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PHYTOPATHOGENIC CONTROL OF THE CAUSES OF THE MAIN TYPES OF CEREAL GRAIN CULTURE DISEASES OF FUNGAL ETIOLOGY

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Conducting constant monitoring of phytosanitary, effective diagnosis and making predictions as to the development and spread of some harmful organisms of fungal etiology are the important parts in ensuring the health of plants and maintaining the appropriate phytosanitary state of the agrocenoses. This scientific paper presents the conclusions of the author's own research of the spread and the development of pathogens of the main types of diseases of cereal grain crops (namely the winter wheat and the spring barley) of fungal etiology for the period of 2004–2022. It was determined that the phytopathogenic complex of agrocenoses of the winter wheat was dominated by the following root rots: helminthosporium (Bipolaris sorokiniana), fusarium (Fusarium spp.), cercosporella (Oculimacula yallundae), ophiobolus (Gaeumannomyces graminis), which affected on average up to 70.0% of the researched plants, the spread of diseases was 50%, and their development reached 1.81%. In the phytopathogenic complex of the spring barley, in addition to the root rot types (Bipolaris sorokiniana, Fusarium spp.), the dominated varieties of spotting were discovered as the following: the dark brown (Cochliobolus sativus), the stripes (Pyrenophora graminea), the reticulate (Pyrenophora teres), the leaf septoria (Mycosphaerella graminicola), the powdery mildew (Blumeria graminis), and the rhynchosporium (Rhynchosporium secalis). The areas of the spring barley crops affected by these diseases are on average 5.1% –75.0% of the total amount of the crops, the prevalence of these diseases varies from 2.0% to 65.0%, and their development is 1.2%–35.0%. Phytopathogenic microorganisms increased the level of biological pollution of the agrocenoses and increased certain ecological risks in the agroecosystems. Therefore, the availability of up-to-date information makes it possible to timely assess the level of danger and the risks associated with the negative effects of phytopathogenic microorganisms, as well as develop and apply effective plant protection measures and minimize crop losses.

Key words: *phytopathogenic microorganisms, phytosanitary monitoring, agrocenosis, biological pollution.*

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Фітопатогенний контроль збудників основних видів хвороб зернових колосових культур грибної етіології.
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Важливим у забезпеченні здоров'я рослин і підтриманні належного фітосанітарного стану агроценозів є ведення постійного фітосанітарного моніторингу, ефективна діагностика та прогнозування розвитку і поширення шкідливих організмів грибної етіології. В роботі наводяться матеріали власних досліджень авторів щодо поширення та розвитку збудників основних видів хвороб зернових колосових культур (пшениці озимої та ячменю ярого) грибної етіології за період 2004–2022 рр. Визначено, що у фітопатогенному комплексі агроценозів пшениці озимої домінують кореневі гнилі: гельмінтоспоріозна (Bipolaris sorokiniana), фузаріозна (Fusarium spp.), прикоренева церкоспорельозна (Oculimacula yallundae), офіобольозна (Gaeumannomyces graminis), якими уражено у середньому до 70,0%, поширення хвороб – 50%, їх розвиток – 1,81%. У фітопатогенному комплексі ячменю ярого, окрім кореневих гнилей (Bipolaris sorokiniana, Fusarium spp.), домінували різновиди плямистості: темно-бура (Cochliobolus sativus), смугаста (Pyrenophora graminea), сітчаста (Pyrenophora teres), септоріоз листя (Mycosphaerella graminicola), борошниста роса (Blumeria graminis), ринхоспоріоз (Rhynchosporium secalis). Площі посівів ячменю ярого, уражених зазначеними хворобами, становлять у середньому 5,1–75,0%, поширеність цих хвороб коливається від 2,0 до 65,0%, а їхній розвиток – 1,2–35,0%. Фітопатогенні мікроорганізми підвищують рівень біологічного забруднення агроценозів та посилюють екологічні ризики в агроекосистемах, тому наявність актуальної інформації дає змогу вчасно оцінити рівень небезпеки та ризики, пов'язані з негативною дією фітопатогенних мікроорганізмів, розробити та застосувати ефективні заходи захисту рослин та мінімізувати втрати врожаю.

