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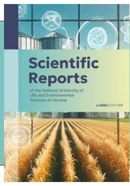

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Influence of infection by pathogens on the physiological parameters of *Triticum aestivum* L.

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Abstract. The purpose of the study was to establish the influence of damage to the main pathogens of winter wheat on its physiological parameters and to determine the sources of resistance of the variety to these pathogens. Breeding work to identify sources of resistance was carried out under the

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conditions of artificial inoculation with pathogens in field infectious nurseries. In order to identify sources of resistance to major pathogens in the collection nursery, approximately 400 collection samples of winter wheat were tested under artificial infection conditions with *Septoria tritici*, *Puccinia recondita*, *Fusarium graminearum*, *Tilletia caries*, *Cercosporella herpotrichoides* and a challenge background of *Erysiphe graminis*. The results of studies conducted in the autumn tillering phase showed that powdery mildew damage to plants causes a violation of the structural and functional state of cell membranes, accompanied by an increase in the electrical conductivity of tissues. At the level of leaf surface damage of 30-50%, the value of this indicator increased more than twice compared to healthy plants. In the earing phase, powdery mildew damage to the flag leaf caused an increased yield of electrolytes from cells, especially in genotypes with increased susceptibility to the pathogen. A similar pattern was observed for the development of septoria leaf blotch and brown rust. When plants are affected by the pathogen *Cercosporella herpotrichoides*, there was also a gradual increase in the electrical conductivity of cell membranes with an increase in the degree of development of the disease. A direct relationship was established between the intensity of plant damage and the level of electrical conductivity of cell membranes. The maximum values of electrical conductivity of cell membranes (98.8-100.0%) were recorded in susceptible varieties 'Donska Napivkarlykova' (affected by septoria leaf blotch) and 'Myronivska 10' (affected by brown rust) in the earing phase with the development of diseases up to 50%, the minimum electrical conductivity (8.4%) was observed in immune plants in the autumn tillering phase with the complete absence of powdery mildew infection. The identified patterns between the degree of plant damage by pathogens and the level of electrical conductivity of tissues can be used in breeding practice for early selection of resistant genotypes

Keywords: winter wheat; *Septoria tritici*; brown rust; powdery mildew; electrical conductivity of tissues; disease resistance; selection

Introduction

Soft wheat (*Triticum aestivum* L.) is one of the most important food crops in the world, but its productivity is significantly reduced by infection with plant pathogens. The development of pathogens negatively affects the physiological state of plants, in particular, the intensity of photosynthesis, the content of photosynthetic pigments, water regime and metabolic processes, which leads to crop losses and deterioration of grain quality. The investigation of changes in physiological parameters due to plant disease is important for revealing the mechanisms of wheat resistance and improving crop protection measures in agricultural production (Juroszek & Tiedemann, 2013).

Considerable attention of researchers was paid to the physiological mechanisms of interaction of soft wheat (*Triticum aestivum* L.) with pathogens, since it is the physiological responses of plants that largely determine the level of their resistance and productivity. Of particular importance are studies aimed at establishing a link between the development of the infectious process and changes in the functional state of the plant organism. J. Mapuranga *et al.* (2022) summarised current data on the physiological, biochemical, and molecular mechanisms of wheat interaction with the powdery mildew pathogen, and considered the role of resistance genes, reactive oxygen species, and plant defence responses. L.C. Ferreira *et al.* (2024) found that the infection of wheat by the tan spot pathogen (*Pyrenophora tritici-repentis*) is accompanied by significant changes in carbohydrate metabolism. The researchers found a decrease in the content of individual sugars, a restructuring of metabolic processes and activation of plant protection systems. The researchers stressed that metabolic changes can be used as markers of disease resistance.

