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ANALYSIS OF THE RESULTS OF STUDYING THE SOFT WINTER WHEAT COLLECTION BY RESISTANCE TO POWDERY MILDEW

R. S. Vyskub, O. O. Viniukov
Donetsk State Agricultural Experimental Station of NAAS, 1 Zakhysnykiv Ukrainy St., Pokrovsk, Donetsk region, 85307, Ukraine

Topicality. *The analysis and systematization of wheat collection material will allow us to obtain new sources of resistance and create a trait collection to develop resistant varieties suitable for cultivation in different ecological zones of Ukraine. Yield losses from pathogens can be reduced by introducing new varieties with a wide genetic base of group resistance.* ***Purpose.*** *To evaluate the soft winter wheat collection in terms of powdery mildew resistance in the conditions of the Southern Forest Steppe of Ukraine.* ***Materials and Methods.*** *During 2011–2019, the research was conducted at the Ustymivka Experimental Station of Plant Production Institute named after V. Ya. Yuriev of NAAS of Ukraine. We studied 1406 samples of soft winter wheat (Triticum aestivum* L.*) from 33 countries, including 53.1 % – Ukrainian origin, 10.1 % – from Turkey, 8.6 % – from the United States, 6.9 % – from Russia, 17.0 % – from Europe. The research methods used were as follows: field, dialectical, hypothesis, synthesis, induction, statistical, and observation.* ***Results.*** *The manifestation of the main foliar diseases on collection samples of soft winter wheat was observed to determine field resistance to diseases in the following organogenesis stages: autumn tillering, spring budding, stem elongation, beginning of heading, milk-dough maturity. In the early growth and development stages of wheat plants (seedlings – heading), plants were insignificantly damaged by powdery mildew. In the autumn tillering phase, among 234 samples, 5 samples were detected without powdery mildew: 831/10, 853/10 (UKR), Pesma (YUG), Gruia, Gloria (ROU). In the period of stem elongation, there are 12 samples of soft winter wheat susceptible to this disease in this stage of organogenesis. The dry conditions of 2012 and 2013 allowed us to differentiate wheat collections by disease resistance at the heading stage. The percentage of susceptible and slightly susceptible samples was about 14%.The maximum damage of wheat plants by this pathogen occurs in stage of milky-wax ripeness. Therefore, the distribution of samples by resistance level depended significantly on the conditions of a particular year. In 2011 (extremely humid conditions), the percentage of susceptible samples of wheat to the pathogen was 57.5%; in 2012 and 2013, a larger group of samples was noted as weakly susceptible. It was established that the precipitation amount and the level of hydrothermal coefficient (HTC) significantly affect the number of wheat samples susceptible to powdery mildew during heading (r = 0.83 and r = 0.91, respectively). There was an average correlation between the number of wheat samples highly susceptible to the disease and the HTC level (r=0.33).The distant hybridization method using foreign genes helps to develop more resistant lines to specific pathogens of soft winter wheat.* ***Conclusions.*** *Distribution of winter wheat samples by the level of resistance to powdery mildew depended significantly on the conditions of a particular year. The special collection of samples resistant to the most common diseases of soft winter wheat allows you to systematize the selection of parental lines on specific traits to develop more resistant lines.*

Key words: *soft winter wheat, resistance, powdery mildew, organogenesis stage, hydrothermal coefficient, distant hybridization method*

Introduction. Field resistance to major diseases determines the economic value of the variety in a particular area, and also determines its promising use as a parental component in the breeding process. The immunological properties of many varieties of winter wheat are lost due to the emergence of new races and pathotypes of major pathogens.

Author information:
Roman S. Vyskub, *Candidate in Agricultural Sciences, Senior Researcher at the Department of Breeding and Seed Production of Grain and Forage Crops,* https://orcid.org/0000-0001-7679-2188
Oleksandr O. Viniukov, *Doctor of Agricultural Sciences, Senior Researcher, Director,* e-mail: alex.agronomist@gmail.com, https://orcid.org//0000-0002-2957-5487

Yield losses due to diseases reach 15–32% annually, and in case of epiphytoties – 50% or more. To prevent crop losses caused by pathogens, new varieties with a wide genetic base of group resistance need to be introduced into the production.