Ключові слова: *фітопатогенні мікроорганізми, фітосанітарний моніторинг, агроценоз, біологічне забруднення.*
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Introduction

Protecting plants from the effects of harmful organisms should guarantee an optimal phytosanitary conditions for obtaining high and stable yields. The phytopathogenic state of the agrocenosis has a great influence on the formation of the crops. The spread and the development of pathogens and, accordingly, their harmfulness depend on a combination of such factors as the weather conditions, the genetic resistance of plants, and the presence of the pathogen. A regular phytopathological examination of agrocenoses of grain crops makes it possible to establish the dynamics of the damage for making further decisions regarding the system of protection against the diseases (Tatarynova, Burdulaniuk, Rozhkova 2018).

Any changes in the weather and climate conditions, a reduction in the rotation of grain crops, the use of uncertified seeds, non-observance of sowing dates and improper soil cultivation led to a deterioration of the phytosanitary situation in the agrocenoses of grain ear crops (Vasilyeva 2019; Korniychuk 2019). A number of the scientists noted that the changes in the structure of the phytopathogenic complex of cereal grain crops, the harmfulness of the diseases such as root rot, septoriosis, powdery mildew, volatile and hard soot, septoriosis and fusarium head blight, as well as other diseases of winter wheat crops that previously had no economic significance, had increased (Dermenko 2016; Vaughan 2016; Kyrychenko et al. 2021). Basically, every year, the agrocenoses of grain crops are dominated by some pathogens of fungal diseases, which, under optimal agrotechnical conditions, are at the permissible levels of harmfulness and have stability in their development, which corresponds to the homeostatic state of natural cenoses. Phytopathogenic microorganisms can be restrained by the varietal potential and a number of other agrotechnical techniques. The imbalance of phytopathogens in the agrocenoses of cereal grain crops occurs as a result of some extreme abiotic and biotic factors (Lishchuk et al. 2022).

Developing resistant varieties of cultivated plants is an environmentally safe method of protecting them from diseases. However, the benefits of many resistant varieties are short-lived as the new types of phytopathogenic microorganisms appear during their cultivation or their frequency increases, which weakens the previous resistance (Beznosko et al. 2021). Widely specialized necrotrophic species of fungi, which are capable of parasitizing a significant number of species of the cultivated plants, quickly accumulate and live on seeds, fruits, root crops, plant residues and in the soil for a long time, are considered particularly dangerous (Parfenyuk 2017). Therefore, a resistant variety, created especially by genetic modification, is a powerful factor of the targeted selection in the populations of microorganisms based on the signs of the pathogenicity and aggressiveness, and a susceptible variety is a powerful factor of their population growth. They significantly influence the qualitative and quantitative indicators of the phytopathogenic background, which significantly worsens the conditions of the agrophytocenoses and, to some extent, the biological safety of the agroecosystems (Parfenyuk 2016).

In order to ensure the health of plants and maintain the proper phytosanitary state of the agrocenoses, it is very important to conduct a constant phytosanitary monitoring, an effective diagnostics and making predictions as to the development and spread of harmful organisms in agricultural crops, which becomes especially relevant in the conditions of changes in climatic parameters (Mostovyak et al. 2020). The availability of up-to-date information makes it possible to timely assess the level of danger and the risks associated with the negative effects of the harmful organisms, to develop and apply effective plant protection measures, and to minimize crop losses. Therefore, the phytopathogenic control of the state of the agrocenoses of the cereal grain crops always remains relevant.

Materials and methods

The field research was conducted on the fields of the Left Bank Forest-Steppe of Ukraine for the period of 2004–2022 in the conditions of production crops in the Kyiv province (Skyrsk experimental farm of organic production, Institute of Agroecology and Nature Management of the National Academy of Sciences).

The records of the grain crop diseases (in the winter wheat and the spring barley) were carried out according to the generally accepted methods (Omelyuta et al. 1986; Trybel et al. 2001). When making the phytopathological records, the spread of the disease in the agrocenosis and the degree of the disease development or the average damage of the individual organs in percentages were determined according to the methods used by the Institute of Plant Protection of the National Academy of Sciences (Trybel et al. 2010).

The prevalence was calculated according to the following formula:

$$P = \frac{n \times 100}{N} \quad (1)$$

where P – the prevalence of the disease, %
n – the number of the diseased plants or individual organs;
N – the total number of plants in the samples.