S. Francesconi *et al.* (2021), using advanced methods of remote monitoring and analysis of gene expression, investigated the physiological responses of durum wheat to Fusarium head blight infection. It was found that the development of the disease is accompanied by changes in the temperature regime of plants, a violation of the water balance, and activation of protective response genes. The results obtained confirmed a close relationship between the physiological state of plants and the degree of development of the infectious process. Researchers paid special attention to the investigation of oxidative and antioxidant processes in wheat plants. V. Turenko *et al.* (2024) investigated the specifics of septoria leaf blotch development in the Forest-Steppe of Ukraine, finding that with an increase in the degree of plant damage, the indicators of their physiological state worsen, the assimilation activity of the leaf apparatus decreases, and a crop shortage is formed. O.O. Molodchenkova *et al.* (2022) investigated the features of the course of oxidative-antioxidant reactions in plants infected with *Septoria tritici*. The researchers found that the development of septoria leaf blotch is accompanied by the accumulation of lipid peroxidation products, changes in the activity of antioxidant enzymes, and a violation of cellular homeostasis. The detected changes were more pronounced in susceptible genotypes compared to resistant ones. M. Battache *et al.* (2024) found that the effectiveness of pathogen penetration through stomata is one of the key factors in the development of wheat resistance to septoria leaf blotch, and the physiological state of the stomatal apparatus determines the further development of infection.

A significant contribution to the understanding of the physiological responses of wheat plants to powdery mildew infection was made by V.V. Zhuk *et al.* (2022). They showed that the development of the disease is accompanied by the accumulation of hydrogen peroxide, a change in the activity of antioxidant defence enzymes and a restructuring of metabolic processes. The researchers concluded that physiological and biochemical parameters can be used to assess the level of resistance of genotypes to the pathogen. A.Yu. Zhupyna *et al.* (2022) investigated the patterns of inheritance of powdery mildew resistance in winter wheat hybrids of various ecological and genetic origins. The researchers established the features of the manifestation of the trait in the offspring and identified promising parental forms for creating resistant varieties. A.C. Velho *et al.* (2022) found that activation of plant defence reactions is accompanied by changes in antioxidant activity, accumulation of protective compounds, and a decrease in the intensity of powdery mildew development.

Along with studying the physiological reactions of plants, a significant amount of research was devoted to the search for sources of resistance to diseases. L.A. Murashko *et al.* (2022) evaluated winter wheat varieties on artificial infectious backgrounds of the main pathogens. Based on the results of research, a number of varieties with group resistance to a complex of pathogens have been identified, which can be used in breeding programmes. V. Plyhun *et al.* (2022) summarised current data on resistance genes to *Blumeria graminis* and mechanisms of their functioning. The researchers showed that the effectiveness of genetic protection is largely determined by the ability of plants to quickly activate the physiological and biochemical mechanisms of response to pathogen penetration.

The analysis of contemporary scientific literature showed that the defeat of wheat plants by pathogens is accompanied by a complex of physiological and biochemical changes, among which the most common are the suppression of photosynthesis, the development of oxidative stress, violation of carbohydrate metabolism, and the functioning of cell membranes. Most studies are devoted to individual pathogens or individual physiological indicators. The issues of the complex influence of the main pathogens of winter wheat on the permeability of cell membranes and the possibility of using the electrical conductivity index of tissues as an integral criterion for assessing plant resistance remain insufficiently investigated. There is also limited information on the use of this indicator for rapid screening of breeding material in conditions of artificial infectious backgrounds. That is why the purpose of this study was to identify the influence of damage to the main pathogens of winter wheat on the physiological parameters of plants and identify a source of resistance against them.

Materials and Methods

The study was conducted during 2020-2024 in the field infection nurseries of the Department of Plant Protection at the V.M. Remeslo Myronivka Institute of Wheat, National Academy of Agrarian Sciences of Ukraine, located in Tsentralne Village, Obukhiv District, Kyiv Oblast, in the northern part of the Right-Bank Forest-Steppe zone of Ukraine. Breeding work to identify sources of resistance against the main pathogens was carried out under conditions of artificial inoculation with them in field infectious nurseries according to generally accepted methods. The study was consistent with the principles set out in the Convention on Biological Diversity (1992).