These varieties can be grown for a long time in intensive production without the application of chemical plant protection products and can provide significant economic benefits, as well as reduce the negative impact of agricultural production on the environment. The success of the breeding work in this direction largely depends on the involvement and use of new initial material with the best resistance to pathogenic factors. The gene pool of the National Center for Plant Genetic Resources of Ukraine (NCPGRU) collection is the main source of initial material resistant to pathogenic factors. A comprehensive study, analysis and systematization of the initial material of the NCPGRU's world winter wheat collection will allow us to obtain new sources of resistance to major pathogens and create a trait collection, which in turn will significantly improve the status of the national collection of NCPGRU. All this determines the topicality of the study and is of undoubted scientific and practical interest.

According to the analysis of recent publications, there is a need to constantly search for resistant forms of winter wheat in the world collection to create varieties suitable for cultivation in different ecological zones of Ukraine.

Thus, the researchers of the Cereals Genetic Resources Laboratory of the Plant Production Institute named after V. Ya. Yuriev NAAS of Ukraine studied 602 wheat samples, including 403 soft winter wheat and 15 hard winter wheat ones. A catalog containing information on wheat samples resistant to pathogens was published [1–3].

The Ustymivka Experimental Station of Plant Production is constantly studying samples of the world collection for the winter wheat resistance to powdery mildew and brown rust. We have selected 85 samples with individual resistance to a particular disease, 65 samples with group resistance, and 100 immune samples out of 613 samples due to their high productivity [4].

During 2005–2009, H. M. Kovalyshyna studied the resistance to powdery mildew, brown rust and covered smut pathogens of soft wheat samples with different ecological and geographical origin. The following samples were identified as resistant to powdery mildew: Avalon, Rendezvous (UK), PI 170911 (USA) [5].

During 2008–2011, scientists of the Laboratory of Plant Immunity to Diseases and Pests of the Institute of Plant Protection examined 114 winter wheat cultivars in terms of resistance to brown rust, powdery mildew, septoria disease, and Cercospora pathogens, resulting in 23 cultivars with group resistance to certain pathogens [6, 7].

The scientific literature on disease resistance research focuses on the selection of specific samples and the creation of specimen collections for a specific purpose [8–14]. However, we have not found any papers that would address the issue of characterizing the entire wheat collection for a specific trait, in this case, powdery mildew resistance concentrated in a particular genetic center.

The purpose of the research is to characterize a soft winter wheat collection for resistance to powdery mildew in the Southern Forest-Steppe of Ukraine.

Materials and Methods. The studies were conducted in the scientific fields of the Ustymivka Experimental Station of Plant Production at the Plant Production Institute named after V. Ya. Yuriev NAAS of Ukraine during 2011–2019. The studies involved 1406 samples of soft winter wheat (*Triticum aestivum* L.) from 33 countries, including 53.1 % from Ukraine, 10.1 % from Turkey, 8.6 % from the USA, 6.9 % from Russia, and 17.0 % from European countries.

The research was conducted using certified and standardized methods in Ukraine [15, 16]. Evaluation of wheat disease resistance was conducted according to the guidelines accepted in CME member countries [17].

The research method was as follows: field method to determine the field resistance of wheat samples to diseases, as well as the level of other economic and biological traits; special methods were used for the scientific substantiation and generalization of the results of experimental work, along with well-known methods: dialectical, hypothesis, synthesis, induction, statistical.

The arrangement of replications in the experimental variants is sequential. Agricultural practices in the experimental nursery are common for the Southern Forest-Steppe zone. The predecessor for wheat was black fallow. Fertilizers (ammonium nitrate) were applied as spring feeding at the rate of 150 kg/ha. No irrigation was used. The seeds were not treated. In the collection nursery, blocks of national standards and reference varieties were sown every 20 numbers in three replications: Donskaya polukarlikovaya, Ukrainka Odeska, Albatros Odeskyi, Albidum 114, Myronovska 808, Bezostaya 1, Smuglianka, Yednist, Podolianka, Bunchuk, TX95V4926, Redut.

Analysis of the meteorological conditions in the spring-summer for wheat plant growth and development revealed the following: the driest conditions were in 2012, 2013, 2017 and 2018; excessively moist conditions were observed in 2011 and 2015; optimal conditions for wheat cultivation were in 2014, 2016 and 2019 (Fig. 1).

Results and Discussion. The field resistance of soft winter wheat collection samples to the major leaf diseases was determined in the following stages of organogenesis: autumn tillering; spring tillering; stem elongation; beginning of heading; milky-wax ripeness.