The indicator of the intensity of plant damage was estimated by the area of the affected plant surface. The intensity of disease development was determined by the formula:

$$I = \frac{\Sigma(ab)}{n} \quad (2)$$

where I – the intensity of the disease development, %;
∑ (ab) – the sum of the products of the number of the examined plants (a) by their corresponding percentage of the damage intensity (b);
n – the number of the diseased plants or individual organs.

The identification of microscopic fungi to genus and species was carried out using a biological microscope DN-200D according to the determinants (Sessitsch et al. 2001; Campbell et al. 2013; Guaro et al. 2013) and using the online MycoBank database.

Results

Monitoring of the phytosanitary state of the agrocenoses of the winter wheat and the spring barley testified to the significant spread and development of pathogens of the main types of grain crop diseases of fungal etiology for the period of 2004–2022 (Mostovyak et al. 2020). It was established that during the growing seasons of 2004–2022, the winter wheat plants were dominated by the following types of root rot: common or helminthosporous (species *Cochliobolus sativus* (Ito&Kurib.) Drechsler ex Dastur (anamorph *Bipolaris sorokiniana* (Sacc.) Shoemaker), fusarium wilt of plants (*Fusarium* spp.), cercosporella (*Oculimacula yallundae* (Wallwork & Spooner) Crous & W. Gams), ophiobolus (*Gaeumannomyces graminis* Arx et Ol.), also septoriosis of the leaves (species – *Septoria tritici* Roberge in Desmaz, teleomorph *Mycosphaerella graminicola* (Fuckel) J. Schröt.), powdery mildew (species – *Blumeria graminis* Speer f. sp. Tritici Marchal) and pyrenophorosis, or the yellow spotting (*Pyrenophora tritici-repentis* Died.).

The areas of the winter wheat crops affected by the specified diseases reached on average 5.8–7.0%. The prevalence of these diseases ranged from 2.0 to 75.0%, and their development ranged from 0.5 to 18.0%. According to the research data presented in Table 1, it was established that the root rot was characterized by a high area of damage to the agrocenoses of the winter wheat, which reached up to 70%, the spread of the plant diseases ranged from 6.7 to 50%, and the development of the diseases ranged from 2.1 to 18.0%. Area of affected crops of powdery mildew it ranged between 12.3%and 65%, the spread of the disease in the agrocenoses of the winter wheat plants ranged between 13.0 and 50%, and the development varied between 7.1 and 16.4%.

It was established that the share of the areas affected by other leaf and stem diseases (the dark brown spot, the brown leaf spot, the stem (linear), the yellow rust, the septoriosis of leaves, pyrenophorosis, the snow mold) varied within 6.1 and 60%, the prevalence ranged between 2.0 and 48.0%, the development varied between 0.4% and 12.1% (see Table 1).

The highest economically significant damage to the crops was caused by annual damage to the plants by some root and root rot diseases. They caused up to 20–48% plant death during the growing season and a decrease in the productivity due to an increase in the level of the damage, which is aggravated by adverse weather conditions. Also, the powdery mildew, which develops intensively under the conditions of the application of unbalanced rates of nitrogen fertilizers, prevailed among the mentioned diseases in the winter wheat agrocenoses. An increase in the development of the disease in the recent years was determined, which is associated with the intensification of the grain production and leads to a significant decrease in the yield and its quality in various regions of Ukraine (Vasilyeva 2019). Depending on the cultivated varieties and the agro-climatic conditions of the year, the degree of damage can vary from 14% to 40%, and grain losses vary from 10% to 50% of the harvest.

Among the diseases of the spring barley, the following ones were found to be the most common: the root rot, including (*Cochliobolus sativus* (Ito&Kurib.) Drechsler ex Dastur (anamorph *Bipolaris sorokiniana* (Sacc.) Shoemaker, *Fusarium* spp.); the types of spotting inlcuded the dark brown (*Cochliobolus sativus* (Ito&Kurib.) Drechsler ex Dastur (anamorph *Bipolaris sorokiniana* (Sacc.) Shoemaker) striped (*Pyrenophora graminea* Ito&Kurib.; anamorph *Drechslera graminea* (Rabenh.) Shoemaker), the reticulate (*Pyrenophora teres* Drechsler; anamorph *Drechslera teres* (Sacc.) Shoemaker), the leaf septoria (*Mycosphaerella graminicola* (Fuckel) J. Schröt.), the powdery mildew (*Blumeria graminis* (DC.), Rhynchosporium (*Rhynchosporium secalis*