To identify sources of resistance to the major wheat pathogens, 400 winter wheat accessions representing different ecological and geographical groups, together with 108 entries from the ecological variety trial, were evaluated in the collection nursery using separate artificial inoculation backgrounds of *Septoria tritici*, *Puccinia recondita*, *Fusarium graminearum, Tilletia caries,* and *Cercosporella herpotrichoides*, and a disease-conducive background for *Erysiphe graminis*. Assessment of the resistance of winter wheat plants against pathogens was carried out in dynamics (to study the increase in the disease), the main assessment was considered during the period of maximum development of diseases. For *Erysiphe graminis*, *Septoria tritici*, *Fusarium graminearum* – winter wheat flowering phase, *Puccinia Recondita* – milk ripeness phase, *Tilletia caries* – milk-wax ripeness phase was determined according to V.V. Kyrylenko *et al.* (2018). Experiments on evaluating wheat varieties and numbers for disease resistance using artificial inoculation were conducted using the method of S.O. Tkachyk *et al.* (2017). Physiological tests were performed in the laboratory of plant genetics and physiology according to the methods provided by T.V. Parshykova (2010), Z.M. Hrytsaienko *et al.* (2003). To determine the effect of abiotic factors, in particular, weather conditions (precipitation and temperature), on the development of diseases and pest infestation, the hydrothermal coefficient (HTC) was used (Pykalo *et al.*, 2021).

Results and Discussion

Both biotic and abiotic factors influence the development of winter wheat diseases and pest infestation. Weather conditions of the growing year are one of the most important factors for the development of pathogenic organisms of grain crops throughout the growing season, so it is necessary to monitor them. Weather conditions of the growing seasons of 2023-2024 significantly affected the development of major diseases of winter wheat. The winter of 2022/2023 was favourable for overwintering plants, and excessive moisture in April 2023 (exceeding the precipitation rate by 40.0 mm) contributed to the development of leaf diseases. The intensity of powdery mildew damage was 1.0-15.0%, septoria leaf blotch – 3.0-30.0%, brown rust – 10.0-15.0%. However, the lack of precipitation in May-June (HTC 0.46-0.67) restrained the further spread of pathogens. Despite a significant amount of precipitation in July (183.5 mm), no significant effect on the increase in diseases was observed. The autumn period of 2023 was characterised by dry conditions, which limited the development of infection and the colonisation of crops by pests. In 2024, the resumption of vegetation took place on March 21. Excessive moisture in March-April (excess of precipitation by 51.3 and 24.6 mm, respectively) contributed to the initial development of leaf diseases. However, an acute lack of precipitation in May (5.8 mm; HTC 0.12) stopped the development of pathogens. Elevated air temperatures during April-July, which exceeded the annual average by 2.0-3.3°C, also restrained the spread of leaf diseases and root rot. In general, the dry conditions of the autumn and spring-summer periods contributed to a decrease in the intensity of the development of major diseases of winter wheat and the number of pests.

Analysis of the intensity of damage by the main pathogens of wheat from the tillering period to full ripeness helped to identify the average development of pathogens *Erysiphe graminis, Septoria tritici*, *Puccinia Recondita, Fusarium graminearum*, *Tilletia caries, Cercosporella herpotrishoides* on winter wheat varieties of various breeding centres of Ukraine and a collection nursery in 2024. Higher development of common bunt (*Tilletia caries*) was noted in 2023, when the average infection rate was 55.1%. Maximum development of Fusarium head blight (*Fusarium graminearum*) was also observed in 2023 – 7.4%, which was conditioned by favourable weather conditions for the pathogen during the period of grain development and maturation. The greatest development of root rot (*Cercosporella herpotrichoides*) was recorded in 2022 at the level of 37.1%. The highest incidence of powdery mildew (*Erysiphe graminis*) (33.8%) and brown rust (*Puccinia recondita*) (29.7%) was also recorded in the same year, indicating that conditions throughout the growing season were favourable for the development of foliar diseases. Among the pathogens studied, the highest level of development was noted for septoria leaf blotch (*Septoria tritici*), which reached 47.9% in 2020. This confirms the significant harmfulness of this disease and its high dependence on weather conditions, primarily the availability of moisture. The results obtained indicate a significant influence of hydrothermal conditions of the year on the formation of the phytosanitary state of winter wheat crops and the intensity of development of the main pathogens (Fig. 1).