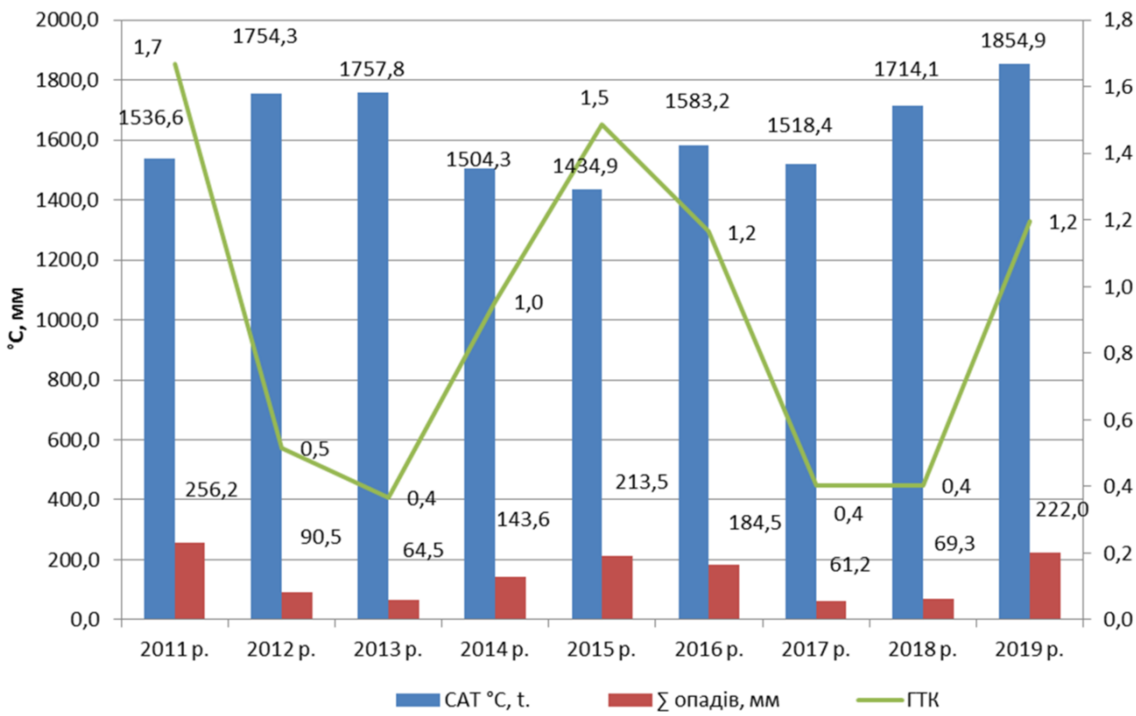

Fig. 1. Meteorological conditions of spring-summer growth season for soft winter wheat plants (according to the data of the meteorological station of Ustymivska Experimental Station of Plant Production, 2011–2019)

A slight powdery mildew damage was observed in the early stages of wheat plant growth and development (germination – heading) (Fig. 2).

It was noted a significant effect of the precipitation amount and the level of hydrothermal coefficient (HTC) on the number of susceptible wheat samples to powdery mildew during the heading stage (r=0.83 and 0.91, respectively). The maximum development of powdery mildew is observed during the period of milky-wax ripeness of wheat. The average level of correlation was between the number of highly susceptible wheat samples to this disease and the level of HTC (r=0.33), the sum of active temperatures (ATS) for the period from the date of spring steady transition of the average daily air temperature through +10 °C - the date of accounting during the period of milky-wax ripeness (r=0.59) and the amount of precipitation (r=0.47).

In the autumn tillering stage, 5 samples out of 234 were not affected by powdery mildew: 831/10, 853/10 (UKR), Pesma (YUG), Gruia, Gloria (ROU) (Table 1).

Blaho and 467/10 (UKR) varieties had the lowest juvenile resistance points to this pathogen, which significantly reduced their winter hardiness and, as a result, their breeding value.

We identified 11 wheat samples susceptible to the disease, which is 4.7% of the total collection samples studied: 945/10, Barvina, Zorepad, Lord, Vatazhok, Kokhana, Shestopalivka (UKR), Albidum 114, Bezostaya 1 (RUS), Tupaeh (MDA), TX95V4926 (USA).