Table 1. The spread and development of the main plant diseases of soft (winter) wheat (Triticum aestivum L.) in growing seasons, the average for 2004–2022

The agents of common diseases	**Area of affected crops, %**		**Spread the disease,%**		**Development of the diseases,%**	
	min.	**max.**	**min.**	**max.**	**min.**	**max**
The root rot: common or helminthosporous (species *Cochliobolus sativus* (Ito&Kurib.) Drechsler ex Dastur (anamorph *Bipolaris sorokiniana* (Sacc.) Shoemaker), fusarium wilt of plants (*Fusarium* spp.), cercosporella (*Oculimacula yallundae* (Wallwork & Spooner) Crous & W. Gams), ophiobolus (*Gaeumannomyces graminis* Arx et Ol.)	33.0	70	6.7	50	2.1	18.0
Dark brown of spotting: species *Cochliobolus sativus* (Ito&Kurib.) Drechsler ex Dastur (anamorph *Bipolaris sorokiniana* (Sacc.) Shoemaker)	8.0	60	5.2	48.0	0.7	12.0
Brown leaf rust (*Puccinia triticina* Eriks.)	15.6	58	6.5	45	0.4	9.0
Stem rust (*Puccinia graminis* Pers.)	11.0	48	5.8	16	2.5	10.5
Pyrenophorosis (yellow spotting) (*Pyrenophora tritici-repentis* Died.)	6.1	55	9.0	45	5.1	12.1
Snow mold (*Microdochium nivale* (Fr.) Samuels & I.C. Hallett)	5.8	55	2.0	16	0.5	2.5
Leaf septoria (*Septoria tritici* Roberge in Desmaz, teleomorph *Mycosphaerella graminicola* (Fuckel) J. Schröt.)	14.0	50	15	48	3.5	8.1
Powdery mildew (*Blumeria graminis* Speer f. sp. tritici Marchal)	12.3	65	13	50	7.1	16.4
Yellow rust (*Puccinia striiformis* Westend)	8.6	35	3.0	25	2.1	7.0

(Oudem.) Davis.); the rust diseases included the dwarf (*Puccinia hordei* G.H. Orth.), the yellow (*Puccinia striiformis* West.), the stem (linear) (*Puccinia graminis*). According to the research data presented in Table 2, it was established that the area of the spring barley crops affected by the specified diseases was on average from 5.1% to 75.0%. The prevalence of these diseases ranged from 2.0% to 65.0%, and their development varied between 1.2% and 35.0%.

Among the specified diseases, the dark brown spotting dominated, the area of affected crops of spring barley varied between 10.7% and 75.0%, the spread of the disease ranged between 12.0% and 65.0%, and the development varied between 3.7% and 35.0%; the striped and reticulate spotting, where the area affected by crops, was in the range between 5.1% and 75.0%, the spread of the disease varied between 2.0% and 46.0%, and the development ranged between 3.0% and 22.0% (Table 2).

The share of areas affected by the root rot, the septoriosis of leaves, the powdery mildew, and rhynchosporiosis ranged from 6.0 to 70.0%, their spread ranged between 1.0 and 50.0%, and their development varied between 1.1% and 20.0%. Rusty diseases (the dwarf, the yellow, the stem rust) spread much less, the share of the areas affected by them was on average between 6.7% and 20.1%, the spread of the diseases varied between 2.0 and 10.0%, the development of the diseases ranged between 0.5 and 12.0% The neglect of the crop rotation and cultivation of plant (winter) wheat and (spring) barley with low resistance to diseases caused the accumulation of an infectious potential and the development of spotting to the extent of epiphytotia. The sources of the infection are the seeds (infected and sporulated), plant residues of the previous year's sowing, the affected plants, and the wild cereals that are susceptible to the diseases. Rising temperatures and the manifestation of drought due to the climate changes led to rapid aging of leaves, which increased the spread of the spotting. Therefore, carrying out constant a phytopathogenic control of the agrocenoses of grain crops turned out to be an important component of a comprehensive system of the protection against diseases, and it requires further scientific research.