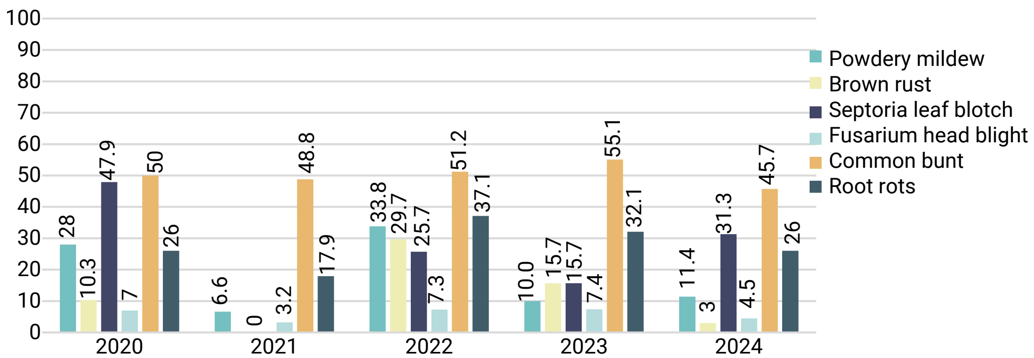

***Figure 1.** Development of pathogens of major diseases on winter wheat varieties of collection and ecological nurseries, %, 2020-2024*

Source: compiled by the authors

Immunological characteristics of varieties with group resistance against the main pathogens showed that the defeat of varieties from different growing zones was in the range from 0 to 14.1%, with the defeat of the variety – standard 'Podolianka' from 10.0% (septoria leaf blotch) to 50.0% (Fusarium head blight). Immunity against powdery mildew was characterised by the variety of Myronivska selection 'MIP Yuvileyna', and against common bunt – 'Kolumbiia' and 'Smuhlianka' (joint selection of IPPG, MIP). It should be noted that the variety 'Smuhlianka' has developed a high resistance against five diseases (*Erysiphe graminis, Septoria tritici*, *Puccinia Recondita, Fusarium graminearum*, *Tilletia caries*) (Table 1).

Table 1. *Immunological characterisation of winter wheat varieties in the ecological variety trial for complex resistance to winter wheat diseases, average for 2020-2024*

Variety	Origin	Disease infection, %					
		powdery mildew	septoria leaf blotch	brown rust	common bunt	root rots	Fusarium head blight
'Podolianka'	IPPG, MIP	15.0	10.0	30.0	50.0	35.7	10.0
'Kolumbiia'	IPPG, MIP	10.0	5.0	10.0	0	5.7	3.0
'Smuhlianka'	IPPG, MIP	5.0	3.0	5.0	0.5	14.1	5.0
'Volodarka'	IPPG, MIP	8.0	5.0	11.0	5.0	13.5	5.0
'Slavna'	IPPG, MIP	5.0	3.0	10.0	5.0	11.0	3.0
'Dobirna'	IPPG, MIP	10.0	5.0	12.0	3.0	10.5	10.0
'Epoha Odeska'	PBGI	3.0	8.0	10.0	5.0	14.0	7.0
'Zhayvir'	PBGI	3.0	3.0	10.0	5.0	15.0	7.0
'Ekonomka'	MIP, IPP	1.0	6.0	8.0	15.0	10.2	7.0
'MIP Dniprianka'	MIP	3.0	5.0	10.0	15.0	10.0	5.0
'MIP Yuvileyna'	MIP	0	5.0	10.0	10.0	13.0	5.0
'MIP Feyeriya'	MIP	3.0	3.0	10.0	15.0	9.5	8.0
'MIP Lada'	MIP	3.0	3.0	10.0	9.0	8.0	3.0

Note: IPPG – Institute of Plant Physiology and Genetics of the National Academy of Sciences of Ukraine (NAS of Ukraine); MIP – V.M. Remeslo Myronivka Institute of Wheat of the National Academy of Agrarian Sciences of Ukraine (NAAS of Ukraine); PBGI – Plant Breeding and Genetics Institute – National Centre of Seed and Cultivar Investigation of the National Academy of Agrarian Sciences of Ukraine (NAAS of Ukraine); IPP – Institute of Plant Protection of the National Academy of Agrarian Sciences of Ukraine (NAAS of Ukraine)
Source: compiled by the authors

