. Kyiv). Kyiv: TOV “TsP KOMPRYNT” (in Ukrainian).

Stack, W. R. (1992). Bipolaris. In: Singleton, L. L., Mihail, J. D., and Rush, C. M. (eds.). Methods for Research on Soilborne Pathogenic Fungi. American Phytopathological Society, St. Paul, MN.

Tinline, R. D., Diehl, J. A., & Spurr, D. T. (1994). Assessment methods for evaluating common root rot in spring wheat and infection of subterranean plant parts by the causal fungus *Cochliobolus sativus*. Can J Plant Pathol, 16, 207-214.

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