Conclusion

Monitoring of the phytosanitary state of the agrocenoses of grain ear crops has proven a significant spread and development of pathogens of the main types of diseases of fungal etiology. The phytopathogenic complex of the agrocenoses of the winter wheat was dominated by the follow-

Table 2. The spread and development of the main diseases of the common (spring) barley (Hordeum vulgare L.) plants during the growing seasons, average for 2004–2022

The agents of common diseases	Area of affected crops, %		Spread the disease,%		Development of the diseases, %	
	min.	max.	min.	max.	min.	max
The root rot: (*Cochliobolus sativus* (Ito&Kurib.) Drechsler ex Dastur (anamorph *Bipolaris sorokiniana* (Sacc.) Shoemaker, Fusarium spp.).	20.6	70	5.4	50	1.1	20
Dark brown of spotting: (*Cochliobolus sativus* (Ito&Kurib.) Drechsler ex Dastur (anamorph *Bipolaris sorokiniana* (Sacc.) Shoemaker)	10.7	75	12.0	65.0	3.7	35.0
Dwarf rust: (Puccinia hordei G.H. Orth.)	6.7	35	2.5	10.0	2.4	12.0
Yellow rust: (*Puccinia striiformis* West.).	3.0	20.1	2.2	10.0	0.5	9.0
Stem (linear) rust: (*Puccinia graminis* Pers. f. tritici Eriks. et Henn)	5.1	14.0	2.0	8.2	1.8	10.2
Leaf septoria: (*Mycosphaerella graminicola* (Fuckel) J. Schröt.)	6.0	49.1	2.4	14.2	1.2	14.0
Powdery mildew (*Blumeria graminis* (DC.) Speer f. sp. hordei Marchal.)	13.7	50.6	7.1	45.0	1.6	15.0
Spotting: striped – *Pyrenophora graminea* Ito&Kurib. (anamorph *Drechslera graminea* (Rabenh.) Shoemaker, reticulate– *Pyrenophora teres Drechsler* (анаморфа *Drechslera teres* (Sacc.) Shoemaker)	5.1	75.0	2.0	56.0	3.0	22.0
Rhynchosporiosis (*Rhynchosporium secalis* (Oudem.) Davis.)	10.0	55.0	3.5	50.0	3.2	10.0

ing root rots: helmintosporium (*Bipolaris sorokiniana*), fusarium (*Fusarium* spp.), root cercosporellosis (*Oculimacula yallundae*), ophiobolus (*Gaeumannomyces graminis*), which affect up to 70.0% on average, the spread of diseases was 50%, their development totaled 1.81%. At the same time, in the phytopathogenic complex of the spring barley, in addition to the root rot (*Bipolaris sorokiniana*, *Fusarium* spp.), the varieties of spotting like the dark brown (*Cochliobolus sativus*), the striped (*Pyrenophora graminea*), the reticulated (*Pyrenophora teres*), septoriosis of leaves (*Mycosphaerella graminicola*), the powdery mildew dew (*Blumeria graminis*), rhynchosporiosis (*Rhynchosporium secalis*) dominated. The areas of the spring barley crops affected by the specified diseases are on average 5.1–75.0%, the prevalence of these diseases varies from 2.0 to 65,0%, the development ranged between 1.2 and 35.0%. Phytopathogenic microorganisms increased the level of biological contamination of the agrocenoses and the environmental risks in the agroecosystems.

BEZNOSKO, I., PARFENYUK, A., GORGAN, T. (2021) Ecological role of winter wheat varieties is in phytosanitary optimization of agroecosystems. *Ahrobiolohia,* 1, 180–187. (in Ukrainian). DOI: 110.33245/2310-9270-2021-163-1-180–187

CAMPBELL, C.K., JOHNSON, E.M., WARNOCK, D.W. (2013) *Identification of pathogenic fungi*. Wiley-Blackwell, USA.

GUARO, J., GENE, J., STCHIGEL, M., FIGUERAS, A. (2012) *Atlas of soil Ascomycetes*. Issue 10 of CBS Biodiversity Series. Centraalbureau voor Schimmelcultures, Holland.

KORNIYCHUK, M.S. (2019) *Fitosanitarnyi stan ahrotsenoziv v umovakh zminy klimatu ta shliakhy yoho pokrashchennia*. Natsionalnyi naukovyi tsentr «Instytut zemlerobstva Natsionalnoi akademii ahrarnykh nauk Ukrainy», Kyiv (in Ukrainian).

KYRYCHENKO, A., HAVRYLIUK, N., KUZMENKO, L., RAICHUK, T., & BORKO, Y. (2021) Influence of weather conditions on entomological and phytopathogenic complexes of winter wheat in autumn and spring-summer growth season of the forest-steppe zone. *Ukrainian Journal of Ecology*, 11(2), 155–158.