According to group resistance (damage from 0 to 15.0%), the following samples were identified among the collection samples: 'Century', 'HBF 0140-19' (USA), 'Cerco 41', 'Hadmers leben' (GEO), 'UH 755', 'so 83-1946' (CZE), 'MV-Suveges' (USA), 'Nobeoka bozu' (JPN), etc., while susceptibility standards ranged from 15.0 % (Fusarium head blight) to 60.0 % (common bunt). Immune against *Erysiphe graminis*, and *Puccinia Recondita* were varieties 'Hadmers leben' (GEO), 'UH 755', 'SO 83-1946' (CZE), 'MV-Suveges' (USA). High group resistance in various combinations to six diseases (*Erysiphe graminis*, *Septoria tritici*, *Puccinia Recondita*, *Fusarium graminearum*, *Tilletia caries*, *Cercosporella herpotrishoides*) was noted on the varieties: 'Hadmers leben' (GEO), 'VR 89 Bo 22' (FRA) and 'Dromos' (GEO), up to five in various combinations: 'Century' , 'HBF 0140-19' (USA), 'UH 755' (CZE), 'Nobeoka bozu' (JPN). The remaining samples had high to moderate resistance to pathogens (Table 2).

Table 2. *Immunological characteristics of winter wheat variety samples of the collection nursery for complex resistance against diseases of winter wheat, average for 2020-2024*

Variety sample	Country	Intensity of disease damage, %					
		powdery mildew	brown rust	septoria leaf blotch	root rots	common bunt	Fusarium head blight
'Myronivska 10' – susceptibility standard	UKR	50.0	25.0	35.0	34.4	50.0	15.0
'Keprok' – susceptibility standard	USA	30.0	25.0	25.0	22.0	50.0	15.0
'Donska Napivkarlykova' – susceptibility standard	RUS	30.0	20.0	30.0	26.0	60.0	15.0
'Century'	USA	5.0	5.0	3.0	8.0	10.0	3.0
'HBF 0140-19'	USA	3.0	1.0	5.0	1.0	15.0	1.0
'Cerco 41'	GEO	6.0	5.0	5.0	10.0	6.0	3.0

***Table 2.** Continued*

Variety sample	Country	Intensity of disease damage, %					
		powdery mildew	brown rust	septoria leaf blotch	root rots	common bunt	Fusarium head blight
'Hadmers leben'	GEO	0	0	5.0	2.0	8.0	3.0
'UH 755'	CZE	0	0	5.0	8.0	15.0	1.0
'SO 83-1946'	CZE	0	0	3.0	10.0	10.0	1.0
'MV-Suveges'	USA	0	0	1.0	10.2	10.0	3.0
'Nobeoka bozu'	JPN	1.0	3.0	3.0	10.0	6.0	1.0
'VR 89 Bo 22'	FRA	1.0	0	5.0	6.0	5.0	3.0
'Dromos'	GEO	5.0	0	3.0	7.0	8.0	1.0

Source: compiled by the authors

The study of the effect of pathogen damage on the physiological parameters of winter wheat plants (leaves during earing) revealed that with an increase in disease damage, the electrical conductivity of cell membranes increases. Ear diseases do not cause significant disruption of the cell membranes of the leaf surface, so the difference in electrical conductivity between affected and non-affected plants is not significant. The results of tests conducted in the autumn period in the tillering phase of winter wheat, with the defeat of leaves by the causative agent of powdery mildew indicate that the defeat of the above-mentioned pathogen leads to irritation of cell membranes, which in turn increases the electrical conductivity and with the defeat of the leaf surface by 30-50%, this feature increases more than twice. In the earing phase of winter wheat, powdery mildew damage to the flag leaf causes a higher outflow of electrolytes in a more susceptible variety. A similar pattern was observed on varieties affected by septoria leaf blotch and brown rust. For plant damage caused by the pathogen *Cercosporella herpotrichoides*, the electrical conductivity of cell membranes increases as plant damage grows. The greater the damage to the variety, the greater the electrical conductivity of cell membranes (Table 3).