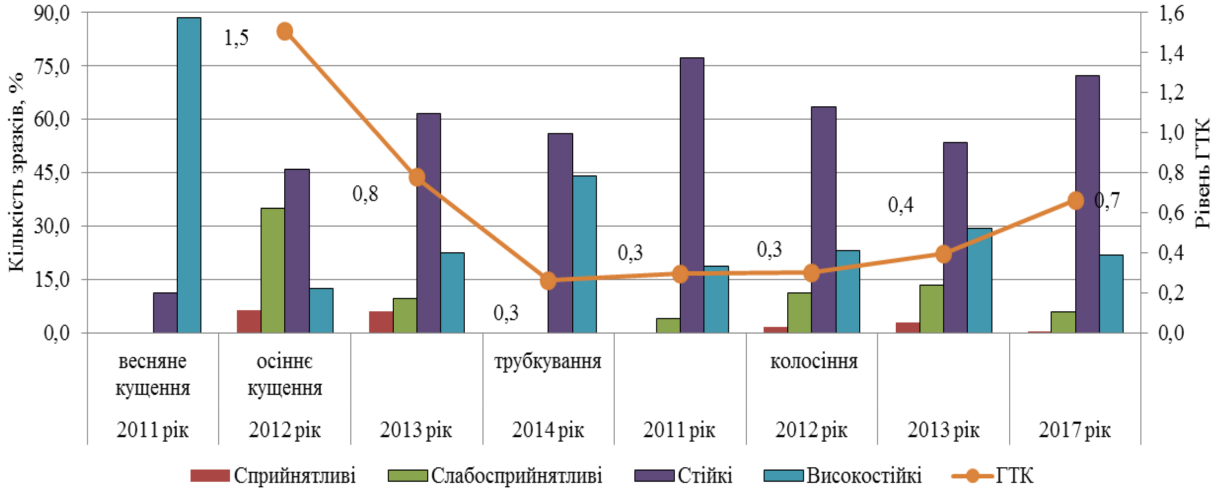

Fig. 2. Distribution of soft winter wheat collections by powdery mildew resistance during the germination-heading period, 2011–2017.

Table 1. Level of juvenile resistance of soft winter wheat samples to powdery mildew, 2012

No.	Name of samples	Origin	Powdery mildew, points
1	831/10	UKR	9
2	853/10	UKR	9
3	Pesma	YUG	9
4	Gruia	ROU	9
5	Gloria	ROU	9
6	Blaho	UKR	3
7	467/10	UKR	3
8	Lord	UKR	4
9	Zorepad	UKR	4
10	Kokhana	UKR	4
11	Albidum 114	RUS	4
12	TX95V4926	USA	4
13	Tupaeh	MDA	4
14	Barvina	UKR	4
15	Shestopalivka	UKR	4
16	Bezostaya 1	RUS	4
17	Vatazhok	UKR	4
18	945/10	UKR	4

During the booting stage, the weather conditions were favorable for the development of powdery mildew, thus, 12 winter wheat samples susceptible to this disease at this stage of organogenesis were identified: 467/10 (UKR), Albidum 114 (RUS), Dunavka (BGR), Xiao Yan107 (CHN), TX95V4926, KS93U161, KS93U194, KS93U59, KS93U61, KS93U62, KS93U63 (USA), Vienna (CAN). Over the years under study, during the specified stage of plant development, no noticeable damage was observed in most of samples the collection material.

The years 2012 and 2013 were more favorable for differentiating wheat collections by disease resistance at the heading stage, when the percentage of susceptible and slightly susceptible samples was about 14%. We identified 20 samples with the lowest juvenile disease resistance (3-4 points): Albidum 114 (RUS), Dunavka (BGR), Sonmez-2001, 362K2.111//TX71A1039.VI*3/AMI/3/ES14/130L1.12//MNCH (IU067603), Jagger/Cetinel (TUR), Xiao Yan107 (CHN), KS93U161, KS93U60, KS93U194, KS93U59, KS93U61, KS93U62, KS93U63, Thunderbird, 2180*K/2163//?/3/ W1062A* HVA114/W3416 (UA0108862), Madsen/Malcolm/6/Hill/3/Cer//Ymh/Hys/4/Cer// Ymh/Hys/5/Rossini/Ysatis//Oracle (IU067766), N95L189, Rawhide (USA), Vienna (CAN), PYN/BAUSWM15182-61WM-0WM-030WM-030WM-2WM-0WM (UDS02897) (MEX).