LISCHUK, A.M., PARFENYUK, A.I., GORODYSSKA, I.M., BORODAI, V.V., DRAGA, M.V. (2022) Osnovni vazheli upravlinnia ekolohichnymy ryzykamy v ahrotsenozakh. *Agroecological journal*, 2, 74–85 (in Ukrainian).

MOSTOVYAK, I.I., DEMYANIUK, O.S., BORODAI, V.V. (2020) Osoblyvosti formuvannia fitopatohennoho fonu mikromitsetiv – zbudnykiv khvorob v ahrotsenozakh zernovykh zlakovykh kultur Pravoberezhnoho Lisostepu Ukrainy. *Agroecological journal,* 1, 28–38 (in Ukrainian).

MOSTOVYAK, I.I., DEMYANYUK, O.S., PARFENYUK, A.I., BEZNOSKO, I.V. (2020) Sort yak faktor formuvannia stiikykh ahrotsenoziv zernovykh kultur. *Visnyk Poltavskoi derzhavnoi ahrarnoi akademii,* 2, 110–118 (in Ukrainian).

OMELIUTA, V.P., HRYHOROVYCH, I.V., CHABAN V.S., PIDOPLICHKO, V.N., KALENYCH, F.S., PETRUKHA, O.Y., ANTONIUK, S.I., POZHAR, Z.A., TYSHCHENKO, YE.I., HRYHORENKO, V.H., KOVAL, M.K., CHERNENKO, O.O. (1986) *Oblik shkidnykiv i khvorob silskohospodarskykh kultur*. Urozhai, Kyiv (in Ukrainian).

PARFENYUK, A.I. (2017) Sort roslyn yak chynnyk biolohichnoi bezpeky v ahrotsenozakh Ukrainy. *Agroecological journal,* 2, 155–163 (in Ukrainian). DOI: 10.33730/2077-4893.2.2017.220172

PARFENYUK, A.I., VOLOSHCHUK, N.M. (2016) Formuvannia fitopatohennoho fonu v ahrofitotsenozakh. *Agroecological journal,* 4, 106–113 (in Ukrainian). DOI: 10.33730/2077-4893.4.2016.271247

PETRENKOVA, V.P., LUCHNA, I.S., (2016) Zalezhnist fitosanitarnoho stanu posiviv pshenytsi ozymoi vid pohodnykh umov. *Visnyk Tsentru naukovoho zabezpechennia APV Kharkivskoi oblasti*, 20, 60–68 (in Ukrainian).

SESSITSCH, A., WEILHARTER, A., GERZABEK, M. (2001) Microbial Population Structures in Soil Particle Size Fractions of a Long-Term Fertilizer Field Experiment. Applied *and* Environmental Microbiology, 67(9), 4215–4224. DOI: 10.1128/AEM.67.9.4215-4224.2001

TATARYNOVA, V.I., BURDULANIUK, A.O., ROZHKOVA, T.O. (2018) Fitopatohennyi control hrotsenoziv zernovykh kultur. *Visnyk Sumskoho natsionalnoho ahrarnoho universytetu: naukovyi zhurnal. Seria Ahronomiia i biolohiia,* 3(35), 8–13 (in Ukrainian).

TRYBEL, S.I., SIHAROVA, D.D., SEKUN, M.P. (2001) *Metodyky vyprobuvannia i zastosuvannia pestytsydiv*. Svit, Kyiv, pp. 174–175 (in Ukrainian).

TRYBEL, S.O., HETMAN, M.V., ANDRUSHCHENKO, A.V. (2010) *Metodolohiia otsiniuvannia stiykosti sortiv pshenytsi proty shkidnykiv i zbudnykiv khvorob*. Kolobih, Kyiv (in Ukrainian).

VASILYEVA, T.N., ALYAEVA, O.V., BIKTASHEVA, F.H., IVANOVA, E.A., LEBEDEV, S. (2019) Analysis of the soil treatment in the Urals conditions. *In: IOP Conference Series: Earth and Environmental Science,* 341(1), 1–5.

VAUGHAN, M., BACKHOUSE, D., PONTE, E. (2016) Climate change impacts on the ecology of *Fusarium graminearum* species complex and susceptibility of wheat to Fusarium head blight: A review. *World Mycotoxin*, 9(5), 685–700.