***Table 3.** Influence of pathogen damage on physiological parameters indicators of winter wheat plants, 2024*

Variety sample	Pathogen damage, %		Electrical conductivity of cell membranes, %	
	infected	not infected	infected	not infected
Cercosporella herpotrichoides				
'Cerco 3715/80'	2	0	70.8	65.3
'Tarzo'	8	0	88.5	66.7
'MV-Emese'	10	0	90.0	76.0
'Myronivska 61' – susceptibility standard	44	0	100.0	79.6
Fusarium graminearum				
'MV-62/7'	3	0	71.7	70.9
'KRISTADORA'	15	0	81.6	78.9
'Akter'	20	0	87.9	83.5
'Myronivska 61' – susceptibility standard	25	0	90.0	85.4
Tilletia caries				
'Sel.M 65-3157 (Bt 9)'	0	0	37.6	37.2
'OK 941611'	5.0	0	37.5	35.2
'Farandol'	30.0	0	46.7	44.2
'Myronivska 808' – susceptibility standard	80.0	0	54.4	50.1

***Table 3.** Continued*

Variety sample	Pathogen damage, %		Electrical conductivity of cell membranes, %	
	infected	not infected	infected	not infected
Erysiphe graminis				
Autumn tillering				
'Pi 170911'	0	0	8.4	8.6
'V 1275'	10	0	15.3	9.9
'Flamura'	30	0	20.0	8.8
'Keprok' – susceptibility standard	50	0	21.0	10.0
Earing				
'Pi 170911'	0	0	62.0	61.7
'V 1275'	10	0	73.3	69.7
'Flamura'	30	0	79.5	64.3
'Keprok' – susceptibility standard	40	0	89.6	67.4
Septoria tritici				
'Dromos'	5	0	58.1	57.7
'Ocapi'	15	0	85.3	63.6
'HE-14-15'	25	0	92.1	69.7
'Donska Napivkarlykova' – susceptibility standard	50	0	98.8	70.4
Puccinia recondita				
'VR 89 Bo 22'	1	0	78.5	78.2
'R. 5-1'	10.0	0	89.4	79.1
'TAM-107'	30.0	0	96.8	80.4
'Myronivska 10' – susceptibility standard	50.0	0	100.0	80.8

Source: compiled by the authors

The highest electrical conductivity of cell membranes of 98.8% and 100.0% were found for pathogen damage up to 50.0% in susceptible varieties 'Donska Napivkarlykova' (septoria leaf blotch) and 'Myronivska 10' (brown rust) during earing, and the lowest – 8.4% on immune plants (powdery mildew infection 0%) during autumn tillering. Differences in physiological parameters were revealed in different varieties of winter wheat in terms of resistance to diseases and between plants with different degrees of powdery mildew and septoria leaf blotch. It was found that with the growth of plant damage by pathogens, the intensity of respiration decreases and the electrical conductivity of cell membranes increases. A smaller difference between the physiological parameters of healthy and affected leaves in more resistant wheat varieties has been proven.

The results obtained are consistent with the data by U. Adhikari *et al.* (2023), who found that the development of septoria leaf blotch disease in wheat is largely dependent on weather conditions, primarily precipitation and humidity. The researchers noted that wet periods promote the rapid spread of infection and increase the rate of disease development in plants. Similar patterns were noted by K. Sunic *et al.* (2023), who showed that high humidity and moderate temperatures contribute to the active development of Fusarium head blight, while arid conditions restrain the development of pathogens and reduce the intensity of disease manifestation. The results of current observations also support the conclusions of V. Turenko *et al.* (2024), who established a gradual increase in the prevalence and development of septoria leaf blotch from the tillering phase to milky-waxy ripeness. The researchers noted the crucial role of weather conditions in the formation of the epiphytotic process and the need for constant monitoring of the development of the disease. In addition, the obtained indicators of the development of powdery mildew, septoria leaf blotch, and common bunt are comparable with the results of research by Ukrainian researchers on the evaluation of wheat collection material on artificial infectious backgrounds. In their studies, the level of development of septoria leaf blotch reached 44.8-63.3%, powdery mildew – 18.0-54.5%, and common bunt – 55.2-78.4%, which confirms a significant dependence of the development of pathogens on the weather conditions of the year and the genetic characteristics of varieties.