During milky-wax ripeness, the maximum damage to plants by powdery mildew pathogens occurs, and the distribution of wheat samples by resistance level by year was as follows: in 2011, due to intense precipitation in the first half of the second ten-day period of June (total precipitation for 6 days was 103.9 mm) followed by hot weather, there were favorable conditions for the reproduction and growth of powdery mildew - the percentage of susceptible wheat samples to the pathogen was 57.5%. A similar situation was observed in 2014, there was 50.3 mm of precipitation in nine days in late May and early June, and the percentage of susceptible wheat samples to the disease was 41.0%. In 2012 and 2013, most of the samples were slightly susceptible to the disease. In 2017, most wheat samples showed medium disease resistance. In 2018, despite the dry conditions of the wheat growing season, there was an intensive spread of the disease. In 2015 and 2019, we were unable to objectively differentiate the collection by disease resistance, and there was almost no powdery mildew damage due to unfavorable conditions for the development of powdery mildew pathogens (Table 2).

Most of the collection's samples of soft winter wheat were developed in the period from the 70s of the twentieth century to the present day. Average resistance to powdery mildew and brown rust was observed in samples of Radosinska rana 594 (SVK) bred in 1948 and Kharkivska 159 (UKR) bred in 1969.

Table 2. Distribution of soft winter wheat collection by resistance to the pathogen powdery mildew in the period of their maximum damage, 2011–2019

Samples / Indicators	Years of research, %								
	2011	2012	2013	2014	2015	2016	2017	2018	2019
Highly susceptible samples	5.0	0.9	0.6	0.9		0.0	0.0	1.6	
Susceptible samples	57.5	18.8	10.3	41.0		8.0	20.5	33.2	
Low susceptibility samples	22.0	46.9	35.8	29.1		21.4	23.2	34.1	
Resistant samples	13.2	30.8	32.0	25.6		53.6	48.2	28.5	
Highly resistant samples	2.3	2.6	21.4	3.4		17.0	8.0	2.6	
ATS for the spring-summer period of disease development, °C	1176	1244	1176	1114	993	1087	995	1216	1165
Sum of precipitation during the spring-summer period of disease development, mm	127	80.4	41.3	102	83.9	115.5	47.8	40.7	194
HTC during the spring-summer period of disease development	1.1	0.6	0.4	0.9	0.8	1.1	0.5	0.3	1.7
Relative humidity during the spring-summer period of disease development, %	62.7	68.9	61.1	62.1	61.1	66.9	57.8	57.3	66.4

Among the samples bred in the 70s, average resistance to powdery mildew was observed in Myronivska 808 improved (UKR) and UH 202 (CZE), Noroit (FRA), Hiplains (USA), Kiten (BGR) varieties. High resistance to the disease was noted in Atla (GBR) varieties bred in the 80s. In the 90s, varieties such as Cartago (Germany), Beauford (UK), and Snezhinka (Russia) with high resistance to diseases were noted (Fig. 3).

Most highly susceptible varieties to powdery mildew originate from Turkey, the USA, Canada, Kazakhstan, and China (Fig. 4).

Disease resistance of varieties from different countries depends on the soil and climatic conditions of the region where the variety was bred, as well as the presence of the pathogen in the territory of origin.

The research has shown that the method of remote hybridization using foreign genes helps to obtain lines more resistant to specific pathogens of winter wheat.