Data on the high resistance of the 'Smuhlianka' variety to five pathogens were obtained (*Erysiphe graminis, Septoria tritici, Puccinia recondita, Fusarium graminearum, Tilletia caries*), confirming the current trend of using varieties with complex or broad-spectrum resistance as the most effective and environmentally safe way to protect wheat crops. According to research data from L. Golosna *et al.* (2021), T. Bapela *et al.* (2023), it is the combination of several genes and resistance mechanisms that provides long-term control of powdery mildew, rust, and other economically important grain diseases.

The results obtained regarding the increase in the electrical conductivity of cell membranes with an increase in the degree of damage to winter wheat plants indicate an increase in physiological and biochemical disorders in plant tissues under the influence of the pathogen. This is consistent with the data by M. Dmochowska-Boguta *et al.* (2021), who during the study of the reaction of wheat to infection with the causative agent of brown rust (*Puccinia recondita*) found that the infectious process is accompanied by activation of oxidative processes, accumulation of reactive oxygen species, development of necrotic reactions and violation of the integrity of cellular structures. The researchers also showed the key role of polyamine oxidase in the development of a protective response of plants and proved that the intensity of oxidative stress directly depends on the degree of disease development. Therefore, an increase in the electrical conductivity of membranes in this study can be considered as one of the manifestations of destabilisation of cellular structures and an increase in the release of electrolytes from cells in the context of the progression of the pathological process.

In susceptible genotypes, physiological disorders were significantly more pronounced than in resistant forms. The revealed relationship between the degree of damage to the leaf apparatus and the increase in tissue electrical conductivity is consistent with the data of H. Yang & P. Luo (2021), who noted that fungal pathogens cause destabilisation of cell membranes, increased oxidative processes, and disruption of the water regime of plants. The researchers have proven that infection of wheat plants with pathogens is accompanied by a decrease in the content of chlorophyll, disruption of photosystems 1 and 2, a decrease in the intensity of photosynthesis and transpiration. H. Yang & P. Luo concluded that the parameters of photosynthetic activity can serve as sensitive indicators of early detection of plant damage by pathogens and assessment of their resistance.

Thus, the results of the study show that the development of major diseases of winter wheat is determined not only by the hydrothermal conditions of the year, but also by the biological characteristics of pathogens and the genotypic specifics of varieties. The revealed differences between resistant and susceptible forms confirm that the defeat of plants by fungal pathogens is not limited to external symptoms, but is accompanied by deeper physiological changes, in particular, a violation of the permeability of cell membranes and an increase in the release of electrolytes from cells. The most pronounced increase in the electrical conductivity of tissues in susceptible varieties with the development of septoria leaf blotch, brown rust, powdery mildew, and cercosporellous root rot gives grounds to consider this indicator as an informative marker of the functional state of plants and a potential criterion for selecting stable breeding material.