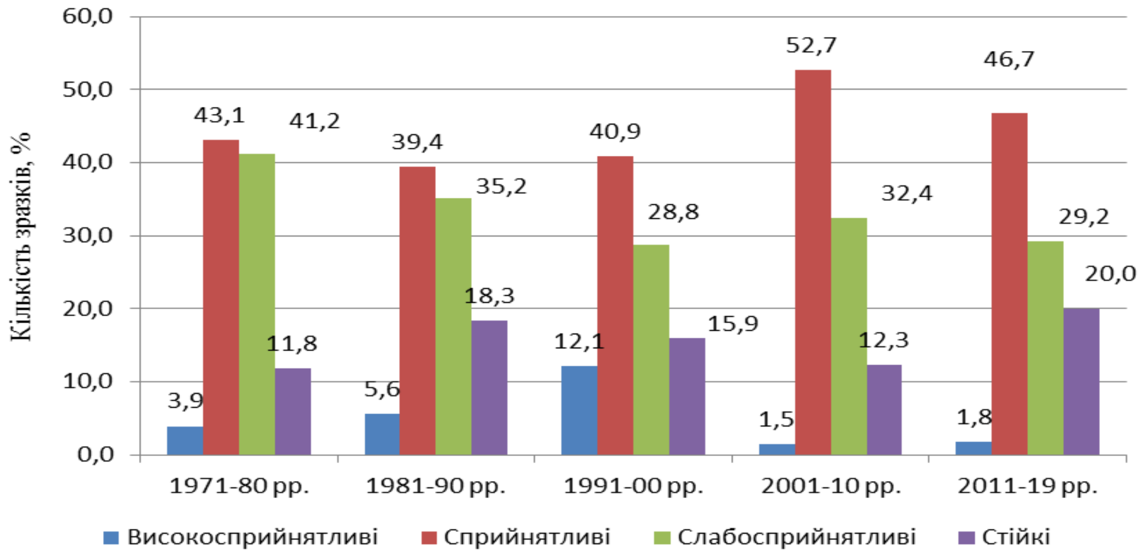

Fig. 3. Distribution of soft winter wheat collections by powdery mildew resistance depending on the year of development, 2011–2019.

The medium susceptibility to powdery mildew was noted in Milturum 1 (UKR), which was developed using durum wheat (*Tr.durum Desf.*) [25], among winter wheat samples obtained by crossing with *Ae. speltoides Tausch.*: Rodina/Ae.speltoides (10 KR) (IU062132), CV. Rodina/Ae.speltoides (10 KR) (IU062133), and 3 sister lines with group resistance to diseases obtained by crossing with Ae. speltoides Tausch. and rye (*S.cereale* L.) were also identified: CV. Rodina/Ae.speltoides (10 KR)/S.cereale (1.0KR) (IU061826), CV. Rodina/Ae.speltoides (10 KR)/S.cereale (1.0KR) (UA0108993), CV. Rodina/Ae.speltoides (10 KR)/S.cereale (1.0KR) (IU062135).

Conclusions. The meteorological conditions analysis over the years of research allows us to differentiate winter soft wheat samples by resistance to the main leaf diseases by organogenesis stages. Thus, during the autumn tillering stage, only 2% of the varieties in the collection were resistant to powdery mildew. In the stage of milky-wax ripeness, when the maximum damage to wheat plants by this pathogen occurs, the distribution of samples by the level of resistance significantly depended on the conditions of a given year.

In 2011 (excessively wet conditions), the percentage of susceptible wheat samples to the pathogen was 57.5%; in 2012 and 2013 (dry conditions), most samples were noted as slightly susceptible.

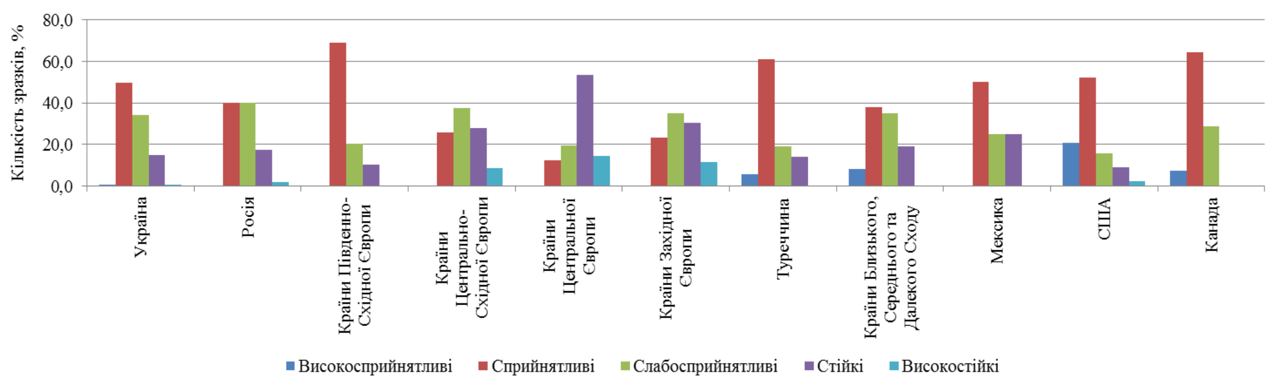

Fig. 4. Distribution of the collection by powdery mildew resistance depending on the country of origin, 2011–2019.

A significant effect of precipitation and hydrothermal coefficient (HTC) on the number of susceptible wheat samples to powdery mildew during the heading period was found (r=0.83 and r=0.91, respectively). The average level of correlation between the number of highly susceptible wheat samples to this disease and the level of HTC was noted (r=0.33).

Studies have shown that the method of distant hybridization using foreign genes allows us to obtain the lines that are more resistant to specific pathogens of winter wheat, primarily due to crossing with *Ae. speltoides*, 2 sister lines were identified by group resistance to diseases, as well as 3 sister lines by crossing with *Ae. speltoides* and rye (*S.cereale*).

A special collection of winter wheat samples resistant to the most common diseases allows us to systematize the selection of parental lines based on certain traits, which will allow us to develop more resistant lines.

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Актуальність. Аналіз та систематизація колекційного матеріалу пшениці дозволить отримати нові джерела стійкості та створити ознакову колекцію для створення стійких сортів. придатних для вирощування в різних екологічних зонах України. **Визначення проблеми.** Для запобігання втрати врожаю від патогенів потрібно вводити у виробничий процес нові сорти з широкою генетичною базою групової стійкості. **Мета.** Охарактеризувати колекцію пшениці м'якої озимої за стійкістю до борошнистої роси в умовах Південного Лісостепу України. **Матеріали і методи.** Дослідження були проведені в Устимівській дослідній станції рослинництва ІР НААН України впродовж 2011–2019 рр. Для дослідження було взято 1406 зразків пшениці м'якої озимої (Triticum aestivum L.) з 33 країн світу, серед яких 53.1 % – з України, 10.1 % – з Туреччини, 8.6 % – з США, 6.9 % – з Росії, 17.0 % – з країн Європи. Методи дослідження: польовий, діалектичний, гіпотез, синтезу, індукції, статистичний, спостереження. **Результати.** Визначення польової стійкості колекційних зразків пшениці м'якої озимої до прояву основних листкових хвороб проводилось в наступні фази органогенезу: у фазу осіннього кущіння; у фазу весняного кущіння; у фазу виходу рослин в трубку; у фазу початку колосіння; у фазу молочно-воскової стиглості. У ранні етапи росту і розвитку рослин пшениці (сходи-колосіння) відмічалося незначне ураження рослин борошнистою росою. В осінню фазу кущіння із 234 зразків виявлено 5 зразків. на яких не спостерігалося ураження борошнистою росою: 831/10. 853/10 (UKR). Pesma (YUG). Gruia. Gloria (ROU). В період трубкування виявлено 12 зразків пшениці м'якої озимої. сприйнятливих до прояву цієї хвороби у цю фазу органогенезу. Для диференціації колекції пшениці за стійкістю до хвороби у період колосіння більш сприятливим виявилися 2012 та 2013 рр. (посушливі умови). в яких відсоток сприятливих та слабо сприйнятливих зразків. що вивчалися. становив приблизно 14 %. У фазі молочно-воскової стиглості. коли відбувається максимальне ураження даним патогеном рослин пшениці. розподіл зразків за рівнем стійкості значно залежав від умов конкретного року. Так. у 2011 р. (надмірно зволожені умови) відсоток сприйнятливих зразків пшениці до патогену становив 57.5 %; у 2012 та 2013 рр. більша група зразків відмічалася як слабо сприйнятлива. Встановлено суттєвий вплив суми опадів та рівня гідротермічного коефіцієнта (ГТК) на показник кількості сприйнятливих зразків пшениці до борошнистої роси в період колосіння (r=0.83 та r=0.91 відповідно). Відмічений середній рівень кореляційного зв'язку між показниками кількості високо сприйнятливих зразків пшениці до даної хвороби та рівнем ГТК (r=0.33). Метод віддаленої гібридизації з використанням чужорідних генів сприяє отриманню ліній більш стійких до конкретних збудників хвороб пшениці м'якої озимої. **Висновки**. Розподіл зразків рослин пшениці озимої за рівнем стійкості до борошнистої роси значно залежав від умов конкретного року. Створення спеціальної колекції зразків стійких до найпоширеніших хвороб пшениці м'якої озимої дозволяє систематизувати процеси підбори батьківських ліній за конкретними ознаками. що дозволить створити більш стійкі лінії.

Ключові слова: *пшениця м'яка озима. стійкість. борошниста роса. фази органогенезу. гідротермічний коефіцієнт. метод віддаленої гібридизації*