Conclusions

It was established that dry weather conditions in the autumn period of recent years restrained the development of major diseases of winter wheat and reduced the level of pest infestation of crops. 108 samples of ecological variety testing and about 400 collectible samples of winter wheat were evaluated on artificial infectious backgrounds of the main pathogens. Among the varieties of ecological variety testing, sources of group resistance to the pathogen complex identified 'Kolumbiia', 'Volodarka', 'Slavna', 'Dobirna', 'Epoha Odeska', 'Zhayvir', 'Ekonomka', 'MIP Dniprianka', 'MIP Yuvileyna', 'MIP Feyeriya', and 'MIP Lada'. In the collection nursery,samples 'Century', 'HBF 0140-19', 'Cerco 41', 'Hadmers Leben', 'UH 755', 'SO 83-1946', and 'MV-Suveges' were isolated by group resistance (0-15.0% damage). Immunity to *Erysiphe graminis and Puccinia recondita* samples of 'Hadmers Leben', 'UH 755', 'SO 83-1946', and 'MV-Suveges' were found. Studies of the physiological response of plants to pathogen damage have shown a direct relationship between the degree of development of the disease and the level of electrical conductivity of cell membranes. Damage to plants by powdery mildew, septoria leaf blotch, brown rust, and cercosporellous root rot was accompanied by an increase in the permeability of cell membranes and an increase in the release of electrolytes from cells. In the autumn tillering phase, when powdery mildew affected at the level of 30-50%, the electrical conductivity of tissues increased more than twice compared to healthy plants. A similar pattern was noted during the earing period with the development of other studied diseases. The maximum values of electrical conductivity of cell membranes (98.8–100.0%) were recorded in susceptible varieties 'Donska Napivkarlykova' and 'Myronivska 10' with the development of septoria leaf blotch and brown rust up to 50%. The lowest rate (8.4%) was observed in immune plants in the absence of powdery mildew damage in the autumn tillering phase.

The results obtained confirm the possibility of using the electrical conductivity index of cell membranes as a fast and informative physiological marker for assessing the resistance of winter wheat to major fungal diseases. Selected sources of group resistance can be involved in breeding programmes to create new varieties with complex resistance to pathogens. Further research should focus on elucidating the physiological and biochemical mechanisms underlying disease resistance and developing rapid methods for selecting breeding material based on cell membrane permeability indicators.

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Conflict of Interest

None.

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Вплив ураження збудниками хвороб на фізіологічні показники рослин *Triticum aestivum* L.

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Анотація. Метою дослідження було встановити вплив ураження основними збудниками хвороб пшениці озимої на її фізіологічні показники, визначення джерел стійкості сорту до цих збудників.

Селекційна робота щодо виявлення джерел стійкості здійснювалася за умов застосування штучної інокуляції збудниками в польових інфекційних розсадниках. З метою ідентифікації джерел стійкості до основних збудників хвороб у колекційному розсаднику на штучних інфекційних фонах збудників *Septoria tritici*, *Puccinia recondita*, *Fusarium graminearum*, *Tilletia caries*, *Cercosporella herpotrichoides* та провокаційному фоні *Erysiphe graminis* було досліджено близько 400 колекційних зразків пшениці озимої та 108 номерів екологічного сортовипробування. Результати досліджень, проведених у фазі осіннього кущіння, засвідчили, що ураження рослин борошнистою росою викликає порушення структурно-функціонального стану клітинних мембран, що супроводжується зростанням електропровідності тканин. За рівня ураження листкової поверхні 30-50 % значення цього показника збільшувалося більш ніж у два рази порівняно зі здоровими рослинами. У фазі колосіння ураження прапорцевого листка борошнистою росою зумовлювало посилений вихід електролітів із клітин, особливо у генотипів із підвищеною сприйнятливістю до патогена. Аналогічна закономірність спостерігалася за розвитку септоріозу листя та бурої іржі. При ураженні рослин збудником *Cercosporella herpotrichoides* також відмічено поступове підвищення електропровідності клітинних мембран зі збільшенням ступеня розвитку хвороби. Встановлено пряму залежність між інтенсивністю ураження рослин та рівнем електропровідності клітинних мембран. Максимальні значення електропровідності клітинних мембран (98,8-100,0 %) були зафіксовані у сприйнятливих сортів ‘Донська напівкарликова’ (за ураження септоріозом листя) та ‘Миронівська 10’ (за ураження бурою іржею) у фазі колосіння за розвитку хвороб до 50 %, мінімальний показник електропровідності (8,4 %) відмічено в імунних рослин у фазі осіннього кущіння за повної відсутності ураження борошнистою росою. Виявлені закономірності між ступенем ураження рослин патогенами та рівнем електропровідності тканин можуть бути використані в селекційній практиці для раннього добору стійких генотипів

Ключові слова: пшениця озима; *Septoria tritici*; бура іржа; борошниста роса; електропровідність тканин; стійкість до хвороб; селекційний добір